BRITISH STANDARD

BS EN 207:2009

Personal eye-protection equipment — Filters and eye-protectors against laser radiation (laser eye-protectors)

ICS 13.340.20

British Standards

National foreword

This British Standard is the UK implementation of EN 207:2009. It supersedes BS EN 207:1999 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PH/2, Eye protection.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Personal eye-protection equipment - Filters and eye-protectors against laser radiation (laser eye-protectors)

Protection individuelle de l'oeil - Filtres et protecteurs de l'oeil contre les rayonnements laser (lunettes de protection laser)

Persönlicher Augenschutz - Filter und Augenschutzgeräte gegen Laserstrahlung (Laserschutzbrillen)

This European Standard was approved by CEN on 14 November 2009.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Management Centre: Avenue Marnix 17, B-1000 Brussels

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Contents

Foreword

This document (EN 207:2009) has been prepared by Technical Committee CEN/TC 85 "Eye protective equipment", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2010, and conflicting national standards shall be withdrawn at the latest by June 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 207:1998.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

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

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard applies to eye-protectors used for protection against accidental exposure to laser radiation as defined in EN 60825-1:2007 in the spectral range 180 nm (0,18 µm) to 1 000 µm. It defines the requirements, test methods and marking. A guide is given in Annex B for the selection and use of laser eye-protectors.

This European Standard does not apply to protectors for intentional exposure to laser radiation.

EN 208 applies for laser adjustment eye-protectors.

NOTE Before selecting eye protection according to this European Standard, a risk assessment should first be undertaken (see Annex B).

2 Normative references

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

EN 166:2001, *Personal eye-protection — Specifications*

EN 167:2001, *Personal eye-protection — Optical test methods*

EN 168:2001, *Personal eye-protection — Non-optical test methods*

EN 60825-1:2007, *Safety of laser products — Part 1: Equipment classification and requirements (IEC 60825- 1:2007)*

ISO 11664-1:2007, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO 11664-2:2007, *Colorimetry — Part 2: CIE standard illuminants*

3 Requirements

3.1 Spectral transmittance of filters and frames

When tested according to 4.2, the maximum spectral transmittance at the wavelength(s) or in the wavelength range(s) of protection shall not exceed the values specified in Table 1 for the applicable scale number.

3.2 Luminous transmittance of filters

When assessed in accordance with 4.3, the luminous transmittance of the filter relative to the D65 standard illuminant (see ISO 11664-2:2007) shall be at least 20 %. However, luminous transmittance lower than 20 % may be accepted provided that the manufacturer supplies information related to the increase of the intensity of illumination at the relevant workplace in accordance with Clause 5.

3.3 Resistance of filters and frames to laser radiation

When tested according to 4.4, the filters and frames shall meet the requirements of 3.1 and shall not lose their protective effect under the influence of laser radiation of the power (E) or energy density (H) as specified in Table 1 and shall not show any induced transmission (reversible bleaching). No splinters shall come away from the side of the filter facing the eye under the influence of the laser radiation. Any melting or other damage of the surface during the course of irradiation is not considered negative if the protective effect is still maintained.

Table 1 — Scale numbers (maximum spectral transmittance and resistance to laser radiation) of the filters and/or eye-protectors against laser radiations

Scale number	Maximum spectral transmittance at the laser wavelength	Power (E) and energy (H) density for testing the protective effect and resistance to laser radiation in the wavelength range								
		180 nm to 315 nm			> 315 nm to 1 400 nm			> 1 400 nm to 1 000 µm		
		For test condition/pulse duration in seconds (s)								
		D $\geq 3 \times 10^{4}$	I, R 10^{-9} to 3×10^{4}	M $< 10^{-9}$	D $> 5 \times 10^{-4}$	I, R 10^{-9} to 5×10^{-4}	M $< 10^{-9}$	D > 0,1	I, R 10^{-9} to 0,1	M $< 10^{-9}$
	$\tau(\lambda)$	E_D W/m²	$H_{I,R}$ J /m²	E_M W/m²	E_D W/m²	$H_{I,R}$ J/m²	H_M J/m²	E_D W/m²	$H_{I,R}$ J/m²	E_M W/m²
LB1	10^{-1}	0,01	3×10^{2}	3×10^{11}	10^{2}	0,05	$1,5 \times 10^{-3}$	10^{4}	10^{3}	10^{12}
LB2	10^{-2}	0,1	3×10^{3}	3×10^{12}	10^{3}	0,5	$1,5 \times 10^{-2}$	10^{5}	10^{4}	10^{13}
LB3	10^{-3}	1	3×10^{4}	3×10^{13}	10^{4}	5	0,15	10^{6}	10^{5}	10^{14}
LB4	10^{-4}	10	3×10^{5}	3×10^{14}	10^{5}	50	1,5	10^{7}	10^{6}	10^{15}
LB5	10^{-5}	10^{2}	3×10^{6}	3×10^{15}	10^{6}	5×10^{2}	15	10^{8}	10^{7}	10^{16}
LB6	10^{-6}	10^{3}	3×10^{7}	3×10^{16}	10^{7}	5×10^{3}	$1,5 \times 10^{2}$	10^{9}	10^{8}	10^{17}
LB7	10^{-7}	10^{4}	3×10^{8}	3×10^{17}	10^{8}	5×10^{4}	$1,5 \times 10^{3}$	10^{10}	10^{9}	10^{18}
LB8	10^{-8}	10^{5}	3×10^{9}	3×10^{18}	10^{9}	5×10^{5}	$1,5 \times 10^{4}$	10^{11}	10^{10}	10^{19}
LB9	10^{-9}	10^{6}	3×10^{10}	3×10^{19}	10^{10}	5×10^{6}	$1,5 \times 10^{5}$	10^{12}	10^{11}	10^{20}
LB10	10^{-10}	10^{7}	3×10^{11}	3×10^{20}	10^{11}	5×10^{7}	$1,5 \times 10^{6}$	10^{13}	10^{12}	10^{21}
The symbols D, I, R and M relative to the test conditions are explained in Table 4.										

3.4 Refractive values of filters and eye-protectors

When assessed in accordance with 4.5, the maximum refractive values of filters and eye-protectors with no corrective effect shall be as given in Table 2. The maximum refractive values apply to the range specified in 7.1.2.1 of EN 166:2001.

Table 2 — Maximum refractive values of filters and eye-protectors with no corrective effect

Spherical power	Astigmatic power	Prismatic power difference		
		horizontal		vertical
		base out	base in	
m^{-1}	m^{-1}	cm/m	cm/m	cm/m
± 0,09	0,09	0,75	0,25	0,25

3.5 Quality of material and surface of filters

3.5.1 Material and surface defects

The material and surface defects of filters shall be assessed in accordance with 4.6.1.

Except for a marginal area of 5 mm wide, filters shall be free from any material or surface defects likely to impair the intended use, such as bubbles, scratches, inclusions, dull spots, mould marks, scoring or other defects originating from the manufacturing process. No holes are allowed anywhere in the filters.

3.5.2 Diffusion of light

The reduced luminous coefficient l^* of a filter, determined in accordance with 4.6.2, shall not be greater than

$$l^* = 0{,}50\ \frac{\mathrm{cd/m^2}}{\mathrm{lx}} \qquad (1)$$

3.6 Stability of filters and eye-protectors to ultraviolet radiation and elevated temperature

3.6.1 Stability to ultraviolet radiation

When exposed to ultraviolet radiation in accordance with 4.7.1, the properties of filters and eye-protectors shall not change to such an extent that they can no longer satisfy the requirements of 3.1, 3.2, 3.4 and 3.5. The relative change in the luminous transmittance shall be ≤ 10 %:

$$\left|\frac{\Delta\tau_v}{\tau_v}\right| \le 10\ \% \qquad (2)$$

The spectral transmittance for the laser wavelengths shall, however, in no case exceed the maximum spectral transmittance corresponding to the indicated scale number.

3.6.2 Stability at elevated temperature

After exposure to elevated temperature in accordance with 4.7.2, filters and eye-protectors shall satisfy the requirements of 3.1, 3.2, 3.4 and 3.5. The relative change in the luminous transmittance shall not exceed 5 %:

$$\left|\frac{\Delta\tau_v}{\tau_v}\right| \le 5\ \% \qquad (3)$$

The spectral transmittance for the laser wavelength shall, however, in no case exceed the maximum spectral transmittance corresponding to the indicated scale number.

3.7 Resistance of filters and frames to ignition by contact with hot surfaces

When tested in accordance with 4.8, the filters and frames shall not ignite or continue to glow.

3.8 Field of vision of eye-protectors

Eye-protectors shall have a clear field of vision of at least 40° in the vertical and horizontal directions for each eye when measured in accordance with 4.9 (see Figure 1).

3.9 Construction of filters and frames

Filters shall be constructed so that when tested in accordance with 4.4 followed by a visual inspection no splinters are detached from the side of the filter facing the eye. If the filters consist of several individual filters, they shall be assembled in such a way that they cannot be interchanged.

Filters shall not be interchangeable in the frame. An exception is possible if the protection to laser radiation is determined only by the filter(s) and no part of the frame lies inside the protected range as defined below. In this case the marking of the eye-protector shall be on the filter(s) and there is no requirement for the frame to satisfy 3.3 on resistance to laser radiation.

The frame shall be designed so that no laser radiation can penetrate from the side. This requirement is met if for the horizontal angle range α from - 50° (nasal side) to + 90° (temporal side) the vertical angle range β is protected within the following limit angles in degrees (°).

The upward limit β_u of the protected range shall be:

$$\beta_u = 55 - 0{,}001\,3\,(\alpha - 12)^2 - 1{,}3 \times 10^{-6}\,(\alpha - 12)^4 \quad (4)$$

The downward limit β_l of the protected range shall be:

$$\beta_l = -70 + 10^{-5}\,(\alpha - 22)^2 + 2{,}3 \times 10^{-6}\,(\alpha - 22)^4 \quad (5)$$

Testing shall be done in accordance with 4.10.

3.10 Mechanical strength of eye-protectors

3.10.1 Basic requirement

Filters for protection against laser radiation shall satisfy the requirement for minimum robustness as specified in 7.1.4.1 of EN 166:2001.

The frames of the eye-protectors shall satisfy the requirements of 7.1.4.2 or 7.2.2 of EN 166:2001.

3.10.2 Optional requirements

If the mechanical strength of filters and eye-protectors against laser radiation is required to satisfy more stringent requirements, the requirements specified in 7.1.4.2 or the requirements specified in 7.2.2 of EN 166:2001 shall be met.

4 Testing

4.1 General

The testing schedule in Table 3 shall be applied to testing of filters, frames and complete eye-protectors. The sequence of testing 1 to 9 and 13 to 16 may be changed. At least 16 filters or eight complete eye-protectors are required for testing. If testing for several wavelengths (wavelength ranges) or testing conditions according to 4.4 and/or several optional requirements has to be done, more than 16 samples may be necessary.

Table 3 —Test schedule for filters, frames and complete eye-protectors for protection against laser radiation

Order of testing	Requirement	According to clause	Number of filter/frame samples				
			3	3	10	Depends on specification/ requirement	
1	Marking	6	+	+			
2	Material and surface defects	3.5.1	+	+			
3	Field of vision	3.8	1 frame				
4	Construction of filters and frames	3.9	+	+			
5	Frames	3.9	+	+			
6	Diffusion of light	3.5.2	+	+			
7	Luminous transmittance	3.2	+	+			
8	Refractive values	3.4	+	+			
9	Prismatic power difference	3.4	3 frames				
10	Spectral transmittance at wavelength λ	3.1	+	+	3 filters/frames per λ and test condition	3 filters/frames per λ and test condition	
11	Stability to UV radiation	3.6.1	+				
12	Stability to elevated temperature	3.6.2	+				
13	Material and surface defects	3.5.1	+	+			
14	Diffusion of light	3.5.2	+	+			
15	Luminous transmittance	3.2	+	+			
16	Refractive values	3.4	+				
17	Spectral transmittance	3.1	+	+			
18	Mechanical strength	3.10			+		
19	Resistance to laser radiation and spectral transmittance at wavelength λ	3.3			3 filters/frames per λ and test condition	3 filters/frames per λ and test condition	
20	Ignition	3.7			3 filters/ frames		
21	Optional requirements as given in EN 166:2001	according to applicable clause of EN 166:2001					depends on requirement/ test procedure
Explanation of the symbols: + Testing to be carried out on the indicated specimen; Empty field No testing specified.							

4.2 Spectral transmittance of filters and frames

The spectral transmittance shall be determined for normal incidence. Filters with angular-dependent transmittance (such as interference layers) for the wavelength range from 400 nm to 1 400 nm shall be measured at angles of incidence between 0° and 30° with polarized radiation and an orientation of the polarization direction giving the highest value of the spectral transmittance. Filters with angular-dependent transmittance for other wavelengths shall be measured at angles of incidence between 0° and 90° with polarized radiation. In this case, the scale number results from the highest of the spectral transmittance values measured.

Testing shall be done in accordance with EN 167:2001, Clause 6.

4.3 Luminous transmittance of filters

The luminous transmittance shall be determined for normal incidence, relative to the D65 standard illuminant (see ISO 11664-1:2007 and ISO 11664-2:2007).

The test shall be performed according to EN 167:2001, Clause 6.

4.4 Resistance of filters and frames to laser radiation

The test shall be carried out with laser radiation of the specified wavelengths and the power and energy densities given in Table 1. The spectral transmittance shall be measured for each laser wavelength during the exposure to laser radiation.

The values of energy density (H) in Table 1 for testing the resistance against laser radiation for pulsed lasers (I, R, M) shall be multiplied with the factor $N^{1/4}$, where N is the number of pulses in 5 s.

The frame shall be exposed to radiation at the point of least thickness for each of the materials used (with the exception of headbands).

The diameter d_{63} of the laser beam during this test shall be (1 $\pm$ 0,1) mm.

For pulse durations < 1 ns, the diameter d_{63} of the laser beam during this test shall be $\geq$ 0,5 mm.

In the case of rectangular beams, the dimensions specified apply to the shortest side of the rectangle.

The duration of the test shall be taken from Table 4.

Table 4 — Duration of test for filters and eye-protectors against laser radiation

Test conditions for laser type	Typical laser type	Pulse length s	Minimum number of pulses
D	Continuous wave laser	5	1
I	Pulsed laser	> 10^{-6} to 0,25	50
R	Q switch pulsed laser	> 10^{-9} to 10^{-6}	50
M	Mode-coupled pulse laser	< 10^{-9}	50

NOTE The pulse lengths for test conditions I and R do not follow consecutively. Neither are they a continuation of the length for test condition D. The pulse lengths indicated are characteristic values of typical lasers. It is recommended to use a laser with a pulse length in this range.

Testing shall be done at least for 5 s, but in the case of pulsed operation never with less than 50 pulses.

For pulsed lasers, testing shall be done with low repetition rates (≤ 25 Hz). If it is not possible, the energy density used for testing shall be given and the product shall be marked in accordance with 6.1, d).

All laser protective filters and frames shall be tested in accordance with the test condition D. If commercially available, testing at mode D shall be done with a real CW laser. If it is not feasible, testing shall be done with a pulsed laser system at a minimum pulse repetition frequency ν of $\nu \geq 25$ Hz. If no laser with pulse repetition rates higher than 25 Hz is available, a pulsed laser system at a minimum pulse repetition frequency of $\nu \geq 5$ Hz shall be used to test condition D.

If additional protection against pulsed lasers is required, the filters and laser radiation eye-protectors shall be tested according to one or several of the test conditions I, R or M.

Lasers which do not show spiking at the beginning of the emission shall be used. The spatial and temporal beam profile shall be documented, except for temporal profiles of M mode lasers.

4.5 Refractive value of filters and eye-protectors

The test shall be carried out in accordance with Clause 3 of EN 167:2001.

4.6 Quality of material and surface of filters

4.6.1 Material and surface defects

The test shall be carried out in accordance with Clause 5 of EN 167:2001.

NOTE Thin film filters should be carefully examined for defects (scratches and holes) as damage of deposited layer can affect protection against laser radiation.

4.6.2 Diffusion of light

The test shall be carried out in accordance with Clause 4 of EN 167:2001.

If the simplified method cannot be used because the spectral transmittance is too low, the basic method shall be used.

4.7 Stability to UV radiation and stability to elevated temperature

4.7.1 Stability to UV radiation

The test shall be carried out in accordance with Clause 6 of EN 168:2001, with the lamp running at a power of 450 W and an exposure time of (50 ± 0,2) h.

4.7.2 Stability to elevated temperature

Filters and eye-protectors shall be stored for at least 7 h in a climatic cabinet at a temperature of (55 ± 2) °C and a relative humidity of > 60 %, and then stored for at least 2 h at room temperature.

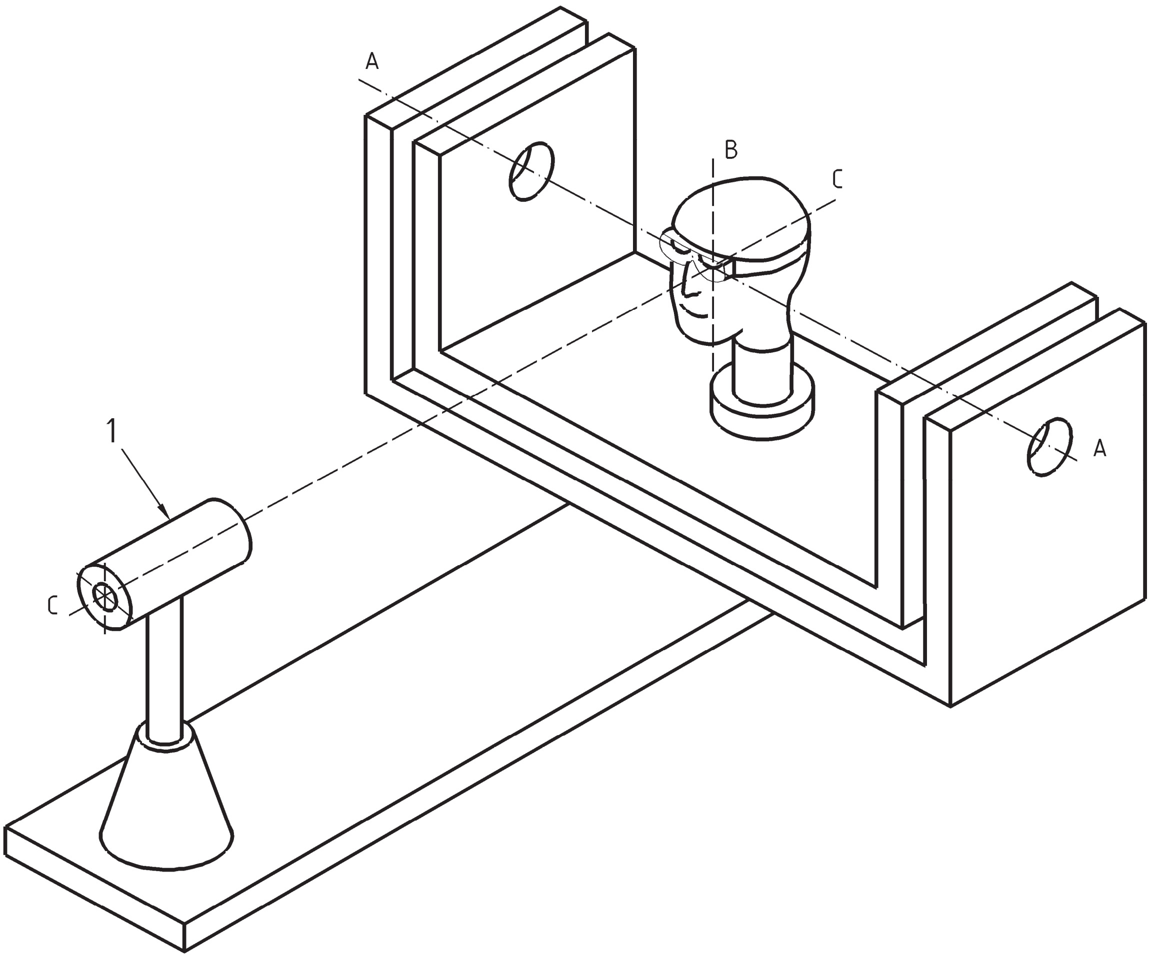
4.8 Resistance of filters and frames to ignition by contact with hot surfaces

The test shall be carried out in accordance with Clause 7 of EN 168:2001.

4.9 Field of vision of eye-protectors

For measuring the field of vision, the test head specified in EN 168:2001 with the eye-protector without filters shall be mounted as shown in the example of set up illustrated in Figure 1 so that the two axes of rotation A and B and the optical axis C intersect in the middle of the front surface of one eye. Irradiation is provided by a laser beam of maximum diameter (1 ± 0,5) mm along axis C. When rotated around axis A, the difference in the angular positions at which the light beam no longer hits the eye gives the vertical field of vision. By rotating around axis B, the difference between the angular position at which the light beam no longer hits the eye and the line of vision of the test head parallel to the optical axis C gives half the horizontal field of vision.

Other methods are permissible if they give identical results.



Key

1 Laser

A, B, C Axis (see text)

Figure 1 — Example of test set-up for the measurement of field of vision

4.10 Determination of the protected range

Using the apparatus as given in 4.9 the scan shall verify that the eye-protector covers at least the range as defined by the limits β_u and β_l.

4.11 Frames

4.11.1 It shall be tested by means of manual and visual inspection whether the filters are interchangeable.

4.11.2 The test shall be carried out using the method given in 4.9. The zero values of the angles α and β are reached when the axis A, B and C of the test apparatus are perpendicular to each other.

4.12 Mechanical strength

The test shall be carried out in accordance with Clause 4 of EN 168:2001.

5 Information supplied by the manufacturer

The information shall be in the language(s) of the country in which the eye-protector is sold.

In addition to the requirements of EN 166:2001, Clause 10, the selection criteria and instructions for use shall contain at least the following:

a) luminous transmittance;

b) if the luminous transmittance is less than 20 %, this shall be indicated and the user shall be recommended to increase the intensity of illumination at the workplace;

c) in the case of tinted and coloured filters a warning to the user that the recognition of warning lights or warning signals can be impaired;

d) the information that eye-protectors are only intended to give protection against accidental radiation and that both the limit values and the resistance tests are based on a maximum period of 5 s;

e) a warning that eye-protectors and filters against laser radiation which have been damaged, have scratched oculars or which have undergone a colour change shall not be used any more;

f) an explanation of the symbols used in the marking;

g) details regarding an appropriate cleaning method;

h) in case of filters with angle dependent transmittance an information shall be given that the protection is only provided for angles of incidence up to 30°.

Instructions shall include a warning of risk of exposure to laser radiation due to reflection from reflective parts (including eye-protectors), tilting or misalignment of optical components.

Instructions shall include a recommendation that in areas where there is a risk of exposure to laser radiation appropriate eye-protection should be worn by all personnel.

In addition, the manufacturers shall supply additional data in the form of transmission curves.

6 Marking

6.1 Eye-protectors

The following shall be marked permanently on the filters or the frames for identification:

a) wavelength(s) or wavelength range (given in nanometres (nm)) in which the filter provides protection;

b) the symbol for the test condition (see Table 4);

c) scale number;

If the filter guarantees protection in one or several spectral ranges, the lowest scale number shall be given in the corresponding spectral range.

d) if the eye-protector is not tested with low repetition rates (≤ 25 Hz), the suffix Y shall be added to the scale number, e.g. RLB5Y;

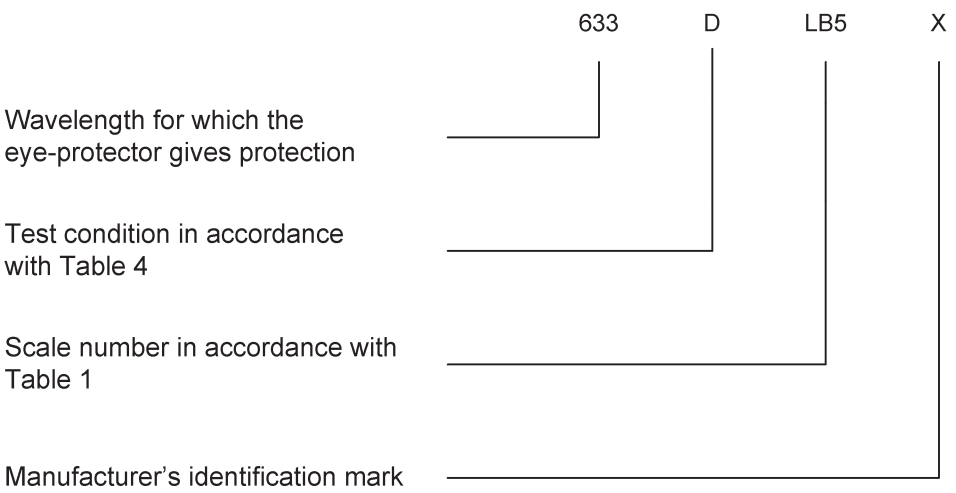
e) manufacturer's identification mark;

In order to prevent multiple use, only marks granted at European or national level shall be used.

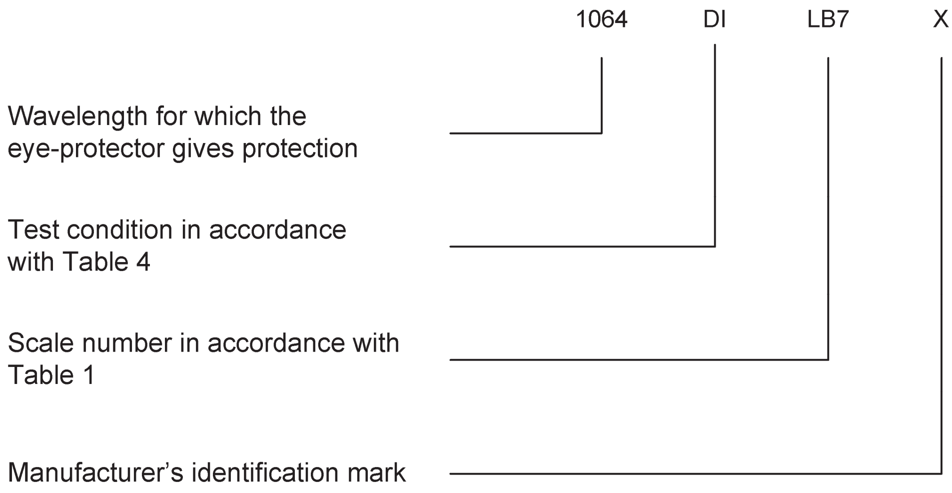
f) if the eye-protector satisfies the mechanical strength requirement of 3.10.2, one of the marks specified in Clause 9 of EN 166:2001 shall also be added.

If the symbols are marked on the filters, they shall not impair vision nor the protective effect.

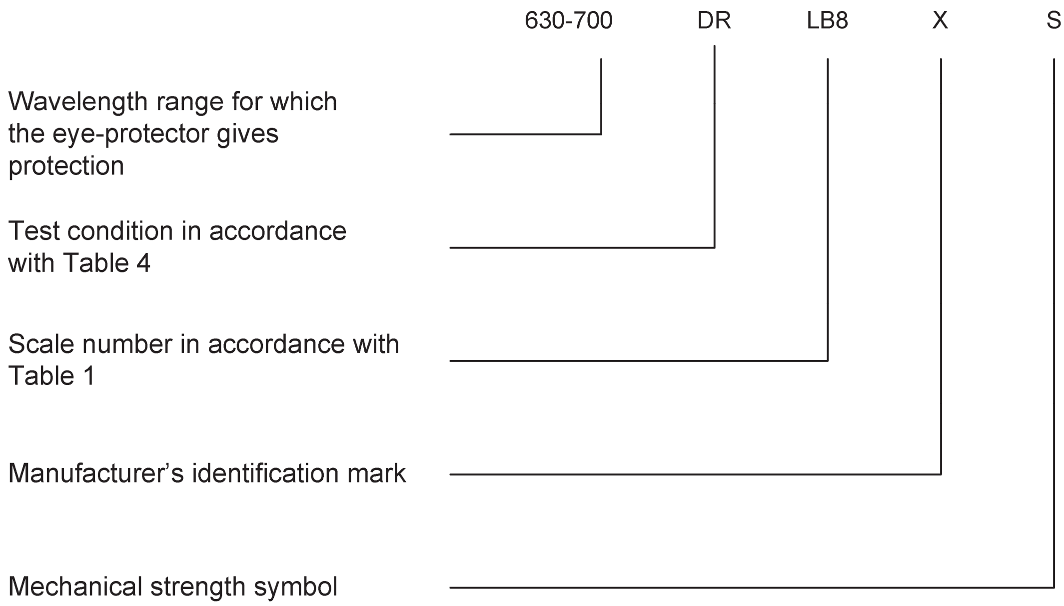
EXAMPLE 1



EXAMPLE 2



EXAMPLE 3



If several marks apply to a laser radiation eye-protector, all these marks shall be applied, or alternatively the manufacturer's identification mark, the certification mark and the mechanical strength symbol shall be specified only once; the other identification elements shall be separated by a +.

EXAMPLE 4 Marking might become very lengthy if a filter or a frame protects against several wavelength. In these cases, the mark may be pooled as follows:

10600 D LB3 + IR LB4

1064 DI LB8 + R LB9

633 D LB4 + IR LB5

X S

where the symbols have the same meaning as in precedent examples.

6.2 Filters

As filters in eye-protectors against laser radiation shall not be interchangeable, they need not be marked separately if the complete eye-protectors are marked.

Filters to be used as viewing windows in appliances and installations shall be marked in accordance with 6.1.

Annex A
(informative)

Principle

A.1 Limit values and time base

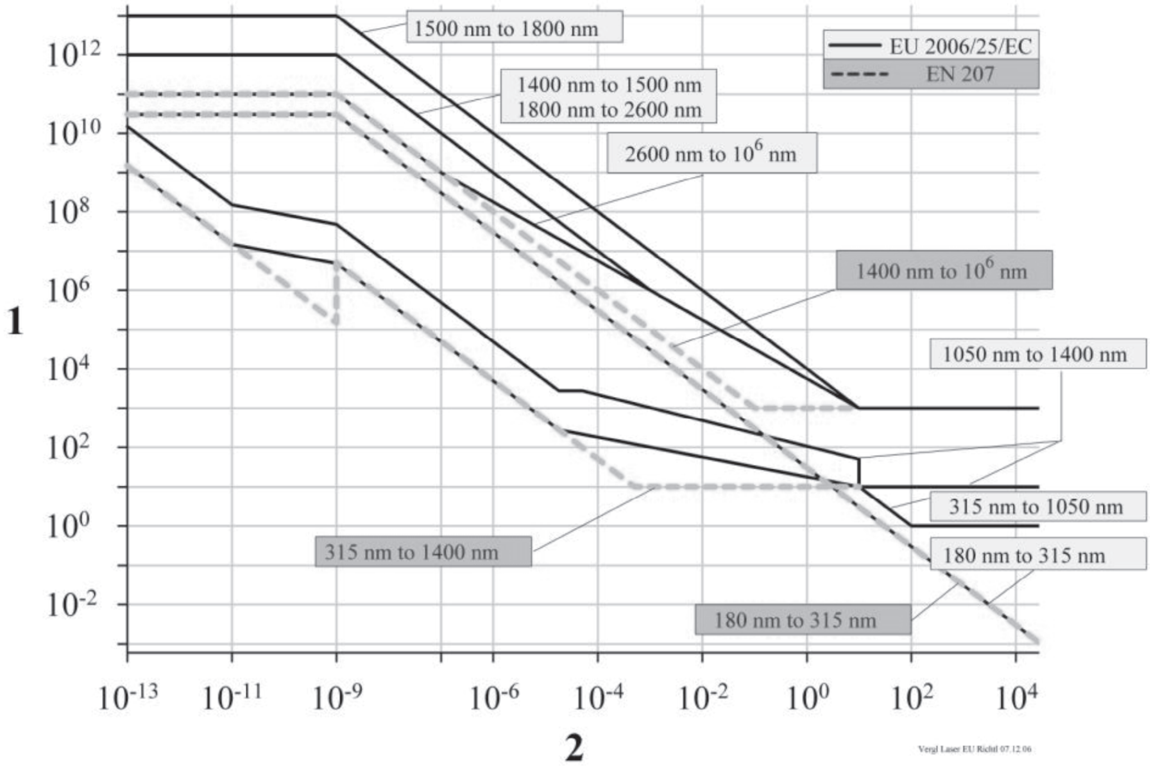
The maximum permissible exposure (MPE) to laser radiation on the cornea is specified in EN 60825-1. These limit values indicate a complicated dependency on time and wavelength. This standard uses simplified limits which either agree or are conservative compared with MPE. In the wavelength range 180 nm to 315 nm, the permissible limit values for 30 000 s were used, otherwise the permissible limit values for a 5 s period of radiant exposure. The simplified values are shown in Table A.1.

Figure A.1 compares the values of Table A.1 with those of the European Directive 2006/25/EC on artificial optical radiation. It is shown by the figure that the values of Table A.1 are conservative compared with the limit values of the Directive.

Table A.1 — Simplified maximum permissible irradiation values for the cornea

Wavelength range	**Irradiance *E***				**Radiant exposure *H***			
	D		M		M		I, R	
nm	Pulse duration s	W/m^2	Pulse duration s	W/m^2	Pulse duration s	J/m^2	Pulse duration s	J/m^2
180 to 315	30 000	0,001	$< 10^{-9}$	3×10^{10}	-	--	$> 10^{-9}$ to 3×10^{4}	30
> 315 to 1 400	$> 5 \times 10^{-4}$ to 10	10	-	-	$< 10^{-9}$	$1,5 \times 10^{-4}$	$> 10^{-9}$ to 5×10^{-4}	0,005
> 1 400 to 10^{6}	> 0,1 to 10	1 000	$< 10^{-9}$	10^{11}	-	-	$> 10^{-9}$ to 0,1	100

For repetitively pulsed lasers, see EN 60825-1 and B.3.3.



Key

1 Irradiance (W/m²)
2 Exposure duration (s)

Figure A.1 — Comparison of the limit values specified in EU 2006/25/EC and the simplified values of EN 207

A.2 Beam areas

EN 60825-1 specifies diameters which are to be used for averaging when calculating the energy density and power density. In the wavelength range 400 nm to 1 400 nm, this is a diameter of 7 mm corresponding to an area of 38,5 mm^2. As a number of typical lasers (e.g. argon lasers, He-Ne lasers, Nd-YAG lasers) in this wavelength range have a beam diameter of approximately 1 mm, the power/energy density in their beam is considerable higher than if an average was calculated over a cross-sectional area of 38,5 mm^2. As the performance of filters is limited not by their absorption, but by their resistance to laser radiation, the beam area (A) based on the actual beam diameter is used in this European Standard when calculating the power/energy density.

Generally, the smallest accessible beam diameter is used for the calculation.

In the cases of diverging laser radiation (e.g. from optical fibres or diode lasers) the beam diameter 10 cm from the divergence point may be used as a basis for calculating the power density and energy density.

A.3 Angle dependence

The measurements of the angle dependence of the spectral transmittance is limited to the angle range from 0° to 30° for filters covering the wavelength range between 400 nm and 1 400 nm. This limitation of the angle range is justified by the fact that eye movements for the fixation of an object are usually limited to a maximum angle of 15°. For objects which would appear under a larger angle the head would move.

A.4 Example test report

The report for the test of resistance to laser radiation should contain at least the following information.

Table A.2 — Test report

	Laser parameter	**Symbol**	**Unit**	**Value**
Laser specifications	Wavelength	λ		
	Average power range	P_m		
	Pulse frequency range	F		
	Pulse energy	Q_{pulse}		
	Peak power	P_{peak}		
	Optical pulse duration	T_{pulse}		
	Beam diameter at beam exit	$D_{86,5}$		
	Beam quality	M^2		
	Beam divergence (full angle)	Θ		
	Beam polarisation	-		
Laser beam diagnostics and detection equipment	**Measuring devices**	**Type**		**Manufacturer**
	Power measurement			
	Energy measurement			
	Beam analyser			
	Transmission measurement			
Report No.		**Date**		
Sample No.		**Operator**		
Test conditions				**Observations**
Scale number	D LB		-	**During irradiation:**
Required power density	E		W/m^2	
Beam diameter at sample surface	d_{63}		mm	**Laser side:**
Irradiated area	A_{63}		m^2	
Pulse duration	cw	-	-	**Eye side:**
Average power measured externally	P		W	
Measured scale number	-		*D LB	**Transmittance:**
Test duration	T_{test}		s	

Table A.2 (*continued*)

Scale number	I R M LB		-	**During irradiation:**
Required energy density	*H*		J/m^2	
Beam diameter at sample surface	D_{63}		mm	**Laser side:**
Irradiated area	A_{63}		m^2	
Pulse duration	t_{pulse}		s	**Eye side:**
Repetition rate	*F*		Hz	
Average power measured externally	P_m		W	
Measured scale number	-		*I R M LB	**Transmittance:**
Testing time	t_{test}		s	

Arrangement drawing of the testing set-up	
Comments	

Annex B
(informative)

Recommendations for the use of laser radiation eye-protectors

B.1 General

This annex gives recommendations for the selection of laser radiation eye-protectors depending on the type of laser and the operating conditions.

Before selecting eye protection a risk assessment should be undertaken and the risk minimised by engineering and administrative controls. Control methods are outlined in EN 60825-1 and applicable national regulations and guidance.

Filters for viewing windows should be chosen so that they are able to withstand incident laser radiation for the possible total duration of exposure.

NOTE The information contained in Table B.1 is equivalent to that of Table 1 of 3.1 and is repeated here in order to facilitate the application of this European Standard.

B.2 Types of lasers

It is possible to make a distinction between the different types of lasers according to their duration of operation and pulse length. The meaning of the symbols D, I, R, and M is given in Table 4.

Table B.1 — Recommended scale numbers for use of filters and eye-protectors against laser radiation

Scale number	Maximum spectral transmittance at the laser wavelength $\tau(\lambda)$	Maximum power (*E*) and/or energy (*H*) density in the wavelength range								
		180 nm to 315 nm			> 315 nm to 1 400 nm			> 1 400 to 1 000 µm		
		Laser type/exposure duration in seconds (s)								
		D $\geq 3 \times 10^4$	I, R 10^{-9} to 3×10^4	M $< 10^{-9}$	D $> 5 \times 10^{-4}$	I, R 10^{-9} to 5×10^{-4}	M $< 10^{-9}$	D $> 0,1$	I, R 10^{-9} to 0,1	M $< 10^{-9}$
		E_D W/m^2	$H_{I,R}$ J/m^2	E_M W/m^2	E_D W/m^2	$H_{I,R}$ J/m^2	H_M J/m^2	E_D W/m^2	$H_{I,R}$ J/m^2	E_M W/m^2
LB1	10^{-1}	0,01	3×10^2	3×10^{11}	10^2	0,05	$1,5 \times 10^{-3}$	10^4	10^3	10^{12}
LB2	10^{-2}	0,1	3×10^3	3×10^{12}	10^3	0,5	$1,5 \times 10^{-2}$	10^5	10^4	10^{13}
LB3	10^{-3}	1	3×10^4	3×10^{13}	10^4	5	0,15	10^6	10^5	10^{14}
LB4	10^{-4}	10	3×10^5	3×10^{14}	10^5	50	1,5	10^7	10^6	10^{15}
LB5	10^{-5}	10^2	3×10^6	3×10^{15}	10^6	5×10^2	15	10^8	10^7	10^{16}
LB6	10^{-6}	10^3	3×10^7	3×10^{16}	10^7	5×10^3	$1,5 \times 10^2$	10^9	10^8	10^{17}
LB7	10^{-7}	10^4	3×10^8	3×10^{17}	10^8	5×10^4	$1,5 \times 10^3$	10^{10}	10^9	10^{18}
LB8	10^{-8}	10^5	3×10^9	3×10^{18}	10^9	5×10^5	$1,5 \times 10^4$	10^{11}	10^{10}	10^{19}
LB9	10^{-9}	10^6	3×10^{10}	3×10^{19}	10^{10}	5×10^6	$1,5 \times 10^5$	10^{12}	10^{11}	10^{20}
LB10	10^{-10}	10^7	3×10^{11}	3×10^{20}	10^{11}	5×10^7	$1,5 \times 10^6$	10^{13}	10^{12}	10^{21}

B.3 Determination of the scale numbers

B.3.1 General

In the following calculations of the power density or energy density, the actual beam area (i.e. the area of the smallest circle containing 63 % of the laser power and energy) should be used. For non-circular cross-sections, a similar procedure should be employed and the smallest rectangle containing 63 % of the laser power and energy should be used.

Scale numbers are determined for the different laser modes D, I, R, and M. For pulsed lasers a scale number for one of the symbols I, R, or M may be derived and a scale number for mode D. For each of the two modes an individual scale number may be applied or the maximum of the two values.

If beam diameters *d* other than 1 mm (diameter to test the resistance to laser radiation) are used to determine the scale number of an appropriate filter, power and energy densities of Table B1 should be multiplied by the following functions (*d* is the beam diameter in millimetres (mm)), depending on the main constituent of the protecting filter:

Glass $F(d) = d^{1,1693}$

Plastic $F(d) = d^{1,2233}$

NOTE Due to heat dissipation, the resistance to laser radiation depends not only on the power and energy density but also on the diameter of the irradiated area.

B.3.2 Continuous wave laser (D)

The power density *E* of the laser beam is derived from the laser power *P* and the beam area *A* as follows:

$$E = \frac{P}{A} \tag{B.1}$$

The required scale number can then be deduced from column D of Table B.1 corresponding to the wavelength of the laser. The laser type symbol is D.

B.3.3 Pulsed lasers (I, R), pulse duration ≥ 10^{-9} s

B.3.3.1 General

For the determination of the scale number basically two criteria – pulse criterion and criterion of the average power – shall be applied as outlined in the following. From the first criterion a scale number corresponding to I or R mode results (depending on the pulse duration of the laser) and from the second a scale number according to mode D results, although the safety requirements for a pulsed laser are analysed.

B.3.3.2 Calculation for the pulsed mode

The energy density *H* of the laser beam is derived from the pulse energy *Q* and the beam area *A* as follows:

$$H = \frac{Q}{A} \tag{B.2}$$

For lasers in the wavelength range from 400 nm to 10^6 nm, pulse durations of < 0,25 s and pulse repetition frequencies $\nu > 1$ Hz this energy density for the single pulse shall be multiplied by a correction factor *k*.

$$H' = H \times k \qquad \text{(B.3)}$$

k is calculated by the number of laser pulses N emitted in the exposure duration T = 5 s as follows:

$$k = N^{1/4} \qquad \text{(B.4)}$$

Then the scale number can be deduced for the maximum of the two values H and H' from column I or R of Table B.1 corresponding to the wavelength of the laser. For pulse durations less than 10^{-6} s symbol R applies, else symbol I. If the pulse duration is longer than the exposure duration given in the head of Table B.1, a scale number for I does not apply and only a scale number for the D mode shall be calculated according to section B.3.3.3.

Remark at the calculation of factor k:

If ν *is* the pulse repetition frequency of the laser, then the total number N of pulses for the exposure duration is calculated by

$$N = \nu \times 5\ s \qquad \text{(B.5)}$$

and k is given by equation (B.4).

Equation (B.5) shall only be applied, if the time separation between consecutive single pulses $\delta T = 1/\nu$ is longer than the wavelength dependent periods T_i given by Table B.2. For pulse intervals shorter than T_i the energy of all pulses during T_i shall be added. The maximum repetition frequency to be applied ν_{max} is then the inverse of the time T_i. In this case the correction factor for the energy density of the single laser pulse is given by the product of k and an additional factor k_{Ti}, which accounts for the number of pulses in the time T_i.

Table B.2 — Periods of time T_i below which energies of single pulses have to be added and maximum pulse repetition frequencies ν_{max} = 1/T_i for the application of (B.4)

	T_i/ [s]	ν_{max}/ [Hz]
400 ≤ λ/nm < 1 050	18×10^{-6}	$55{,}56 \times 10^{3}$
1 050 ≤ λ/nm < 1 400	50×10^{-6}	20×10^{3}
1 400 ≤ λ/nm < 1 500	10^{-3}	10^{3}
1 500 ≤ λ/nm 1 800	10	0,1
1 800 ≤ λ/nm < 2 600	10^{-3}	10^{3}
2 600 ≤ λ/nm < 10	10^{-7}	10^{7}

B.3.3.3 Calculation for the average power

The average power density E_m of the laser beam is derived from the average laser power P_m and the beam area A as

$$E_m = \frac{P_m}{A} \qquad \text{(B.6)}$$

or, if only the pulse energy is known, as

$$E_m = \frac{Q \times N / 5s}{A} \qquad \text{(B.7)}$$

N is the number of pulses during the duration of the exposure, *Q* the single pulse energy. In case of a regularly pulsed laser beam, (*N*/5s) is the repetition frequency of the laser according to (B.5).

The required scale number can then be deduced from column D of Table B.1 corresponding to the wavelength of the laser. The laser type symbol is *D*.

B.3.4 Mode coupled lasers (M), pulse duration < 10^{-9} s

B.3.4.1 General

For the determination of the scale number basically two criteria – pulse criterion and criterion of the mean power – shall be applied as outlined in the following. From the first criterion a scale number corresponding to M mode results and from the second a scale number according to mode D results, although the safety requirements for a pulsed laser are analysed.

B.3.4.2 Calculation for the pulsed mode

B.3.4.2.1 Wavelength range 400 nm to 1 400 nm

The procedure is analogue to that described in B.3.3.2. For the maximum value of *H* and *H*' the required scale number for this wavelength range can be deduced from column M of Table B.1. The laser type symbol is *M*.

B.3.4.2.2 Wavelength ranges < 400 nm and > 1 400 nm

The peak power density shall be calculated using the single pulse peak power P_P:

$$E_P = \frac{P_P}{A} \tag{B.8}$$

The required scale number can then be deduced from column M of Table B.1 corresponding to the wavelength of the laser. The laser type symbol is *M*.

B.3.4.3 Calculation for the average power

The procedure is analogue to that described in B.3.3.3.

The required scale number can then be deduced from column D of Table B.1 corresponding to the wavelength of the laser. The laser type symbol is *D*.

B.4 Time base

The laser radiation eye-protectors specified in Table B.1 are not suitable for continuous exposure to a laser beam. The protection has been designed on the basis of 5 s with regard to transmission (attenuation of the laser beam) for wavelengths in the range above 315 nm, otherwise on the basis of 30 000 s. Resistance to laser radiation is tested for 5 s in both cases.

If the user intends, in special cases, to use a time base greater than 5 s even for wavelengths greater than 315 nm, higher scale numbers should be selected as resulting from the appropriate MPE values of EN 60825-1:2007.

B.5 Filters in appliances

Laser radiation protective filters can be used as inspection windows in shielding applications and in laser appliances. Depending on the time base used (see B.4) and the test conditions (see 4.4), they should mainly afford protection against accidental radiation exposure.

If they are to reduce the radiation to below the limit values for continuous radiation, a filter of the next highest scale number should be used taking EN 60825-1 into consideration. The manufacturer of the appliance should ensure its resistance to laser radiation over the entire period of operation.

Annex C
(informative)

Significant technical changes between this European Standard and the previous edition

Clause, paragraph, table, figure	Change
Table 1, 6.1 and B.2	The scale number is preceded by the letters LB in order to distinct between the old and new standards.
3.9	A clause was added which allows interchangeable filters, if the frame does not contribute to laser safety.
4.2 and 5	New warning for angle dependent filters.
4.4	Correction factor $N^{-1/4}$ for the energy densities in Table 1 was introduced.
4.4	The laser beam diameter for testing was set to 1 mm, the minimum repetition frequency for quasi-cw lasers for testing mode was set to 25 Hz and a clause was added that spiking lasers are not admitted for testing. Also the factor F depending on the beam diameter was moved to Annex B.
A.1	A clause about the limiting values of Directive 2006/25/EC was added.
A.4	A sample test report was added.
B.3	New formula for diameter correction.
NOTE This table refers to the most significant changes since the previous editions; the list is not exhaustive.	

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 89/686/EEC

This European Standard has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the New Approach Directive 89/686/EEC.

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

Table ZA — Correspondence between this European Standard and Directive 89/686/EEC

Clause(s)/subclause(s) of this EN	Essential Requirements (ERs) of Directive 89/686/EEC	Qualifying remarks/Notes
3.7, 3.9	1.2.1 Absence of risks and other "inherent" nuisance factors	
3.5.1	1.2.1.3 Maximum permissible user impediment	
3.3, 3.6.1, 3.6.2, 3.10.1	1.3.2 Lightness and design strength	
5, 6	1.4 Information supplied by the manufacturer	
3.2, 3.4, 3.5.2, 3.8	2.3 PPE for the face, eyes and respiratory tracts	
6	2.12 PEE bearing one or more identification or recognition marks directly or indirectly relating to health and safety	
3.10.2	3.1.1 Impact caused by falling or projecting objects and collision of parts of the body with an obstacle	
3.1	3.9.1 Non-ionizing radiation	

WARNING — Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Bibliography

[1] EN 208, *Personal eye-protection — Eye-protectors for adjustment work on lasers and laser systems (laser adjustment eye-protectors)*

[2] Directive 2006/25/EC on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation), April 2006.

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Tel +44 (0)20 8996 9001
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