*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 2.2-2.4. 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, 2.3 and 2.4 are listed in Table 2.5 and corrections for repetitive exposure are listed in Table 2.6.

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

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

Notes:

dP power expressed in watt [W];

dA surface expressed in square meter [$m^2$];

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];

$\lambda$ wavelength, expressed in nanometres [nm];

$\gamma$ limiting cone angle of measurement field-of-view expressed in milliradians [mrad];

$\gamma_m$ measurement field of view expressed in milliradians [mrad];

$\alpha$ 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] $\lambda$ | 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] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | $10^{-13}$ - $10^{-11}$ | $10^{-11}$ - $10^{-9}$ | $10^{-9}$ - $10^{-7}$ | $10^{-7}$ - $1{,}8 \cdot 10^{-5}$ | $1{,}8 \cdot 10^{-5}$ - $5 \cdot 10^{-5}$ | $5 \cdot 10^{-5}$ - $10^{-3}$ | $10^{-3}$ - $10^{1}$ |
| UVC | 180-280 | 1 mm for $t < 0{,}3$ s; $1{,}5 \cdot t^{0{,}375}$ for $0{,}3 < t < 10$ s | $E = 3 \cdot 10^{10} \cdot [W\ m^{-2}]$ [b] | | $H = 30\ [J\ m^{-2}]$ | | | | |
| UVB | 280-302 | | | | | | | | |
| | 303 | | | | $H = 40\ [J\ m^{-2}]$; if $t < 2{,}6 \cdot 10^{-9}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 304 | | | | $H = 60\ [J\ m^{-2}]$; if $t < 1{,}3 \cdot 10^{-8}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 305 | | | | $H = 100\ [J\ m^{-2}]$; if $t < 1{,}0 \cdot 10^{-7}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 306 | | | | $H = 160\ [J\ m^{-2}]$; if $t < 6{,}7 \cdot 10^{-7}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25} [J\ m^{-2}]$ [c] | | | | |
| | 307 | | | | $H = 250\ [J\ m^{-2}]$; if $t < 4{,}0 \cdot 10^{-6}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 308 | | | | $H = 400\ [J\ m^{-2}]$; if $t < 2{,}6 \cdot 10^{-5}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 309 | | | | $H = 630\ [J\ m^{-2}]$; if $t < 1{,}6 \cdot 10^{-4}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25} [J\ m^{-2}]$ [c] | | | | |
| | 310 | | | | $H = 10^{3}\ [J\ m^{-2}]$; if $t < 1{,}0 \cdot 10^{-3}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 311 | | | | $H = 1{,}6 \cdot 10^{3}\ [J\ m^{-2}]$; if $t < 6{,}7 \cdot 10^{-3}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 312 | | | | $H = 2{,}5 \cdot 10^{3}\ [J\ m^{-2}]$; if $t < 4{,}0 \cdot 10^{-2}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 313 | | | | $H = 4{,}0 \cdot 10^{3}\ [J\ m^{-2}]$; if $t < 2{,}6 \cdot 10^{-1}$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| | 314 | | | | $H = 6{,}3 \cdot 10^{3}\ [J\ m^{-2}]$; if $t < 1{,}6 \cdot 100$ then $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ [c] | | | | |
| UVA | 315-400 | | | | $H = 5{,}6 \cdot 10^{3}\ t^{0{,}25}\ [J\ m^{-2}]$ | | | | |
| Visible & IRA | 400-700 | 7 mm | $H = 1{,}5 \cdot 10^{-4}\ C_E\ [J\ m^{-2}]$ | $H = 2{,}7 \cdot 10^{4}\ t^{0{,}75}\ C_E\ [J\ m^{-2}]$ | $H = 5 \cdot 10^{-3}\ C_E\ [J\ m^{-2}]$ | | $H = 18 \cdot t^{0{,}75}\ C_E\ [J\ m^{-2}]$ | | |
| | 700-1 050 | | $H = 1{,}5 \cdot 10^{-4}\ C_A\ C_E\ [J\ m^{-2}]$ | $H = 2{,}7 \cdot 10^{4}\ t^{0{,}75}\ C_A\ C_E\ [J\ m^{-2}]$ | $H = 5 \cdot 10^{-3}\ C_A\ C_E\ [J\ m^{-2}]$ | | $H = 18 \cdot t^{0{,}75}\ C_A\ C_E\ [J\ m^{-2}]$ | | |
| | 1 050-1 400 | | $H = 1{,}5 \cdot 10^{-3}\ C_C\ C_E\ [J\ m^{-2}]$ | $H = 2{,}7 \cdot 10^{5}\ t^{0{,}75}\ C_C\ C_E\ [J\ m^{-2}]$ | $H = 5 \cdot 10^{-2}\ C_C\ C_E\ [J\ m^{-2}]$ | | | $H = 90 \cdot t^{0{,}75}\ C_C\ C_E\ [J\ m^{-2}]$ | |
| IRB & IRC | 1 400-1 500 | [d] | $E = 10^{12}\ [W\ m^{-2}]$ [b] | | $H = 10^{3}\ [J\ m^{-2}]$ | | | | $H = 5{,}6 \cdot 10^{3} \cdot t^{0{,}25}\ [J\ m^{-2}]$ |
| | 1 500-1 800 | | $E = 10^{13}\ [W\ m^{-2}]$ [b] | | $H = 10^{4}\ [J\ m^{-2}]$ | | | | |
| | 1 800-2 600 | | $E = 10^{12}\ [W\ m^{-2}]$ [b] | | $H = 10^{3}\ [J\ m^{-2}]$ | | | | $H = 5{,}6 \cdot 10^{3} \cdot t^{0{,}25}\ [J\ m^{-2}]$ |
| | 2 600-$10^{6}$ | | $E = 10^{11}\ [W\ m^{-2}]$ [b] | | $H = 100\ [J\ m^{-2}]$ | $H = 5{,}6 \cdot 10^{3} \cdot t^{0{,}25}\ [J\ m^{-2}]$ | | | |

[a] If the wavelength of the laser is covered by two limits, then the more restrictive applies.
[b] Due to lack of data at these pulse lengths, ICNIRP recommends the use of the 1 ns irradiance limits.
[c] 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: $5{,}6 \cdot 10^{3}\ t^{0{,}25}$.
[d] When $1\,400 \leq \lambda < 10^{5}$ nm: aperture diameter = 1 mm for $t \leq 0{,}3$ s and $1{,}5\ t^{0{,}375}$ mm for $0{,}3\ s < t < 10$ s; when $10^{5} \leq \lambda < 10^{6}$ nm: aperture diameter = 11 mm.

Table 2.3: Exposure limit values for laser exposure to the eye Long exposure duration ≥ 10 s

| Wavelength [a] [nm] | | Aperture | Duration [s] | | |
|---|---|---|---|---|---|
| | | | $10^1$ - $10^2$ | $10^2$ - $10^4$ | $10^4$ -3 · $10^4$ |
| UVC | 180-280 | 3,5 mm | H = 30 [J $m^{-2}$] | | |
| UVB | 280-302 | | H = 30 [J $m^{-2}$] | | |
| | 303 | | H = 40 [J $m^{-2}$] | | |
| | 304 | | H = 60 [J $m^{-2}$] | | |
| | 305 | | H = 100 [J $m^{-2}$] | | |
| | 306 | | H = 160 [J $m^{-2}$] | | |
| | 307 | | H = 250 [J $m^{-2}$] | | |
| | 308 | | H = 400 [J $m^{-2}$] | | |
| | 309 | | H = 630 [J $m^{-2}$] | | |
| | 310 | | H = 1,0 $10^3$ [J $m^{-2}$] | | |
| | 311 | | H = 1,6 $10^3$ [J $m^{-2}$] | | |
| | 312 | | H = 2,5 $10^3$ [J $m^{-2}$] | | |
| | 313 | | H = 4,0 $10^3$ [J $m^{-2}$] | | |
| | 314 | | H = 6,3 $10^3$ [J $m^{-2}$] | | |
| UVA | 315-400 | | H = $10^4$ [J $m^{-2}$] | | |
| Visible 400-700 | 400-600 Photochemical [b] Retinal damage | 7 mm | H = 100 $C_B$ [J $m^{-2}$] ($\gamma$ = 11 mrad) [c] | E = 1 $C_B$ [W $m^{-2}$]; ($\gamma$ = 1,1 $t^{0,5}$ mrad) [c] | E = 1 $C_B$ [W $m^{-2}$] ($\gamma$ = 110 mrad) [c] |
| | 400-700 Thermal [b] Retinal damage | | if $\alpha$ < 1,5 mrad then E = 10 [W $m^{-2}$]<br>if $\alpha$ > 1,5 mrad and t ≤ $T_2$ then H = 18$C_E$ $t^{0,75}$ [J $m^{-2}$]<br>if $\alpha$ > 1,5 mrad and t > $T_2$ then E = 18$C_E$ $T_2^{-0,25}$ [W $m^{-2}$] | | |
| IRA | 700-1 400 | 7 mm | if $\alpha$ < 1,5 mrad then E = 10 $C_A$ $C_C$ [W $m^{-2}$]<br>if $\alpha$ > 1,5 mrad and t ≤ $T_2$ then H = 18 $C_A$ $C_C$ $C_E$ $t^{0,75}$ [J $m^{-2}$]<br>if $\alpha$ > 1,5 mrad and t > $T_2$ then E = 18 $C_A$ $C_C$ $C_E$ $T_2^{-0,25}$ [W $m^{-2}$] (not to exceed 1 000 W $m^{-2}$) | | |
| IRB & IRC | 1 400-$10^6$ | [d] | E = 1 000 [W $m^{-2}$] | | |

[a] If the wavelength of the laser is covered by two limits, then the more restrictive applies.

[b] For small sources subtending an angle of 1,5 mrad or less, the visible dual limits E from 400 nm to 600 nm reduce to the thermal limits for 10s ≤ t < T1 and to photochemical limits for longer times. For $T_1$ and $T_2$ see Table 2.5. The photochemical retinal hazard limit may also be expressed as a time integrated radiance G = $10^6$ $C_B$ [J $m^{-2}$ $sr^{-1}$] for t > 10s up to t = 10 000 s and L = 100 $C_B$ [W $m^{-2}$ $sr^{-1}$] for t > 10 000 s. For the measurement of G and L $\gamma_m$ must be used as averaging field of view. The official border between visible and infrared is 780 nm as defined by the CIE. The column with wavelength band names is only meant to provide better overview for the user. (The notation G is used by CEN; the notation $L_t$ is used by CIE; the notation $L_P$ is used by IEC and CENELEC).

[c] For wavelength 1 400-$10^5$ nm: aperture diameter = 3,5 mm; for wavelength $10^5$-$10^6$ nm: aperture diameter = 11 mm.

[d] For measurement of the exposure value the consideration of $\gamma$ is defined as follows: If $\alpha$ (angular subtense of a source) > $\gamma$ (limiting cone angle, indicated in brackets in the corresponding column) then the measurement field of view $\gamma_m$ should be the given value of $\gamma$. (If a larger measurement field of view is used, then the hazard would be overestimated).
If $\alpha$ < $\gamma$ then the measurement field of view $\gamma_m$ must be large enough to fully enclose the source but is otherwise not limited and may be larger than $\gamma$.

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Table 2.4: Exposure limit values for laser exposure of skin

| Wavelength [a][nm] | | Aperture | Duration [s] | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | $< 10^{-9}$ | $10^{-9}$ - $10^{-7}$ | $10^{-7}$ - $10^{-3}$ | $10^{-3}$ - $10^{1}$ | $10^{1}$ - $10^{3}$ | $10^{3}$ - $3 \cdot 10^{4}$ |
| UV (A, B, C) | 180-400 | 3,5 mm | $E = 3 \cdot 10^{10}$ [W m$^{-2}$] | Same as Eye Exposure Limits | | | | |
| Visible & IRA | 400-700 | 3,5 mm | $E = 2 \cdot 10^{11}$ [W m$^{-2}$] | $H = 200\ C_A$ [J m$^{-2}$] | $H = 1{,}1 \cdot 10^{4}\ C_A\ t^{0,25}$ [J m$^{-2}$] | | $E = 2 \cdot 10^{3}\ C_A$ [W m$^{-2}$] | |
| | 700 -1 400 | | $E = 2 \cdot 10^{11}\ C_A$ [W m$^{-2}$] | | | | | |
| IRB & IRC | 1 400-1 500 | | $E = 10^{12}$ [W m$^{-2}$] | Same as Eye Exposure Limits | | | | |
| | 1 500-1 800 | | $E = 10^{13}$ [W m$^{-2}$] | | | | | |
| | 1 800-2 600 | | $E = 10^{12}$ [W m$^{-2}$] | | | | | |
| | 2 600-$10^{6}$ | | $E = 10^{11}$ [W m$^{-2}$] | | | | | |

[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 | $C_C = 10^{\,0{,}018(\lambda\, —\, 1150)}$ |
| | 1 200-1 400 | $C_C = 8{,}0$ |
| $T_1$ | $\lambda < 450$ | $T_1 = 10$ s |
| | 450-500 | $T_1 = 10 \cdot [10^{\,0{,}02\ (\lambda\, —\, 450)}]$ s |
| | $\lambda > 500$ | T1 = 100 s |
| Parameter as listed in ICNIRP | Valid for biological effect | Value |
| $\alpha_{min}$ | all thermal effects | $\alpha_{min} = 1{,}5$ mrad |
| Parameter as listed in ICNIRP | Valid angular range (mrad) | Value |
| $C_E$ | $\alpha < \alpha_{min}$ | $C_E = 1{,}0$ |
| | $\alpha_{min} < \alpha < 100$ | $C_E = \alpha\ /\ \alpha_{min}$ |
| | $\alpha > 100$ | $C_E = \alpha^2\ /\ (\alpha_{min} \cdot \alpha_{max})$ mrad with $\alpha_{max} = 100$ mrad |
| $T_2$ | $\alpha < 1{,}5$ | $T_2 = 10$ s |
| | $1{,}5 < \alpha < 100$ | $T_2 = 10 \cdot [10^{\,(\alpha\, —\, 1{,}5)\ /\ 98{,}5}]$ s |
| | $\alpha > 100$ | $T_2 = 100$ s |
| Parameter as listed in ICNIRP | Valid exposure time range (s) | Value |
| $\gamma$ | $t \leq 100$ | $\gamma = 11$ [mrad] |
| | $100 < t < 10^{4}$ | $\gamma = 1{,}1\ t^{0{,}5}$ [mrad] |
| | $t > 10^{4}$ | $\gamma = 110$ [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 $Cp = N^{-0,25}$, 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 Tmin 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 μs) |
| | $1\,050 < \lambda \leq 1\,400$ | $T_{min} = 50 \cdot 10^{-6}$ s (= 50 μs) |
| | $1\,400 < \lambda \leq 1\,500$ | $T_{min} = 10^{-3}$ 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) |

**P6_TA(2005)0330**

## Competitiveness of audiovisual and information services: protection of minors and human dignity ***I

**European Parliament legislative resolution on the proposal for a recommendation of the European Parliament and of the Council on the protection of minors and human dignity and the right of reply in relation to the competitiveness of the European audiovisual and information services industry (COM(2004)0341 — C6-0029/2004 — 2004/0117(COD))**

(Codecision procedure: first reading)

*The European Parliament,*

— having regard to the Commission proposal to the European Parliament and the Council (COM(2004) 0341) ([1]),

— having regard to Article 251(2) and Article 157 of the EC Treaty, pursuant to which the Commission submitted the proposal to Parliament (C6-0029/2004),

— having regard to Rule 51 of its Rules of Procedure,

— having regard to the report of the Committee on Culture and Education and the opinion of the Committee on Civil Liberties, Justice and Home Affairs (A6-0244/2005),

1. Approves the Commission proposal as amended;

2. Calls on the Commission to refer the matter to Parliament again if it intends to amend the proposal substantially or replace it with another text;

3. Instructs its President to forward its position to the Council and Commission.

([1]) Not yet published in OJ.