



**DIRECTIVE 2006/25/EC OF THE EUROPEAN PARLIAMENT
AND OF THE COUNCIL**

of 5 April 2006

on the minimum health and safety requirements regarding the exposure of workers to risks arising from physical agents (artificial optical radiation) (19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 137(2) thereof,

Having regard to the proposal from the Commission ⁽¹⁾, presented after consultation with the Advisory Committee on Safety and Health at Work,

Having regard to the opinion of the European Economic and Social Committee ⁽²⁾,

After consulting the Committee of the Regions,

Acting in accordance with the procedure laid down in Article 251 of the Treaty ⁽³⁾, in the light of the joint text approved by the Conciliation Committee on 31 January 2006,

Whereas:

- (1) Under the Treaty the Council may, by means of directives, adopt minimum requirements for encouraging improvements, especially in the working environment, to guarantee a better level of protection of the health and safety of workers. Such directives are to avoid imposing administrative, financial and legal constraints in a way which would hold back the creation and development of small and medium-sized enterprises (SMEs).
- (2) The communication from the Commission concerning its action programme relating to the implementation of the Community Charter of the Fundamental Social Rights of Workers provides for the introduction of minimum health and safety requirements regarding the exposure of workers to the risks caused by physical agents. In September 1990 the European Parliament adopted a Resolution concerning this action programme ⁽⁴⁾, inviting the Commission in particular to draw up a specific directive on the risks caused by noise, vibration and any other physical agents at the workplace.
- (3) As a first step, the European Parliament and the Council adopted Directive 2002/44/EC of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (16th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) ⁽⁵⁾. Next, on 6 February 2003 the European Parliament and the Council adopted Directive 2003/10/EC on

⁽¹⁾ OJ C 77, 18.3.1993, p. 12 and OJ C 230, 19.8.1994, p. 3.

⁽²⁾ OJ C 249, 13.9.1993, p. 28.

⁽³⁾ Opinion of the European Parliament of 20 April 1994 (OJ C 128, 9.5.1994, p. 146) confirmed on 16 September 1999 (OJ C 54, 25.2.2000, p. 75), Council Common Position of 18 April 2005 (OJ C 172 E, 12.7.2005, p. 26) and Position of the European Parliament of 16 November 2005 (not yet published in the Official Journal), European Parliament Legislative Resolution of 14 February 2006 (not yet published in the Official Journal) and Decision of the Council of 23 February 2006.

⁽⁴⁾ OJ C 260, 15.10.1990, p. 167.

⁽⁵⁾ OJ L 177, 6.7.2002, p. 13.

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the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise) (17th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) ⁽¹⁾. Thereafter, on 29 April 2004, the European Parliament and the Council adopted Directive 2004/40/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) ⁽²⁾.

- (4) It is now considered necessary to introduce measures protecting workers from the risks associated with optical radiation, owing to its effects on the health and safety of workers, in particular damage to the eyes and to the skin. These measures are intended not only to ensure the health and safety of each worker on an individual basis, but also to create a minimum basis of protection for all Community workers, in order to avoid possible distortions of competition.
- (5) One of the aims of this Directive is the timely detection of adverse health effects resulting from exposure to optical radiation.
- (6) This Directive lays down minimum requirements, thus giving Member States the option of maintaining or adopting more stringent provisions for the protection of workers, in particular the fixing of lower exposure limit values. The implementation of this Directive must not serve to justify any deterioration in the situation which already prevails in each Member State.
- (7) A system of protection against the hazards of optical radiation should limit itself to a definition, free of excessive detail, of the objectives to be attained, the principles to be observed and the basic values to be applied, in order to enable Member States to apply the minimum requirements in an equivalent manner.
- (8) The level of exposure to optical radiation can be more effectively reduced by incorporating preventive measures into the design of workstations and by selecting work equipment, procedures and methods so as to give priority to reducing the risks at source. Provisions relating to work equipment and methods thus contribute to the protection of the workers involved. In accordance with the general principles of prevention as laid down in Article 6(2) of Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work ⁽³⁾, collective protection measures have priority over individual protection measures.
- (9) Employers should make adjustments in the light of technical progress and scientific knowledge regarding risks related to exposure to optical radiation, with a view to improving the safety and health protection of workers.
- (10) Since this Directive is an individual directive within the meaning of Article 16(1) of Directive 89/391/EEC, that Directive applies to the exposure of workers to optical radiation, without prejudice to more stringent and/or specific provisions contained in this Directive.

⁽¹⁾ OJ L 42, 15.2.2003, p. 38.

⁽²⁾ OJ L 159, 30.4.2004, p. 1. Directive as corrected in OJ L 184, 24.5.2004, p. 1.

⁽³⁾ OJ L 183, 29.6.1989, p. 1. Directive as amended by Regulation (EC) No 1882/2003 of the European Parliament and of the Council (OJ L 284, 31.10.2003, p. 1).

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- (11) This Directive constitutes a practical step towards creating the social dimension of the internal market.
- (12) A complementary approach that both promotes the principle of better regulation and ensures a high level of protection can be achieved where the products made by the manufacturers of optical radiation sources and associated equipment comply with harmonised standards devised to protect the health and safety of users from the hazards inherent in such products; accordingly, it is not necessary for employers to repeat the measurements or calculations already undertaken by the manufacturer to determine compliance with the essential safety requirements of such equipment as specified in the applicable Community Directives, provided that the equipment has been properly and regularly maintained.
- (13) The measures necessary for the implementation of this Directive should be adopted in accordance with Council Decision 1999/468/EC of 28 June 1999 laying down the procedures for the exercise of implementing powers conferred on the Commission ⁽¹⁾.
- (14) Adherence to the exposure limit values should provide a high level of protection as regards the health effects that may result from exposure to optical radiation.
- (15) The Commission should draw up a practical guide to help employers, in particular managers of SMEs, better to understand the technical provisions of this Directive. The Commission should strive to complete this guide as quickly as possible so as to facilitate adoption by the Member States of the measures necessary to implement this Directive.
- (16) In accordance with paragraph 34 of the Interinstitutional Agreement on better law-making ⁽²⁾, Member States are encouraged to draw up, for themselves and in the interests of the Community, their own tables illustrating, as far as possible, the correlation between this Directive and the transposition measures, and to make them public,

HAVE ADOPTED THIS DIRECTIVE:

SECTION I

GENERAL PROVISIONS

Article 1

Aim and scope

1. This Directive, which is the 19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC, lays down minimum requirements for the protection of workers from risks to their health and safety arising or likely to arise from exposure to artificial optical radiation during their work.
2. This Directive refers to the risk to the health and safety of workers due to adverse effects caused by exposure to artificial optical radiation to the eyes and to the skin.

⁽¹⁾ OJ L 184, 17.7.1999, p. 23.

⁽²⁾ OJ C 321, 31.12.2003, p. 1.

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3. Directive 89/391/EEC shall apply fully to the whole area referred to in paragraph 1, without prejudice to more stringent and/or more specific provisions contained in this Directive.

*Article 2***Definitions**

For the purposes of this Directive, the following definitions shall apply:

- (a) optical radiation: any electromagnetic radiation in the wavelength range between 100 nm and 1 mm. The spectrum of optical radiation is divided into ultraviolet radiation, visible radiation and infrared radiation:
 - (i) ultraviolet radiation: optical radiation of wavelength range between 100 nm and 400 nm. The ultraviolet region is divided into UVA (315-400 nm), UVB (280-315 nm) and UVC (100-280 nm);
 - (ii) visible radiation: optical radiation of wavelength range between 380 nm and 780 nm;
 - (iii) infrared radiation: optical radiation of wavelength range between 780 nm and 1 mm. The infrared region is divided into IRA (780-1 400 nm), IRB (1 400-3 000 nm) and IRC (3 000 nm-1 mm);
- (b) laser (light amplification by stimulated emission of radiation): any device which can be made to produce or amplify electromagnetic radiation in the optical radiation wavelength range primarily by the process of controlled stimulated emission;
- (c) laser radiation: optical radiation from a laser;
- (d) non-coherent radiation: any optical radiation other than laser radiation;
- (e) exposure limit values: limits on exposure to optical radiation which are based directly on established health effects and biological considerations. Compliance with these limits will ensure that workers exposed to artificial sources of optical radiation are protected against all known adverse health effects;
- (f) irradiance (E) or power density: the radiant power incident per unit area upon a surface expressed in watts per square metre (W m^{-2});
- (g) radiant exposure (H): the time integral of the irradiance, expressed in joules per square metre (J m^{-2});
- (h) radiance (L): the radiant flux or power output per unit solid angle per unit area, expressed in watts per square metre per steradian ($\text{W m}^{-2} \text{sr}^{-1}$);
- (i) level: the combination of irradiance, radiant exposure and radiance to which a worker is exposed.

*Article 3***Exposure limit values**

1. The exposure limit values for non-coherent radiation, other than that emitted by natural sources of optical radiation, are as set out in Annex I.
2. The exposure limit values for laser radiation are as set out in Annex II.



SECTION II

OBLIGATIONS OF EMPLOYERS

*Article 4***Determination of exposure and assessment of risks**

1. In carrying out the obligations laid down in Articles 6(3) and 9(1) of Directive 89/391/EEC, the employer, in the case of workers exposed to artificial sources of optical radiation, shall assess and, if necessary, measure and/or calculate the levels of exposure to optical radiation to which workers are likely to be exposed so that the measures needed to restrict exposure to the applicable limits can be identified and put into effect. The methodology applied in assessment, measurement and/or calculations shall follow the standards of the International Electrotechnical Commission (IEC) in respect of laser radiation and the recommendations of the International Commission on Illumination (CIE) and the European Committee for Standardisation (CEN) in respect of non-coherent radiation. In exposure situations which are not covered by these standards and recommendations, and until appropriate EU standards or recommendations become available, assessment, measurement and/or calculations shall be carried out using available national or international science-based guidelines. In both exposure situations, the assessment may take account of data provided by the manufacturers of the equipment when it is covered by relevant Community Directives.

2. The assessment, measurement and/or calculations referred to in paragraph 1 shall be planned and carried out by competent services or persons at suitable intervals, taking particular account of the provisions of Articles 7 and 11 of Directive 89/391/EEC concerning the necessary competent services or persons and the consultation and participation of workers. The data obtained from the assessment, including those obtained from the measurement and/or calculation of the level of exposure referred to in paragraph 1 shall be preserved in a suitable form so as to permit their consultation at a later stage.

3. Pursuant to Article 6(3) of Directive 89/391/EEC, the employer shall give particular attention, when carrying out the risk assessment, to the following:

- (a) the level, wavelength range and duration of exposure to artificial sources of optical radiation;
- (b) the exposure limit values referred to in Article 3 of this Directive;
- (c) any effects concerning the health and safety of workers belonging to particularly sensitive risk groups;
- (d) any possible effects on workers' health and safety resulting from workplace interactions between optical radiation and photosensitising chemical substances;
- (e) any indirect effects such as temporary blinding, explosion or fire;
- (f) the existence of replacement equipment designed to reduce the levels of exposure to artificial optical radiation;
- (g) appropriate information obtained from health surveillance, including published information, as far as possible;
- (h) multiple sources of exposure to artificial optical radiation;
- (i) a classification applied to a laser as defined in accordance with the relevant IEC standard and, in relation to any artificial source likely to cause damage similar to that of a laser of class 3B or 4, any similar classification;

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(j) information provided by the manufacturers of optical radiation sources and associated work equipment in accordance with the relevant Community Directives.

4. The employer shall be in possession of an assessment of the risk in accordance with Article 9(1)(a) of Directive 89/391/EEC and shall identify which measures must be taken in accordance with Articles 5 and 6 of this Directive. The risk assessment shall be recorded on a suitable medium, according to national law and practice; it may include a justification by the employer that the nature and extent of the risks related to optical radiation make a further, detailed risk assessment unnecessary. The risk assessment shall be updated on a regular basis, particularly if there have been significant changes which could render it out of date, or if the results of health surveillance show it to be necessary.

*Article 5***Provisions aimed at avoiding or reducing risks**

1. Taking account of technical progress and of the availability of measures to control the risk at source, the risks arising from exposure to artificial optical radiation shall be eliminated or reduced to a minimum.

The reduction of risks arising from exposure to artificial optical radiation shall be based on the general principles of prevention set out in Directive 89/391/EEC.

2. Where the risk assessment carried out in accordance with Article 4 (1) for workers exposed to artificial sources of optical radiation indicates any possibility that the exposure limit values may be exceeded, the employer shall devise and implement an action plan comprising technical and/or organisational measures designed to prevent the exposure exceeding the limit values, taking into account in particular:

- (a) other working methods that reduce the risk from optical radiation;
- (b) the choice of equipment emitting less optical radiation, taking account of the work to be done;
- (c) technical measures to reduce the emission of optical radiation including, where necessary, the use of interlocks, shielding or similar health protection mechanisms;
- (d) appropriate maintenance programmes for work equipment, workplaces and workstation systems;
- (e) the design and layout of workplaces and workstations;
- (f) limitation of the duration and level of the exposure;
- (g) the availability of appropriate personal protective equipment;
- (h) the instructions of the manufacturer of the equipment where it is covered by relevant Community Directives.

3. On the basis of the risk assessment carried out in accordance with Article 4, workplaces where workers could be exposed to levels of optical radiation from artificial sources exceeding the exposure limit values shall be indicated by appropriate signs in accordance with Council Directive 92/58/EEC of 24 June 1992 on the minimum requirements for the provision of safety and/or health signs at work (9th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)⁽¹⁾. The areas in question shall be identified, and access to them limited where this is technically possible and where there is a risk that the exposure limit values could be exceeded.

⁽¹⁾ OJ L 245, 26.8.1992, p. 23.

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4. Workers shall not be exposed above the exposure limit values. In any event, if, despite the measures taken by the employer to comply with this Directive in respect of artificial sources of optical radiation, the exposure limit values are exceeded, the employer shall take immediate action to reduce exposure below the exposure limit values. The employer shall identify the reasons why the exposure limit values have been exceeded and shall adapt the protection and prevention measures accordingly in order to prevent them being exceeded again.

5. Pursuant to Article 15 of Directive 89/391/EEC, the employer shall adapt the measures referred to in this Article to the requirements of workers belonging to particularly sensitive risk groups.

*Article 6***Worker information and training**

Without prejudice to Articles 10 and 12 of Directive 89/391/EEC, the employer shall ensure that workers who are exposed to risks from artificial optical radiation at work and/or their representatives receive any necessary information and training relating to the outcome of the risk assessment provided for in Article 4 of this Directive, concerning in particular:

- (a) measures taken to implement this Directive;
- (b) the exposure limit values and the associated potential risks;
- (c) the results of the assessment, measurement and/or calculations of the levels of exposure to artificial optical radiation carried out in accordance with Article 4 of this Directive together with an explanation of their significance and potential risks;
- (d) how to detect adverse health effects of exposure and how to report them;
- (e) the circumstances in which workers are entitled to health surveillance;
- (f) safe working practices to minimise risks from exposure;
- (g) proper use of appropriate personal protective equipment.

*Article 7***Consultation and participation of workers**

Consultation and participation of workers and/or of their representatives shall take place in accordance with Article 11 of Directive 89/391/EEC on the matters covered by this Directive.

SECTION III

MISCELLANEOUS PROVISIONS*Article 8***Health surveillance**

1. With the objectives of the prevention and timely detection of any adverse health effects, as well as the prevention of any long-term health risks and any risk of chronic diseases, resulting from exposure to optical radiation, Member States shall adopt provisions to ensure appropriate health surveillance of workers pursuant to Article 14 of Directive 89/391/EEC.

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2. Member States shall ensure that health surveillance is carried out by a doctor, an occupational health professional or a medical authority responsible for health surveillance in accordance with national law and practice.

3. Member States shall establish arrangements to ensure that, for each worker who undergoes health surveillance in accordance with paragraph 1, individual health records are made and kept up to date. Health records shall contain a summary of the results of the health surveillance carried out. They shall be kept in a suitable form so as to permit consultation at a later date, taking into account any confidentiality. Copies of the appropriate records shall be supplied to the competent authority on request, taking into account any confidentiality. The employer shall take appropriate measures to ensure that the doctor, the occupational health professional or the medical authority responsible for the health surveillance, as determined by Member States as appropriate, has access to the results of the risk assessment referred to in Article 4 where such results may be relevant to the health surveillance. Individual workers shall, at their request, have access to their own personal health records.

4. In any event, where exposure above the limit values is detected, a medical examination shall be made available to the worker(s) concerned in accordance with national law and practice. This medical examination shall also be carried out where, as a result of health surveillance, a worker is found to have an identifiable disease or adverse health effect which is considered by a doctor or occupational health professional to be the result of exposure to artificial optical radiation at work. In both cases, when limit values are exceeded or adverse health effects (including diseases) are identified:

- (a) the worker shall be informed by the doctor or other suitably qualified person of the result which relates to him personally. He shall, in particular, receive information and advice regarding any health surveillance which he should undergo following the end of exposure;
- (b) the employer shall be informed of any significant findings of the health surveillance, taking into account any medical confidentiality;
- (c) the employer shall:
 - review the risk assessment carried out pursuant to Article 4,
 - review the measures provided for to eliminate or reduce risks pursuant to Article 5,
 - take into account the advice of the occupational health professional or other suitably qualified person or the competent authority in implementing any measure required to eliminate or reduce risk in accordance with Article 5, and
 - arrange continued health surveillance and provide for a review of the health status of any other worker who has been similarly exposed. In such cases, the competent doctor or occupational health professional or the competent authority may propose that the exposed persons undergo a medical examination.

*Article 9***Penalties**

Member States shall provide for adequate penalties to be applicable in the event of infringement of the national legislation adopted pursuant to this Directive. These penalties must be effective, proportionate and dissuasive.

▼B*Article 10***Technical amendments**

1. Any modification of the exposure limit values set out in the Annexes shall be adopted by the European Parliament and the Council in accordance with the procedure laid down in Article 137(2) of the Treaty.
2. Amendments to the Annexes of a strictly technical nature in line with:
 - (a) the adoption of Directives in the field of technical harmonisation and standardisation with regard to the design, building, manufacture or construction of work equipment and/or workplaces;
 - (b) technical progress, changes in the most relevant harmonised European standards or international specifications, and new scientific findings concerning occupational exposure to optical radiation,

shall be adopted in accordance with the procedure laid down in Article 11(2).

*Article 11***Committee**

1. The Commission shall be assisted by the Committee referred to in Article 17 of Directive 89/391/EEC.
 2. Where reference is made to this paragraph, Articles 5 and 7 of Decision 1999/468/EC shall apply, having regard to the provisions of Article 8 thereof.
- The period laid down in Article 5(6) of Decision 1999/468/EC shall be set at three months.
3. The Committee shall adopt its rules of procedure.

SECTION IV

FINAL PROVISIONS**▼M1****▼B***Article 13***Practical guide**

In order to facilitate implementation of this Directive the Commission shall draw up a practical guide to the provisions of Articles 4 and 5 and Annexes I and II.

*Article 14***Transposition**

1. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 27 April 2010. They shall forthwith inform the Commission thereof.

When Member States adopt these measures, they shall contain a reference to this Directive or shall be accompanied by such reference on the occasion of their official publication. The methods of making such reference shall be laid down by Member States.

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2. Member States shall communicate to the Commission the text of the provisions of national law which they adopt or have already adopted in the field covered by this Directive.

Article 15

Entry into force

This Directive shall enter into force on the day of its publication in the *Official Journal of the European Union*.

Article 16

Addressees

This Directive is addressed to the Member States.



ANNEX I

Non-coherent optical radiation

The biophysically relevant exposure values to optical radiation can be determined with the formulae below. The formulae to be used depend on the range of radiation emitted by the source and the results should be compared with the corresponding exposure limit values indicated in Table 1.1. More than one exposure value and corresponding exposure limit can be relevant for a given source of optical radiation.

Numbering (a) to (o) refers to corresponding rows of Table 1.1.

$$(a) \quad H_{\text{eff}} = \int_0^t \int_{\lambda=180 \text{ nm}}^{\lambda=400 \text{ nm}} E_{\lambda}(\lambda, t) \cdot S(\lambda) \cdot d\lambda \cdot dt \quad (H_{\text{eff}} \text{ is only relevant in the range 180 to 400 nm})$$

$$(b) \quad H_{\text{UVA}} = \int_0^t \int_{\lambda=315 \text{ nm}}^{\lambda=400 \text{ nm}} E_{\lambda}(\lambda, t) \cdot d\lambda \cdot dt \quad (H_{\text{UVA}} \text{ is only relevant in the range 315 to 400 nm})$$

$$(c), (d) \quad L_{\text{B}} = \int_{\lambda=300 \text{ nm}}^{\lambda=700 \text{ nm}} L_{\lambda}(\lambda) \cdot B(\lambda) \cdot d\lambda \quad (L_{\text{B}} \text{ is only relevant in the range 300 to 700 nm})$$

$$(e), (f) \quad E_{\text{B}} = \int_{\lambda=300 \text{ nm}}^{\lambda=700 \text{ nm}} E_{\lambda}(\lambda) \cdot B(\lambda) \cdot d\lambda \quad (E_{\text{B}} \text{ is only relevant in the range 300 to 700 nm})$$

$$(g) \text{ to } (l) \quad L_{\text{R}} = \int_{\lambda_1}^{\lambda_2} L_{\lambda}(\lambda) \cdot R(\lambda) \cdot d\lambda \quad (\text{See Table 1.1 for appropriate values of } \lambda_1 \text{ and } \lambda_2)$$

$$(m), (n) \quad E_{\text{IR}} = \int_{\lambda=780 \text{ nm}}^{\lambda=3000 \text{ nm}} E_{\lambda}(\lambda) \cdot d\lambda \quad (E_{\text{IR}} \text{ is only relevant in the range 780 to 3 000 nm})$$

$$(o) \quad H_{\text{skin}} = \int_0^t \int_{\lambda=380 \text{ nm}}^{\lambda=3000 \text{ nm}} E_{\lambda}(\lambda, t) \cdot d\lambda \cdot dt \quad (H_{\text{skin}} \text{ is only relevant in the range 380 to 3 000 nm})$$

For the purposes of this Directive, the formulae above can be replaced by the following expressions and the use of discrete values as set out in the following tables:

$$(a) \quad E_{\text{eff}} = \sum_{\lambda=180 \text{ nm}}^{\lambda=400 \text{ nm}} E_{\lambda} \cdot S(\lambda) \cdot \Delta\lambda \quad \text{and } H_{\text{eff}} = E_{\text{eff}} \cdot \Delta t$$

$$(b) \quad E_{\text{UVA}} = \sum_{\lambda=315 \text{ nm}}^{\lambda=400 \text{ nm}} E_{\lambda} \cdot \Delta\lambda \quad \text{and } H_{\text{UVA}} = E_{\text{UVA}} \cdot \Delta t$$

$$(c), (d) \quad L_{\text{B}} = \sum_{\lambda=300 \text{ nm}}^{\lambda=700 \text{ nm}} L_{\lambda} \cdot B(\lambda) \cdot \Delta\lambda$$

$$(e), (f) \quad E_{\text{B}} = \sum_{\lambda=300 \text{ nm}}^{\lambda=700 \text{ nm}} E_{\lambda} \cdot B(\lambda) \cdot \Delta\lambda$$

$$(g) \text{ to } (l) \quad L_{\text{R}} = \sum_{\lambda_1}^{\lambda_2} L_{\lambda} \cdot R(\lambda) \cdot \Delta\lambda \quad (\text{See Table 1.1 for appropriate values of } \lambda_1 \text{ and } \lambda_2)$$

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$$(m), (n) \quad E_{\text{IR}} = \sum_{\lambda = 780 \text{ nm}}^{\lambda = 3\,000 \text{ nm}} E_{\lambda} \cdot \Delta\lambda$$

$$(o) \quad E_{\text{skin}} = \sum_{\lambda = 380 \text{ nm}}^{\lambda = 3\,000 \text{ nm}} E_{\lambda} \cdot \Delta\lambda \quad \text{and} \quad H_{\text{skin}} = E_{\text{skin}} \cdot \Delta t$$

Notes:

$E_{\lambda}(\lambda, t)$, E_{λ} *spectral irradiance or spectral power density*: the radiant power incident per unit area upon a surface, expressed in watts per square metre per nanometre [$\text{W m}^{-2} \text{ nm}^{-1}$]; values of $E_{\lambda}(\lambda, t)$ and E_{λ} come from measurements or may be provided by the manufacturer of the equipment;

E_{eff} *effective irradiance (UV range)*: calculated irradiance within the UV wavelength range 180 to 400 nm spectrally weighted by $S(\lambda)$, expressed in watts per square metre [W m^{-2}];

H *radiant exposure*: the time integral of the irradiance, expressed in joules per square metre [J m^{-2}];

H_{eff} *effective radiant exposure*: radiant exposure spectrally weighted by $S(\lambda)$, expressed in joules per square metre [J m^{-2}];

E_{UVA} *total irradiance (UVA)*: calculated irradiance within the UVA wavelength range 315 to 400 nm, expressed in watts per square metre [W m^{-2}];

H_{UVA} *radiant exposure*: the time and wavelength integral or sum of the irradiance within the UVA wavelength range 315 to 400 nm, expressed in joules per square metre [J m^{-2}];

$S(\lambda)$ *spectral weighting* taking into account the wavelength dependence of the health effects of UV radiation on eye and skin, (Table 1.2) [dimensionless];

$t, \Delta t$ *time, duration of the exposure*, expressed in seconds [s];

λ *wavelength*, expressed in nanometres [nm];

$\Delta \lambda$ *bandwidth*, expressed in nanometres [nm], of the calculation or measurement intervals;

$L_{\lambda}(\lambda), L_{\lambda}$ *spectral radiance of the source* expressed in watts per square metre per steradian per nanometre [$\text{W m}^{-2} \text{ sr}^{-1} \text{ nm}^{-1}$];

$R(\lambda)$ *spectral weighting* taking into account the wavelength dependence of the thermal injury caused to the eye by visible and IRA radiation (Table 1.3) [dimensionless];

L_{R} *effective radiance (thermal injury)*: calculated radiance spectrally weighted by $R(\lambda)$ expressed in watts per square metre per steradian [$\text{W m}^{-2} \text{ sr}^{-1}$];

$B(\lambda)$ *spectral weighting* taking into account the wavelength dependence of the photochemical injury caused to the eye by blue light radiation (Table 1.3) [dimensionless];

L_{B} *effective radiance (blue light)*: calculated radiance spectrally weighted by $B(\lambda)$, expressed in watts per square metre per steradian [$\text{W m}^{-2} \text{ sr}^{-1}$];

E_{B} *effective irradiance (blue light)*: calculated irradiance spectrally weighted by $B(\lambda)$ expressed in watts per square metre [W m^{-2}];

E_{IR} *total irradiance (thermal injury)*: calculated irradiance within the infrared wavelength range 780 nm to 3 000 nm expressed in watts per square metre [W m^{-2}];

E_{skin} *total irradiance (visible, IRA and IRB)*: calculated irradiance within the visible and infrared wavelength range 380 nm to 3 000 nm, expressed in watts per square metre [W m^{-2}];

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- H_{skin} *radiant exposure*: the time and wavelength integral or sum of the irradiance within the visible and infrared wavelength range 380 to 3 000 nm, expressed in joules per square metre (J m^{-2});
- α *angular subtense*: the angle subtended by an apparent source, as viewed at a point in space, expressed in milliradians (mrad). Apparent source is the real or virtual object that forms the smallest possible retinal image.

Table 1.1
Exposure limit values for non-coherent optical radiation

| Index | Wavelength nm | Exposure limit value | Units | Comment | Part of the body | Hazard |
|-------|--|---|---|--|--|--|
| a. | 180-400 (UVA, UVB and UVC) | $H_{\text{eff}} = 30$ Daily value 8 hours | $[J\ m^{-2}]$ | | eye cornea conjunctiva lens skin | photokeratitis conjunctivitis cataractogenesis erythema elastosis skin cancer |
| b. | 315-400 (UVA) | $H_{\text{UVA}} = 10^4$ Daily value 8 hours | $[J\ m^{-2}]$ | | eye lens | cataractogenesis |
| c. | 300-700 (Blue light) <i>see note 1</i> | $L_B = \frac{10^6}{t}$ for $t \leq 10\ 000\ s$ | $L_B: [W\ m^{-2}\ sr^{-1}]$ $t: [seconds]$ | for $\alpha \geq 11\ mrad$ | | |
| d. | 300-700 (Blue light) <i>see note 1</i> | $L_B = 100$ for $t > 10\ 000\ s$ | $[W\ m^{-2}\ sr^{-1}]$ | | | |
| e. | 300-700 (Blue light) <i>see note 1</i> | $E_B = \frac{100}{t}$ for $t \leq 10\ 000\ s$ | $E_B: [W\ m^{-2}]$ $t: [seconds]$ | for $\alpha < 11\ mrad$ <i>see note 2</i> | eye retina | photoretinitis |
| f. | 300-700 (Blue light) <i>see note 1</i> | $E_B = 0,01$ $t > 10\ 000\ s$ | $[W\ m^{-2}]$ | | | |

| Index | Wavelength nm | Exposure limit value | Units | Comment | Part of the body | Hazard | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-------|--------------------------------|---|---|---|--------------------|----------------------------------|----|--------------------------------|---|--|---|------------|--------------------|----------------------------------|----|--------------------------------|--|---|--|------------|--------------------|---|--------------------|---|---|---|----------------------|--------------------|---|----------------------------------|--------------------|---|--|---------------------------------------|------------|--------------------|----------------------------------|----|--------------------|--|---|---|--|--------------------|----------------------------------|----|----------------------------|---|---|----------------------|--------------------|----------------------------------|----------------------------------|----|----------------------------|
| g. | 380-1 400 (Visible and IRA) | $L_R = \frac{2,8 \cdot 10^7}{C_\alpha}$ for $t > 10$ s | [W m ⁻² sr ⁻¹] | $C_\alpha = 1,7$ for $\alpha \leq 1,7$ mrad | eye retina | retinal burn | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | $C_\alpha = \alpha$ for $1,7 \leq \alpha \leq 100$ mrad $C_\alpha = 100$ for $\alpha > 100$ mrad $\lambda_1 = 380; \lambda_2 = 1 400$ | | | h. | 380-1 400 (Visible and IRA) | $L_R = \frac{5 \cdot 10^7}{C_\alpha t^{0,25}}$ for $10 \mu\text{s} \leq t \leq 10$ s | L_R : [W m ⁻² sr ⁻¹] t: [seconds] | | eye retina | retinal burn | | i. | 380-1 400 (Visible and IRA) | $L_R = \frac{8,89 \cdot 10^8}{C_\alpha}$ for $t < 10 \mu\text{s}$ | [W m ⁻² sr ⁻¹] | | | | j. | 780-1 400 (IRA) | $L_R = \frac{6 \cdot 10^6}{C_\alpha}$ for $t > 10$ s | [W m ⁻² sr ⁻¹] | $C_\alpha = 11$ for $\alpha \leq 11$ mrad | eye retina | retinal burn | $C_\alpha = \alpha$ for $11 \leq \alpha \leq 100$ mrad $C_\alpha = 100$ for $\alpha > 100$ mrad (measurement field-of-view: 11 mrad) $\lambda_1 = 780; \lambda_2 = 1 400$ | k. | 780-1 400 (IRA) | $L_R = \frac{5 \cdot 10^7}{C_\alpha t^{0,25}}$ for $10 \mu\text{s} \leq t \leq 10$ s | L_R : [W m ⁻² sr ⁻¹] t: [seconds] | | eye retina | retinal burn | | l. | 780-1 400 (IRA) | $L_R = \frac{8,89 \cdot 10^8}{C_\alpha}$ for $t < 10 \mu\text{s}$ | [W m ⁻² sr ⁻¹] | | | | | m. | 780-3 000 (IRA and IRB) | $E_{IR} = 18 000 t^{-0,75}$ for $t \leq 1 000$ s | E: [W m ⁻²] t: [seconds] | | eye cornea lens | corneal burn cataractogenesis | | n. | 780-3 000 (IRA and IRB) |
| h. | 380-1 400 (Visible and IRA) | $L_R = \frac{5 \cdot 10^7}{C_\alpha t^{0,25}}$ for $10 \mu\text{s} \leq t \leq 10$ s | L_R : [W m ⁻² sr ⁻¹] t: [seconds] | | eye retina | retinal burn | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | i. | 380-1 400 (Visible and IRA) | $L_R = \frac{8,89 \cdot 10^8}{C_\alpha}$ for $t < 10 \mu\text{s}$ | [W m ⁻² sr ⁻¹] | | | | j. | 780-1 400 (IRA) | $L_R = \frac{6 \cdot 10^6}{C_\alpha}$ for $t > 10$ s | [W m ⁻² sr ⁻¹] | $C_\alpha = 11$ for $\alpha \leq 11$ mrad | eye retina | retinal burn | $C_\alpha = \alpha$ for $11 \leq \alpha \leq 100$ mrad $C_\alpha = 100$ for $\alpha > 100$ mrad (measurement field-of-view: 11 mrad) $\lambda_1 = 780; \lambda_2 = 1 400$ | k. | 780-1 400 (IRA) | $L_R = \frac{5 \cdot 10^7}{C_\alpha t^{0,25}}$ for $10 \mu\text{s} \leq t \leq 10$ s | L_R : [W m ⁻² sr ⁻¹] t: [seconds] | | eye retina | retinal burn | | l. | 780-1 400 (IRA) | $L_R = \frac{8,89 \cdot 10^8}{C_\alpha}$ for $t < 10 \mu\text{s}$ | [W m ⁻² sr ⁻¹] | | | | | m. | 780-3 000 (IRA and IRB) | $E_{IR} = 18 000 t^{-0,75}$ for $t \leq 1 000$ s | E: [W m ⁻²] t: [seconds] | | eye cornea lens | corneal burn cataractogenesis | | n. | 780-3 000 (IRA and IRB) | $E_{IR} = 100$ for $t > 1 000$ s | [W m ⁻²] | | eye cornea lens | corneal burn cataractogenesis | | |
| i. | 380-1 400 (Visible and IRA) | $L_R = \frac{8,89 \cdot 10^8}{C_\alpha}$ for $t < 10 \mu\text{s}$ | [W m ⁻² sr ⁻¹] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| j. | 780-1 400 (IRA) | $L_R = \frac{6 \cdot 10^6}{C_\alpha}$ for $t > 10$ s | [W m ⁻² sr ⁻¹] | $C_\alpha = 11$ for $\alpha \leq 11$ mrad | eye retina | retinal burn | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | $C_\alpha = \alpha$ for $11 \leq \alpha \leq 100$ mrad $C_\alpha = 100$ for $\alpha > 100$ mrad (measurement field-of-view: 11 mrad) $\lambda_1 = 780; \lambda_2 = 1 400$ | | | k. | 780-1 400 (IRA) | $L_R = \frac{5 \cdot 10^7}{C_\alpha t^{0,25}}$ for $10 \mu\text{s} \leq t \leq 10$ s | L_R : [W m ⁻² sr ⁻¹] t: [seconds] | | eye retina | retinal burn | | l. | 780-1 400 (IRA) | $L_R = \frac{8,89 \cdot 10^8}{C_\alpha}$ for $t < 10 \mu\text{s}$ | [W m ⁻² sr ⁻¹] | | | | | m. | 780-3 000 (IRA and IRB) | $E_{IR} = 18 000 t^{-0,75}$ for $t \leq 1 000$ s | E: [W m ⁻²] t: [seconds] | | eye cornea lens | corneal burn cataractogenesis | | n. | 780-3 000 (IRA and IRB) | $E_{IR} = 100$ for $t > 1 000$ s | [W m ⁻²] | | eye cornea lens | corneal burn cataractogenesis | | | | | | | | | | | | | | | | | | |
| k. | 780-1 400 (IRA) | $L_R = \frac{5 \cdot 10^7}{C_\alpha t^{0,25}}$ for $10 \mu\text{s} \leq t \leq 10$ s | L_R : [W m ⁻² sr ⁻¹] t: [seconds] | | eye retina | retinal burn | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | l. | 780-1 400 (IRA) | $L_R = \frac{8,89 \cdot 10^8}{C_\alpha}$ for $t < 10 \mu\text{s}$ | [W m ⁻² sr ⁻¹] | | | | | m. | 780-3 000 (IRA and IRB) | $E_{IR} = 18 000 t^{-0,75}$ for $t \leq 1 000$ s | E: [W m ⁻²] t: [seconds] | | eye cornea lens | corneal burn cataractogenesis | | n. | 780-3 000 (IRA and IRB) | $E_{IR} = 100$ for $t > 1 000$ s | [W m ⁻²] | | eye cornea lens | corneal burn cataractogenesis | | | | | | | | | | | | | | | | | | | | | | | | | |
| l. | 780-1 400 (IRA) | $L_R = \frac{8,89 \cdot 10^8}{C_\alpha}$ for $t < 10 \mu\text{s}$ | [W m ⁻² sr ⁻¹] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | m. | 780-3 000 (IRA and IRB) | $E_{IR} = 18 000 t^{-0,75}$ for $t \leq 1 000$ s | E: [W m ⁻²] t: [seconds] | | eye cornea lens | corneal burn cataractogenesis | | n. | 780-3 000 (IRA and IRB) | $E_{IR} = 100$ for $t > 1 000$ s | [W m ⁻²] | | eye cornea lens | corneal burn cataractogenesis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| m. | 780-3 000 (IRA and IRB) | $E_{IR} = 18 000 t^{-0,75}$ for $t \leq 1 000$ s | E: [W m ⁻²] t: [seconds] | | eye cornea lens | corneal burn cataractogenesis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | n. | 780-3 000 (IRA and IRB) | $E_{IR} = 100$ for $t > 1 000$ s | [W m ⁻²] | | eye cornea lens | corneal burn cataractogenesis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| n. | 780-3 000 (IRA and IRB) | $E_{IR} = 100$ for $t > 1 000$ s | [W m ⁻²] | | eye cornea lens | corneal burn cataractogenesis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |



| Index | Wavelength nm | Exposure limit value | Units | Comment | Part of the body | Hazard |
|-------|--|--|--|---------|------------------|--------|
| o. | 380-3 000 (Visible, IRA and IRB) | $H_{\text{skin}} = 20\,000 t^{0,25}$ for $t < 10$ s | H: [J m^{-2}] t: [seconds] | | skin | burn |

Note 1: The range of 300 to 700 nm covers parts of UVB, all UVA and most of visible radiation; however, the associated hazard is commonly referred to as '*blue light*' hazard. Blue light strictly speaking covers only the range of approximately 400 to 490 nm.

Note 2: For steady fixation of very small sources with an angular subtense < 11 mrad, L_B can be converted to E_B . This normally applies only for ophthalmic instruments or a stabilized eye during anaesthesia. The maximum 'stare time' is found by: $t_{\text{max}} = 100/E_B$ with E_B expressed in W m^{-2} . Due to eye movements during normal visual tasks this does not exceed 100 s.



Table 1.2

S (λ) [dimensionless], 180 nm to 400 nm

| λ in nm | S (λ) | λ in nm | S (λ) | λ in nm | S (λ) | λ in nm | S (λ) | λ in nm | S (λ) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 180 | 0,0120 | 228 | 0,1737 | 276 | 0,9434 | 324 | 0,000520 | 372 | 0,000086 |
| 181 | 0,0126 | 229 | 0,1819 | 277 | 0,9272 | 325 | 0,000500 | 373 | 0,000083 |
| 182 | 0,0132 | 230 | 0,1900 | 278 | 0,9112 | 326 | 0,000479 | 374 | 0,000080 |
| 183 | 0,0138 | 231 | 0,1995 | 279 | 0,8954 | 327 | 0,000459 | 375 | 0,000077 |
| 184 | 0,0144 | 232 | 0,2089 | 280 | 0,8800 | 328 | 0,000440 | 376 | 0,000074 |
| 185 | 0,0151 | 233 | 0,2188 | 281 | 0,8568 | 329 | 0,000425 | 377 | 0,000072 |
| 186 | 0,0158 | 234 | 0,2292 | 282 | 0,8342 | 330 | 0,000410 | 378 | 0,000069 |
| 187 | 0,0166 | 235 | 0,2400 | 283 | 0,8122 | 331 | 0,000396 | 379 | 0,000066 |
| 188 | 0,0173 | 236 | 0,2510 | 284 | 0,7908 | 332 | 0,000383 | 380 | 0,000064 |
| 189 | 0,0181 | 237 | 0,2624 | 285 | 0,7700 | 333 | 0,000370 | 381 | 0,000062 |
| 190 | 0,0190 | 238 | 0,2744 | 286 | 0,7420 | 334 | 0,000355 | 382 | 0,000059 |
| 191 | 0,0199 | 239 | 0,2869 | 287 | 0,7151 | 335 | 0,000340 | 383 | 0,000057 |
| 192 | 0,0208 | 240 | 0,3000 | 288 | 0,6891 | 336 | 0,000327 | 384 | 0,000055 |
| 193 | 0,0218 | 241 | 0,3111 | 289 | 0,6641 | 337 | 0,000315 | 385 | 0,000053 |
| 194 | 0,0228 | 242 | 0,3227 | 290 | 0,6400 | 338 | 0,000303 | 386 | 0,000051 |
| 195 | 0,0239 | 243 | 0,3347 | 291 | 0,6186 | 339 | 0,000291 | 387 | 0,000049 |
| 196 | 0,0250 | 244 | 0,3471 | 292 | 0,5980 | 340 | 0,000280 | 388 | 0,000047 |
| 197 | 0,0262 | 245 | 0,3600 | 293 | 0,5780 | 341 | 0,000271 | 389 | 0,000046 |
| 198 | 0,0274 | 246 | 0,3730 | 294 | 0,5587 | 342 | 0,000263 | 390 | 0,000044 |
| 199 | 0,0287 | 247 | 0,3865 | 295 | 0,5400 | 343 | 0,000255 | 391 | 0,000042 |
| 200 | 0,0300 | 248 | 0,4005 | 296 | 0,4984 | 344 | 0,000248 | 392 | 0,000041 |
| 201 | 0,0334 | 249 | 0,4150 | 297 | 0,4600 | 345 | 0,000240 | 393 | 0,000039 |
| 202 | 0,0371 | 250 | 0,4300 | 298 | 0,3989 | 346 | 0,000231 | 394 | 0,000037 |
| 203 | 0,0412 | 251 | 0,4465 | 299 | 0,3459 | 347 | 0,000223 | 395 | 0,000036 |
| 204 | 0,0459 | 252 | 0,4637 | 300 | 0,3000 | 348 | 0,000215 | 396 | 0,000035 |
| 205 | 0,0510 | 253 | 0,4815 | 301 | 0,2210 | 349 | 0,000207 | 397 | 0,000033 |
| 206 | 0,0551 | 254 | 0,5000 | 302 | 0,1629 | 350 | 0,000200 | 398 | 0,000032 |
| 207 | 0,0595 | 255 | 0,5200 | 303 | 0,1200 | 351 | 0,000191 | 399 | 0,000031 |
| 208 | 0,0643 | 256 | 0,5437 | 304 | 0,0849 | 352 | 0,000183 | 400 | 0,000030 |
| 209 | 0,0694 | 257 | 0,5685 | 305 | 0,0600 | 353 | 0,000175 | | |
| 210 | 0,0750 | 258 | 0,5945 | 306 | 0,0454 | 354 | 0,000167 | | |
| 211 | 0,0786 | 259 | 0,6216 | 307 | 0,0344 | 355 | 0,000160 | | |
| 212 | 0,0824 | 260 | 0,6500 | 308 | 0,0260 | 356 | 0,000153 | | |
| 213 | 0,0864 | 261 | 0,6792 | 309 | 0,0197 | 357 | 0,000147 | | |
| 214 | 0,0906 | 262 | 0,7098 | 310 | 0,0150 | 358 | 0,000141 | | |
| 215 | 0,0950 | 263 | 0,7417 | 311 | 0,0111 | 359 | 0,000136 | | |
| 216 | 0,0995 | 264 | 0,7751 | 312 | 0,0081 | 360 | 0,000130 | | |
| 217 | 0,1043 | 265 | 0,8100 | 313 | 0,0060 | 361 | 0,000126 | | |
| 218 | 0,1093 | 266 | 0,8449 | 314 | 0,0042 | 362 | 0,000122 | | |
| 219 | 0,1145 | 267 | 0,8812 | 315 | 0,0030 | 363 | 0,000118 | | |
| 220 | 0,1200 | 268 | 0,9192 | 316 | 0,0024 | 364 | 0,000114 | | |
| 221 | 0,1257 | 269 | 0,9587 | 317 | 0,0020 | 365 | 0,000110 | | |
| 222 | 0,1316 | 270 | 1,0000 | 318 | 0,0016 | 366 | 0,000106 | | |
| 223 | 0,1378 | 271 | 0,9919 | 319 | 0,0012 | 367 | 0,000103 | | |
| 224 | 0,1444 | 272 | 0,9838 | 320 | 0,0010 | 368 | 0,000099 | | |
| 225 | 0,1500 | 273 | 0,9758 | 321 | 0,000819 | 369 | 0,000096 | | |
| 226 | 0,1583 | 274 | 0,9679 | 322 | 0,000670 | 370 | 0,000093 | | |
| 227 | 0,1658 | 275 | 0,9600 | 323 | 0,000540 | 371 | 0,000090 | | |

▼B

Table 1.3

B (λ), R (λ) [dimensionless], 380 nm to 1 400 nm

| λ in nm | B (λ) | R (λ) |
|--------------------------------|-----------------------------------|--|
| $300 \leq \lambda < 380$ | 0,01 | — |
| 380 | 0,01 | 0,1 |
| 385 | 0,013 | 0,13 |
| 390 | 0,025 | 0,25 |
| 395 | 0,05 | 0,5 |
| 400 | 0,1 | 1 |
| 405 | 0,2 | 2 |
| 410 | 0,4 | 4 |
| 415 | 0,8 | 8 |
| 420 | 0,9 | 9 |
| 425 | 0,95 | 9,5 |
| 430 | 0,98 | 9,8 |
| 435 | 1 | 10 |
| 440 | 1 | 10 |
| 445 | 0,97 | 9,7 |
| 450 | 0,94 | 9,4 |
| 455 | 0,9 | 9 |
| 460 | 0,8 | 8 |
| 465 | 0,7 | 7 |
| 470 | 0,62 | 6,2 |
| 475 | 0,55 | 5,5 |
| 480 | 0,45 | 4,5 |
| 485 | 0,32 | 3,2 |
| 490 | 0,22 | 2,2 |
| 495 | 0,16 | 1,6 |
| 500 | 0,1 | 1 |
| $500 < \lambda \leq 600$ | $10^{0,02 \cdot (450 - \lambda)}$ | 1 |
| $600 < \lambda \leq 700$ | 0,001 | 1 |
| $700 < \lambda \leq 1\ 050$ | — | $10^{0,002 \cdot (700 - \lambda)}$ |
| $1\ 050 < \lambda \leq 1\ 150$ | — | 0,2 |
| $1\ 150 < \lambda \leq 1\ 200$ | — | $0,2 \cdot 10^{0,02 \cdot (1\ 150 - \lambda)}$ |
| $1\ 200 < \lambda \leq 1\ 400$ | — | 0,02 |



ANNEX II

Laser optical radiation

The biophysically relevant exposure values to optical radiation can be determined with the formulae below. The formulae to be used depend on the wavelength and duration of radiation emitted by the source and the results should be compared with the corresponding exposure limit values indicated in the Tables 2.2 to 2.4. More than one exposure value and corresponding exposure limit can be relevant for a given source of laser optical radiation.

Coefficients used as calculation tools within the Tables 2.2 to 2.4 are listed in Table 2.5 and corrections for repetitive exposure are listed in Table 2.6.

$$E = \frac{dP}{dA} \text{ [W m}^{-2}\text{]}$$

$$H = \int_0^t E(t) \cdot dt \text{ [J m}^{-2}\text{]}$$

Notes:

- dP *power* expressed in watt [W];
- dA *surface* expressed in square metres [m²];
- E (t), E *irradiance or power density*: the radiant power incident per unit area upon a surface, generally expressed in watts per square metre [W m⁻²]. Values of E(t), E come from measurements or may be provided by the manufacturer of the equipment;
- H *radiant exposure*: the time integral of the irradiance, expressed in joules per square metre [J m⁻²];
- t *time, duration of the exposure*, expressed in seconds [s];
- λ *wavelength*, expressed in nanometres [nm];
- γ *limiting cone angle of measurement field-of-view* expressed in milliradians [mrad];
- γ_m *measurement field of view* expressed in milliradians [mrad];
- α *angular subtense of a source* expressed in milliradians [mrad];
- limiting aperture*: the circular area over which irradiance and radiant exposure are averaged;
- G *integrated radiance*: the integral of the radiance over a given exposure time expressed as radiant energy per unit area of a radiating surface per unit solid angle of emission, in joules per square metre per steradian [J m⁻² sr⁻¹].



Table 2.1

Radiation hazards

| Wavelength [nm] λ | Radiation range | Affected organ | Hazard | Exposure limit value table |
|------------------------------|-----------------|----------------|--|-------------------------------|
| 180 to 400 | UV | eye | photochemical damage and thermal damage | 2.2, 2.3 |
| 180 to 400 | UV | skin | erythema | 2.4 |
| 400 to 700 | visible | eye | retinal damage | 2.2 |
| 400 to 600 | visible | eye | photochemical damage | 2.3 |
| 400 to 700 | visible | skin | thermal damage | 2.4 |
| 700 to 1 400 | IRA | eye | thermal damage | 2.2, 2.3 |
| 700 to 1 400 | IRA | skin | thermal damage | 2.4 |
| 1 400 to 2 600 | IRB | eye | thermal damage | 2.2 |
| 2 600 to 10 ⁶ | IRC | eye | thermal damage | 2.2 |
| 1 400 to 10 ⁶ | IRB, IRC | eye | thermal damage | 2.3 |
| 1 400 to 10 ⁶ | IRB, IRC | skin | thermal damage | 2.4 |

Table 2.2
Exposure limit values for laser exposure to the eye — Short exposure duration < 10 s

| Wavelength ^a [nm] | Aperture | Duration [s] | | | |
|------------------------------|-------------------------|---------------------|------------------|-------------------------|---------------------------------|
| | | $10^{13} - 10^{11}$ | $10^{11} - 10^9$ | $10^7 - 1,8 \cdot 10^5$ | $1,8 \cdot 10^5 - 5 \cdot 10^3$ |
| UVC | 180 - 280 | | | | $10^3 - 10^1$ |
| | 280 - 302 | | | | |
| | 303 | | | | |
| | 304 | | | | |
| | 305 | | | | |
| | 306 | | | | |
| | 307 | | | | |
| | 308 | | | | |
| | 309 | | | | |
| | 310 | | | | |
| UVB | 311 | | | | |
| | 312 | | | | |
| | 313 | | | | |
| | 314 | | | | |
| | 315 - 400 | | | | |
| | 400 - 700 | | | | |
| Visible & IRA | 700 - 1 050 | | | | |
| | 1 050 - 1 400 | | | | |
| | 1 400 - 1 500 | | | | |
| IRB & IRC | 1 500 - 1 800 | | | | |
| | 1 800 - 2 600 | | | | |
| | 2 600 - 10 ⁶ | | | | |
| | | | | | |

a If the wavelength of the laser is covered by two limits, then the more restrictive applies.
 b When $1400 \leq \lambda < 10^6$ nm: aperture diameter = 1 mm for $t \leq 0,3$ s and $1,5 \cdot t^{0,75}$ mm for $0,3 < t < 10$ s; when $10^5 \leq \lambda < 10^6$ nm: aperture diameter = 11 mm.
 c Due to lack of data at these pulse lengths, ICNIRP recommends the use of the 1 ns irradiance limits.
 d The table states values for single laser pulses. In case of multiple laser pulses, then the laser pulse durations of pulses falling within an interval T_{min} (listed in table 2.6) must be added up and the resulting time value must be filled in for t in the formula: $5,6 \cdot 10^3 \cdot t^{0,25}$.

Table 2.4
Exposure limit values for laser exposure of skin

| Wavelength ^a [nm] | | Aperture | Duration [s] | | | | |
|------------------------------|-----------------------|----------|---|--|---------------|---------------|-----------------------|
| | | | $10^9 - 10^7$ | $10^7 - 10^3$ | $10^3 - 10^1$ | $10^1 - 10^3$ | $10^3 - 3 \cdot 10^4$ |
| UV (A, B, C) | 180-400 | 3,5mm | Same as eye exposure limits | | | | |
| | | | | | | | |
| Visible and IRA | 400-700 | 3,5mm | $H = 200 C_A$ | Same as eye exposure limits | | | |
| | 700-1 400 | | $E = 2 \cdot 10^{11} \text{ [W m}^{-2}\text{]}$ | | | | |
| IRB and IRC | 1 400-1 500 | 3,5mm | $H = 1,1 \cdot 10^4 C_A t^{0,25} \text{ [J m}^{-2}\text{]}$ | Same as eye exposure limits | | | |
| | 1 500-1 800 | | $E = 2 \cdot 10^{11} C_A \text{ [W m}^{-2}\text{]}$ | | | | |
| | 1 800-2 600 | | $E = 10^{12} \text{ [W m}^{-2}\text{]}$ | | | | |
| | 2 600-10 ⁶ | | $E = 10^{11} \text{ [W m}^{-2}\text{]}$ | | | | |
| | | | $E = 2 \cdot 10^{11} \text{ [W m}^{-2}\text{]}$ | $E = 2 \cdot 10^3 C_A \text{ [W m}^{-2}\text{]}$ | | | |

a If the wavelength or another condition of the laser is covered by two limits, then the more restrictive applies.



Table 2.5

Applied correction factors and other calculation parameters

| Parameter as listed in ICNIRP | Valid spectral range (nm) | Value |
|-------------------------------|--------------------------------|---|
| C_A | $\lambda < 700$ | $C_A = 1,0$ |
| | 700 — 1 050 | $C_A = 10^{0,002(\lambda - 700)}$ |
| | 1 050 — 1 400 | $C_A = 5,0$ |
| C_B | 400 — 450 | $C_B = 1,0$ |
| | 450 — 700 | $C_B = 10^{0,02(\lambda - 450)}$ |
| C_C | 700 — 1 150 | $C_C = 1,0$ |
| | 1 150 — 1 200 | $C_C = 10^{0,018(\lambda - 1 150)}$ |
| | 1 200 — 1 400 | $C_C = 8,0$ |
| T_1 | $\lambda < 450$ | $T_1 = 10 \text{ s}$ |
| | 450 — 500 | $T_1 = 10 \cdot [10^{0,02(\lambda - 450)}] \text{ s}$ |
| | $\lambda > 500$ | $T_1 = 100 \text{ s}$ |
| Parameter as listed in ICNIRP | Valid for biological effect | Value |
| α_{\min} | all thermal effects | $\alpha_{\min} = 1,5 \text{ mrad}$ |
| Parameter as listed in ICNIRP | Valid angular range (mrad) | Value |
| C_E | $\alpha < \alpha_{\min}$ | $C_E = 1,0$ |
| | $\alpha_{\min} < \alpha < 100$ | $C_E = \alpha / \alpha_{\min}$ |
| | $\alpha > 100$ | $C_E = \alpha^2 / (\alpha_{\min} \cdot \alpha_{\max}) \text{ mrad}$ with $\alpha_{\max} = 100 \text{ mrad}$ |
| T_2 | $\alpha < 1,5$ | $T_2 = 10 \text{ s}$ |
| | $1,5 < \alpha < 100$ | $T_2 = 10 \cdot [10^{(\alpha - 1,5) / 98,5}] \text{ s}$ |
| | $\alpha > 100$ | $T_2 = 100 \text{ s}$ |
| Parameter as listed in ICNIRP | Valid exposure time range (s) | Value |
| γ | $t \leq 100$ | $\gamma = 11 \text{ [mrad]}$ |
| | $100 < t < 10^4$ | $\gamma = 1,1 t^{0,5} \text{ [mrad]}$ |
| | $t > 10^4$ | $\gamma = 110 \text{ [mrad]}$ |



Table 2.6

Correction for repetitive exposure

Each of the following three general rules should be applied to all repetitive exposures as occur from repetitively pulsed or scanning laser systems:

1. The exposure from any single pulse in a train of pulses shall not exceed the exposure limit value for a single pulse of that pulse duration.
2. The exposure from any group of pulses (or sub-group of pulses in a train) delivered in time t shall not exceed the exposure limit value for time t .
3. The exposure from any single pulse within a group of pulses shall not exceed the single-pulse exposure limit value multiplied by a cumulative-thermal correction factor $C_p = N^{-0,25}$, where N is the number of pulses. This rule applies only to exposure limits to protect against thermal injury, where all pulses delivered in less than T_{min} are treated as a single pulse.

| Parameter | Valid spectral range (nm) | Value |
|-----------|------------------------------|---|
| T_{min} | 315 $<\lambda \leq$ 400 | $T_{min} = 10^{-9}$ s (= 1 ns) |
| | 400 $<\lambda \leq$ 1 050 | $T_{min} = 18 \cdot 10^{-6}$ s (= 18 μ s) |
| | 1 050 $<\lambda \leq$ 1 400 | $T_{min} = 50 \cdot 10^{-6}$ s (= 50 μ s) |
| | 1 400 $<\lambda \leq$ 1 500 | $T_{min} = 10^{-3}$ s (= 1 ms) |
| | 1 500 $<\lambda \leq$ 1 800 | $T_{min} = 10$ s |
| | 1 800 $<\lambda \leq$ 2 600 | $T_{min} = 10^{-3}$ s (= 1 ms) |
| | 2 600 $<\lambda \leq$ 10^6 | $T_{min} = 10^{-7}$ s (= 100 ns) |



STATEMENT BY THE COUNCIL

Statement by the Council on the use of the word ‘penalties’ in the English version of legal instruments of the European Community

In the opinion of the Council, when the word ‘penalties’ is used in the English version of legal instruments of the European Community, this word is used in a neutral sense and does not relate specifically to criminal law sanctions, but could also include administrative and financial sanctions, as well as other types of sanction. When Member States are obliged under a Community act to introduce ‘penalties’, it is up to them to choose the appropriate type of sanction in conformity with the case law of the European Court of Justice.

In the Community language data base, the following translations are made of the word ‘penalty’ in some other languages:

in Spanish, ‘*sanciones*’; in Danish, ‘*sanktioner*’; in German, ‘*Sanktionen*’; in Hungarian, ‘*jogkövetkezmények*’; in Italian, ‘*sanzioni*’; in Latvian, ‘*sankcijas*’; in Lithuanian, ‘*sankcijos*’; in Dutch, ‘*sancties*’; in Portuguese, ‘*sanções*’; in Slovak, ‘*sankcie*’; and in Swedish, ‘*sanktioner*’.

If, in revised English versions of legal instruments where the word ‘sanctions’ has previously been used, this word is replaced with the word ‘penalties’, this does not constitute a substantive difference.