Republic of Latvia

Cabinet
Regulation No. 731
Adopted 30 June 2009

Labour Protection Requirements for the Protection of Workers from the Risk Arising from Artificial Optical Radiation in the Work Environment

Issued pursuant to
Section 25, Paragraph eighteen
of the Labour Protection Law

I. General Provisions

1.These Regulations prescribe the labour protection requirements for the protection of workers from the risk arising or likely to arise from exposure to artificial optical radiation (hereinafter – optical radiation) to workers during working hours, especially to the eyes and to the skin.

2. Optical radiation is any electromagnetic radiation in the wavelength range between 100 nm and 1mm. The following types of optical radiation exist:

2.1. non-coherent radiation – any optical radiation other than laser radiation:

2.1.1. ultraviolet radiation – optical radiation of wavelength range between 100 nm and 400 nm. The ultraviolet range is divided into UVA (315-400 nm), UVB (280-315 nm) and UVC (100-280 nm);

2.1.2. visible radiation – optical radiation of wavelength range between 380 nm and 780 nm; and

2.1.3. infrared radiation – optical radiation of wavelength range between 780 nm and 1 mm. The infrared range is divided into IRA (780-1400 nm), IRB (1400-3000 nm) and IRC (3000 nm-1 mm);

2.2. laser radiation – optical radiation from a laser device, with which electromagnetic radiation may be produced or amplified in the optical radiation wavelength range, primarily by the process of controlled stimulated emission.

3. Irradiance or power density is the radiant power incident per unit area upon a surface, expressed in watts per square metre (W/m^2).

4. Radiant exposure is the time integral of the irradiance, expressed in joules per square metre (J/m^2).

5. Radiance is the radiant flux or power output per unit solid angle per unit area, expressed in watts per square metre per steradian (W/m^2 x sr).

6. The level of exposure to optical radiation is the combination of irradiance, radiant exposure and radiance to which a worker is exposed.

7. These Regulations shall apply to all areas of employment, in which workers are or may be exposed to optical radiation in the work environment.

8. An employer shall not expose workers to such optical radiation exposure which exceeds the exposure limit values for non-coherent radiation (Annex 1) and the exposure limit values for laser radiation (Annex 2).

9. The exposure limit values are restrictions to optical radiation exposure, upon compliance with which workers exposed to radiation are protected from harmful effects thereof on health.

10. An employer shall be responsible for the compliance with these Regulations.

11. The State Labour Inspectorate shall control the compliance with the labour protection requirements.

II. Determination of Exposure to Optical Radiation and Assessment of the Risk Caused

12. An employer shall, at all workplaces, perform the initial assessment of the risk arising from optical radiation, specifying whether it includes sources of optical radiation, which might cause harm to the health of workers.

13. If a source of optical radiation is present in the workplace or the results of a health examination of workers confirm that health disorders of workers have been caused by or may have been caused by exposure to optical radiation, the employer shall evaluate the risk caused by optical radiation in accordance with the regulatory enactments regarding the procedures for the performance of internal supervision of the work environment.

14. If an employer establishes that optical radiation causes or may cause risk to the safety and health of workers, he or she shall, if necessary, perform measurements or calculations of optical radiation in accordance with the results acquired, taking into account the exposure limit values (Annex 1 and 2), as well as the information provided by the manufacturer of work equipment regarding the irradiance levels (if the relevant equipment creates optical radiation).

15. The measurements of optical radiation with a calibrated measuring device, which is suitable for the performance of the measurements of relevant optical radiation in accordance with the manufacturer's instructions for use, shall be performed by:

15.1. the laboratories accredited in the territorial unit of the Metrology and Accreditation State Agency – the National Accreditation Bureau of Latvia – in accordance with the standard LVS EN ISO/IEC 17025:2005 *General Requirements for the Testing and Calibration Laboratories*;

15.2. other institutions, which are accredited in European Union Member States and are entitled to perform the measurements of optical radiation;

15.3. the competent institutions or competent specialists in the matters of labour protection;

15.4. the labour protection specialists who have acquired the second level higher education in labour protection in accordance with the regulatory enactments regarding training in the matters of labour protection; or

15.5. persons with a qualification appropriate for the performance of the measurements.

16. An employer, when assessing the risk caused by optical radiation, shall pay particular attention to the following factors:

16.1. the level, wavelength range and duration of exposure to a worker;

16.2. the exposure limit values (Annex 1 and 2);

16.3. any effects concerning the safety and health of the workers belonging to particularly sensitive risk groups (including adolescents, pregnant women and women in the period following childbirth);

16.4. any possible effects on workers' health and safety resulting from workplace interactions between optical radiation and photosensitising chemical substances;

16.5. any indirect effects (including temporary blinding, explosion or fire);

16.6. the condition regarding the existence of replacement equipment designed to reduce the levels of exposure to optical radiation;

16.7. the health examination results of workers, as well as information obtained from scientific investigations regarding the effect of optical radiation on the health of workers;

16.8. the interaction of various sources of optical radiation;

16.9. the classification of lasers or other sources of optical radiation, indicated by the manufacturer of the equipment, and the level of hazard associated thereto, in particular taking into account the damage caused by a laser of Class 3B or 4 or other sources of optical radiation of a similar classification (intermediate or high); and,

16.10. other information provided by the manufacturers of optical radiation sources and associated equipment.

17. An employer shall document and store all the results of the assessment of the risk arising from the optical radiation and measurement results for three years. After expiry of the specified period of time the information shall be transferred for storage to the archives.

III. Prevention or Reduction of the Risk Arising from Optical Radiation

18. In assessing or reducing the risk arising from optical radiation, an employer shall observe the general labour protection principles specified in the Labour Protection Law.

19. An employer, in accordance with the requirements specified in the Labour Protection Law, shall consult with workers or trusted representatives thereof regarding the issues that are related to the risk arising from optical radiation in the work environment, as well as creating the opportunity for the participation of workers in the solving of the relevant issues.

20. An employer shall take the necessary measures in accordance with the results of the risk assessment (including organisational measures – reduction of the period of exposure, rest breaks) for the prevention or reduction of the risk arising from optical radiation to the minimum (the lowest practical level) on the basis of technical progress and using the latest means for the control of the risk source arising from optical radiation.

21. If, when performing a risk assessment of the work environment, it is established that the exposure limit values (Annexes 1 and 2) may be exceeded, an employer shall include the following organisational and technical measures to be performed in specific workplaces, in the plan of labour protection measures:

21.1. to use such work methods which reduce the risk caused by optical radiation;

21.2. to select work equipment which has a lower level of exposure to optical radiation, taking into account the work to be performed;

21.3. to perform technical measures for the reduction of the level of exposure to optical radiation, if necessary, installing equipment for the reduction of the level of exposure to optical radiation, including interlocks, shielding or similar mechanisms to ensure the protection of the health of workers;

21.4. to ensure the cleaning and maintenance of the workstation systems and work equipment in accordance with the regulatory enactments regarding the labour protection requirements in workplaces and when using work equipment;

21.5. to optimise the design and layout of workplaces;

21.6. to restrict the duration and level of exposure to optical radiation;

21.7. to ensure workers with appropriate personal protective equipment; and

21.8. to perform measures in accordance with the instructions of the manufacturer of work equipment.

22. In the workplaces referred to in Paragraph 21 of these Regulations an employer shall place the appropriate safety signs in accordance with the regulatory enactments regarding the labour protection requirements for the use of safety signs. The employer shall ensure the delimitation of hazardous zones and restricted access to these zones, if the exposure to risk caused by optical radiation is justified and the restrictions are technically possible.

23. If, after the labour protection measures performed by an employer for the reduction of the risk caused by optical radiation, the exposure limit values are still exceeded, the employer shall:

23.1. perform measures without delay, in order to prevent the exposure of workers to such optical radiation and to reduce the exposure thereof ensuring that it does not exceed the exposure limit values;

23.2. analyse and determine the reasons, due to which the exposure to optical radiation exceeds the exposure limit values; and

23.3. make changes in the labour protection measures in order to prevent the exposure limit values of optical radiation being exceeded again.

24. An employer shall ensure that workers, who are exposed to risks arising from optical radiation in the work place, and their representatives are appropriately trained and receive information in a comprehensible manner regarding:

24.1. the exposure to optical radiation and the potential risk to the safety and health of workers;

24.2. the labour protection measures, which prevent or reduce the effect of the risk arising from optical radiation on the safety and health of workers to the minimum;

24.3. the results which are acquired in the assessment of the risk caused by optical radiation, and the significance thereof;

24.4. the symptoms of the health disorders arising from exposure to optical radiation, the significance of timely detection of health disorders and the action if health disorders have occurred;

24.5. the conditions in which workers have the right to health surveillance, as well as regarding the significance of the mandatory health examination;

24.6. safe work methods, as well as correct and safe use of work equipment in order to prevent or reduce to the minimum the risk caused by optical radiation; and

24.7. correct and appropriate use of personal protective equipment.

IV. Health Examination of Workers

25. If a worker is exposed to the effect of the risk caused by optical radiation, which exceeds the exposure limit values (Annexes 1 and 2), the employer shall ensure the mandatory health examination of the worker in accordance with the regulatory enactments regarding the procedures by which mandatory health examination shall be performed, in order to diagnose the health disorders caused by optical radiation as soon as possible and to ensure qualitative protection of the health of workers.

26. Upon the request the employer shall ensure access to the results of the assessment of risk caused by optical radiation to the worker, the family doctor of the worker and an occupational health doctor, which performs the mandatory health examination of the worker.

27. If such health disorders are established to the worker during the mandatory health examination, which are assessed by the occupational health doctor as the consequences caused by exposure to optical radiation:

27.1. the doctor shall inform the worker regarding the results of his or her health examination and provide recommendations for health care also after the end of exposure to optical radiation, as well as inform the employer regarding the health examination results in accordance with the regulatory enactments regarding the procedures by which mandatory health examination shall be performed;

27.2. the employer shall, without delay, organise the health examination of other workers which have been exposed to similar effects of optical radiation; and

27.3. the employer shall review the risk assessment which has been performed in accordance with Part II of these Regulations, and the measures for the prevention or reduction of risk.

28. The employer shall ensure documentation of the results of health examinations of workers. Upon a justified request of the State Labour Inspectorate the employer shall issue copies of health examination cards.

29. The employer shall take into account the results of health examinations in planning and determining the labour protection measures for the prevention or reduction of the risk arising from optical radiation to the permissible level.

V. Closing Provision

30. These Regulations shall come into force on 27 April 2010.

Informative Reference to European Union Directive

These Regulations contain legal norms arising from Directive 2006/25/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding exposure of workers to the risks arising from physical agents (artificial optical radiation) (19th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).

Prime Minister, Minister for Children, Family and Integration Affairs	V. Dombrovskis
Minister of Welfare	U. Augulis

Annex 1
Cabinet Regulation
No. 731
30 June 2009

Determination of the Values of Non-coherent Optical Radiation Effects

1. The biophysically relevant exposure values to optical radiation can be determined with the formulae below:

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

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

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

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

(g) to (l) $$L_R = \int_{\lambda_1}^{\lambda_2} L_\lambda(\lambda) \times R(\lambda)\, d\lambda$$ (See Table 1.1 for appropriate values of λ_1 and λ_2)

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

$$H_{ādai} = \int_0^t \int_{\lambda=380nm}^{\lambda=3000nm} E_\lambda(\lambda,t)\, d\lambda\, dt$$ ($H_{ādai}$ is only relevant in the range 380 to 3000 nm)

where

$E_\lambda(\lambda,t)$, 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 (W/m^2 x nm); values of Eλ (λ, t) un Eλ 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, 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 (λ), 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 (λ) spectral weighting taking into account the wavelength dependence of the health effects of UV radiation on eye and skin (Table 1.2) (dimensionless);
t, Δt time, duration of the exposure, expressed in seconds (s);
λ wavelength expressed in nanometres (nm);
Δ λ bandwidth, expressed in nanometres (nm), of the calculation or measurement intervals;
L_λ (λ), L_λ spectral radiance of the source, expressed in watts per square metre per steradian per nanometre (W/m^2 x sr x nm);
R (λ) spectral weighting taking into account the wavelength dependence of the thermal injury caused to the by visible and IRA radiation (Table 1.3) (dimensionless);
L_R effective radiance (thermal injury): calculated radiance spectrally weighted by R (λ) expressed in watts per square metre per steradian (W/m^2 x sr);
B (λ) 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 (λ) expressed in watts per square metre per steradian (W/m^2 x sr);
E_B effective irradiance (blue light): calculated irradiance spectrally weighted by B (λ) expressed in watts per square metre (W/m^2);
E_{IS} total irradiance (thermal injury): calculated irradiance within the infrared wavelength range 780 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 to 3000 nm, expressed in watts per square metre (W/m^2);
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.

2. The aforementioned formulae may be replaced by the following expressions and discrete values:

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

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

(c),(d) $$L_B = \sum_{\lambda=300nm}^{\lambda=700nm} L_\lambda \times B(\lambda) \times \Delta\lambda$$

(e), (f) $E_B = \sum_{\lambda=300nm}^{\lambda=700nm} E_\lambda \times B(\lambda) \times \Delta\lambda$

(g) to (l) $L_R = \sum_{\lambda_1}^{\lambda_2} L_\lambda \times R(\lambda) \times \Delta\lambda$ See 1.1. Table 1.1 in relation to λ_1 and λ_2

(m), (n) $E_{IR} = \sum_{\lambda=780nm}^{\lambda=3000nm} E_\lambda \times \Delta\lambda$

(o) $E_{\bar{a}dai} = \sum_{\lambda=380nm}^{\lambda=3000nm} E_\lambda \times \Delta\lambda$ un $H_{\bar{a}dai} = E_{\bar{a}dai} \times \Delta t$

Notes:

1. The formulae to be used depend on the range of radiation caused by the relevant source, and the results shall be compared with the respective exposure limit values indicated in Table 1.1.
2. More than one exposure value and the corresponding exposure limit value thereof may correspond to one source of optical radiation.
3. Indices a) to o) correspond to the respective rows in Table 1.1.

1.1. Table 1.1

Exposure Limit Values for Non-coherent Optical Radiation

Index	**Wavelength (nm)**	**Exposure limit value**	**Unit of measurement**	**Notes**	**Part of the body**	**Hazard**
a.	180-400 (UVA, UVB and UVC)	$H_{eff} = 30$ Daily value 8 hours	[J/m^2]		eye cornea conjunctiva lens skin	photokeratitis conjunctivitis cataractogenesis erythema elastosis skin cancer
b.	315-400 (UVA)	$H_{UVA} = 10^4$ Daily value 8 hours	[J/m^2]		Eye lens	cataractogenesis
c.	300-700 (Blue light) See Note 1	$L_B = \frac{10^6}{t}$ for t ? 10000 s	L_B: [W/m^2 x sr] t: [seconds]	for t ? 11 mrad	Eye retina	photoretinitis
d.	300-700 (Blue light) See Note 1	$L_B = 100$ for t > 10000 s	[W/m^2 x sr]			
e.	300-700 (Blue light) See Note 1	$E_B = \frac{100}{t}$ for t ? 10000 s	E_B: (W/m^2) t: [seconds]	for t < 11 mrad See Note 2		
f..	300-700 (Blue light)	$E_B = 0{,}01$ t >10 000 s	[W/m^2]			

Index	Wavelength (nm)	Exposure limit value	Unit of measurement	Notes	Part of the body	Hazard
	See Note 1					
g.	380-1400 (Visible and IRA)	$L_R = \frac{2,8 \times 10^7}{C_\alpha}$ for t > 10 s	[W/m² x sr]	C_{α} = 1,7 for α ? 1.7 mrad C_α = α for 1.7 ? α ? 100 mrad C_{α} = 100 for α > 100 mrad λ_1= 380; λ_2= 1400	Eye retina	Retinal burn
h.	380-1400 (Visible and IRA)	$L_R = \frac{5 \times 10^7}{C_\alpha t^{0,25}}$ for 10 µs ? t ? 10 s	L_R: [W/m² x sr] t: [seconds]			
i.	380-1400 (Visible and IRA)	$L_R = \frac{8,89 \times 10^8}{C_\alpha}$ for <10 µs	[W/m² x sr]			
j.	780-1400 (IRA)	$L_R = \frac{6 \times 10^6}{C_\alpha}$ for t > 10 s	[W/m² x sr]	C_{α} = 11 for α ? 11 mrad C_α = α for 11 ? α ? 100 mrad C_{α} = 100 for α > 100 mrad (measurement field-of-view) 11 mrad) λ_1= 780; λ_2= 1400	Eye retina	Retinal burn
(k)	780-1400 (IRA)	$L_R = \frac{5 \times 10^7}{C_\alpha t^{0,25}}$ for 10 µs ? t ? 10 s	L_R: [W/m² × sr] t [seconds]			
l.	780-1400 (IRA)	$L_R = \frac{8,89 \times 10^8}{C_\alpha}$ for t < 10 µs	[W/m² × sr]			
m.	780-3000 (IRA and IRB)	$E_{IR} = 18000t^{0,75}$ for t ? 1 000 s	E: [W/m²] t: [seconds]		eye cornea lens	Corneal burn cataractogenesis
n.	780-3000 (IRA and IRB)	E_{IR} = 100 for t> 1000 s	[W/m²]			
o.	380-3000 (visible, IRA and IRB)	$H_{skin} = 20000\ t^{0,25}$ for t > 10 s	H: [J/m²] t: [seconds]		skin	burn

Notes:

1. The range of 300 to 700 nm covers part 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.

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 stabilised eye during anaesthesia. The maximum “stare time” is found by: $t_{max} = 100/E_B$ with E_B expressed in W/m². Due to eye movements during normal visual tasks this does not exceed 100 s.

1.2. 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		

1.3. Table 1.3

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

λ in nm	B (λ)	R (λ)
300 ? λ <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 < λ ? 600	$10^{0,02.(450-è)}$	1
600 < λ ? 700	0,001	1
700 < λ ? 1050	—	$100^{0.002.(700-\lambda)}$
1050 < λ ? 1150	—	0,2
1150 < λ ? 1200	—	$0{,}2 \times 10^{0{,}02x(1150-\lambda)}$
1200 < λ ? 1400	—	0,02

Minister of Welfare U. Augulis

Annex 2
Cabinet Regulation
No.731
30 June 2009

Determination of the Exposure Value of Laser Optical Radiation

The biophysically relevant exposure values to optical radiation can be determined with the formulae below:

$$E = \frac{dP}{dA} \qquad (W/(m^2)$$

$$H = \int_0^t E(t) \cdot dt \qquad [J/m^2]$$

where
dP power, expressed in watts (W);
dA surface, expressed in square metres (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 meter (W/m^2). Values of E(t) and 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);
? limiting cone angle of measurement, expressed in milliradians (mrad);
$?_m$ 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).

Notes:
1. 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 Tables 2.2 to 2.4.
2. More than one exposure value or effect value can be relevant for a given source of laser optical radiation, for example, the wavelength may be changed for sources and they may have different exposure times. In each case the respective exposure limit value should be applied.
3. Parameters and corrective values which are used for calculations in Tables 2.2 to 2.4 are provided in Table 2.5 and the application thereof for repeat exposure is listed in Table 2.6.

Table 2.1

Laser Radiation Hazards

Wavelength **λ, nm**	Radiation range	Affected organ	Hazard	Exposure limit value
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 1400	IRA	eye	thermal damage	2.2, 2.3
700 to 1400	IRA	skin	thermal damage	2.4
1400 to 2600	IRB	eye	thermal damage	2.2
2600 to 10^6	IRC	eye	thermal damage	2.2
1400 to 10^6	IRB, IRC	eye	thermal damage	2.3
1400 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[1] (nm)		Aperture	Duration (s)						
			10^{-13} - 10^{-11}	10^{-11} - 10^{-9}	10^{-9} - 10^{-7}	10^{-7} - 1,8 ? 10^{-5}	1,8?10^{-5}-5?10^{-5}	5 ? 10^{-5} - 10^{-3}	10^{-3} – 10^{1}
UVC	180-280	1 mm for t<0,3 s; 1,5 $t^{0.375}$ for 0,3<t<10 s							
UVB	280-302				H = 30 (J/m^2)				
	303				H = 40 [J/m^2]; if t < 2,6 · 10^{-9}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	304				H = 60 [J/m^2]; if t < 1,3 · 10^{-8}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	305				H = 100 [J/m^2]; if t < 1,0 · 10^{-7}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	306				H = 160 [J/m^2]; if t < 6,7 · 10^{-7}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	307				H = 250 [J/m^2]; if t < 4,0 · 10^{-6}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	308				H = 400 [J/m^2]; if t < 2,6 · 10^{-5}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	309				H = 630 [J/m^2]; if t < 1,6 · 10^{-4}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	310				H = 10^3 [J/m^2]; if t < 1,0 · 10^{-3}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	311				H = 1,6 10^3 [J/m^2]; if t < 6,7 · 10^{-3}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	312				H = 2,5 10^3 [J/m^2]; if t < 4,0 · 10^{-2}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	313				H = 4,0 10^3 [J/m^2]; if t < 2,6 · 10^{-1}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
	314				H = 6,3 10^3 [J/m^2]; if t < 1,6 · 10^{0}, then H = 5,6 · 10^3 t ^{0,25} [J/m^2] See Note 4				
UVA	315-400				H = 5,6 · 10^3 t ^{0,25} [J/m^2]				
Visible and IRA	400-700	7 mm	H = 1,5 · 10^{-4} C_E [J/m^2]	H = 2,7 · 10^4 t ^{0,75} C_E [J/m^2]	H = 5 · 10^{-3} C_E [J/m^2]		H = 18 · t ^{0,75} C_E [J/m^2]		
	700-1050		H = 1,5 · 10^{-4} C_A C_E [J/m^2]	H=2,7 · 10^4 t ^{0,75} C_A C_E [J/m^2]	H = 5 · 10^{-3} C_A C_E [J/m^2]		H = 18 · t ^{0,75} C_A C_E [J/m^2]		
	1050-1400		H = 1,5 · 10^{-3} C_C C_E [J/m^2]	H =2,7 • 10^5 t ^{0,75} C_C C_E [J/m^2]	H = 5 · 10^{-2} C_C C_E [J/m^2]			H = 90 · t ^{0,75} C_C C_E ([J/m^2]	
IRB and IRC	1400-1500	See Note 2	E = 10^{12} [W/m^2] See Note 3		H = 10^3 (J/m^2)			H = 5.6 . 10^3 . t^{0,25} (J/m^2)	
	1500-1800		E = 10^{13} [W/m^2] See Note 3		H = 10^4 [J/m^2]				
	1800-2600		E = 10^{12} [W/m^2] See Note 3		H = 10^3 [J/m^2]			H = 5,6 ·10^3 · t^{0,25} [J/m^2]	
	2600-10^6		E = 10^{11} [W/m^2] See Note 3		H=100 [J/m^2]	H = 5,6 · 10^3 · t^{0,25} [J/m^2]			

Notes:

1. If the wavelength of the laser is covered by two limits, then the more restrictive applies.
2. When 1400 ? $\lambda<10^5$ nm: aperture diameter = 1 mm for t ? 0,3 s and 1,5 $t^{0,375}$ mm for 0,3 s < t < 10 s; if 10^5 ? $\lambda<10^6$ nm: aperture diameter = 11 mm.
3. Due to lack of data at these pulse lengths, the International Commission on Non-ionizing Radiation Protection (hereinafter – ICNIRP) recommends the use of 1 ns irradiance limits.
4. The table states values for single laser pulses. In case of multiple laser pulses, then the laser pulse duration 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 10^3 $t^{0,25}$

2.3. Table 2.3

Exposure Limit Values for Laser Exposure to the Eye. Long Exposure Duration ≥ 10 s

Wavelength[1] (nm)		Aperture	Duration (s)		
			10^1 - 10^2	10^2 - 10^4	10^4 - 3 · 10^4
UVC	180-280		H = 30 (J/m²)		
	280-302	3.5 mm			
UVB	303		H = 40 (J/m²)		
	304		H = 60 (J/m²)		
	305		H = 100 (J/m²)		
	306		H = 160 (J/m²)		
	307		H = 250 (J/m²)		
	308		H = 400 (J/m²)		
	309		H = 630 (J/m²)		
	310		H = 1.0 10^3 (J/m²)		
	311		H = 1.6 10^3 (J/m²)		
	312		H = 2.5 10^3 (J/m²)		
	313		H = 4.0 10^3 (J/m²)		
	314		H = 6.3 10^3 (J/m²)		
UVA	315-400		H = 10^4 (J/m²)		

Visible 400 – 700	400-600 Photochemical/ retinal damage See Note 2	7 mm	H = 100 C_B [J/m^2] (γ = 11 mrad) See Note 4	E = 1 C_B [W/m^2]; (γ = 1,1 $t^{0,5}$ mrad) See Note 4	E = 1 C_B [W/m^2] (γ = 110 mrad) See Note 4
	Thermal/ retinal damage See Note 2		if α < 1,5 mrad then E = 10 [W/m^2] if α > 1,5 mrad and t ? T_2 then H = 18 C_E $t^{0,75}$ [J/m^2] if α > 1,5 mrad and t > T_2 then E = 18 C_E $T_2^{-0,25}$ [W/m^2]		
IRA	700-1400	7 mm	if α < 1,5 mrad then E = 10 [W/m^2] if α > 1,5 mrad and t ? T_2 then H = 18 C_A C_C C_E $t^{0,75}$ [J/m^2] if α > 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 1000 W/m^2)		
IRB and IRC	1400-10^6	See Note 3	E = 1000 [W/m^2]		

Notes:

1. If the wavelength or another condition of the laser is covered by two limits, then the more restrictive applies.
2. 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 10 s ≤ t <T_1 and to photochemical limits for longer times. For T_1 and T_2 see 2.5. 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] for t > 10s up to t = 10000 s and L = 100 C_B [W/m^2 x sr] for t > 10000 s. For the measurement of G and L y_m must be used as averaging field of view. The official border between visible and infrared is 780 nm as defined by the International Commission on Illumination (hereinafter – CIE). The column with wavelength band names is only meant to provide better overview for the user. The notation G is used by the European Committee for Standardisation (hereinafter – CEN); the notation L_t is used by CIE; the notation L_p is used by IEC and the European Committee for Electrotechnical Standardization (hereinafter – CENELEC).
3. Wavelength 1400-10^5 nm: aperture diameter = 3,5 mm; wavelength 10^5 – 10^6 nm: aperture diameter = 11 mm.
4. For measurement of the exposure value the consideration of γ is defined as follows: If α (angular subtense of a source) > γ (limiting cone angle, indicated in brackets in the corresponding column) then the measurement field of view γ_m should be the given value of γ. If a larger measurement field of view is used then the hazard would be overestimated. If α < γ then the measurement field of view γ_m must be large enough to fully enclose the source but is otherwise not limited and may be larger than γ.

2.4. Table 2.4

Exposure Limit Values for Laser Exposure of Skin

Wavelength (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. 5mm	$E = 3 . 10^{10}$ [W/m²]	Same as eye exposure limits				
Visible and IRA	400-700	3. 5mm	$E = 2 . 10^{11}$ [W/m²]	H=200 C_A [J/m²]	$H = 1{,}1 . 10^{4} C_A t^{0{,}25}$ [J/m²]		$E = 2 . 10^{3} C_A$ [W/m²]	
	700-1400		$E = 2 \cdot 10^{11} C_A$ [W/m²]					
IRB and IRC	1400-1500		$E = 10^{12}$ [W/m²]	Same as eye exposure limits				
	1500-1800		$E = 10^{13}$ [W/m²]					
	1800-2600		$E = 10^{12}$ [W/m²]					
	2600-10^{6}		$E = 10^{11}$ [W/m²]					

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

Table 2.5

Parameters and Correction Factors for the Determination of Laser Radiation Exposure Limit Values

1.	**Parameter as listed in ICNIRP**	**Valid spectral range (nm)**	**Correction value**
1.1.	C_A	λ<700	$C_A = 1{,}0$
		700-1050	$C_A=10^{0{,}002(\lambda - 700)}$
		1050-1400	$C_A = 5{,}0$
1.2.		400-450	$C_B = 1{,}0$

	C_B	450-700	$C_B = 10^{0,02(\lambda - 450)}$
1.3.	C_C	700-1150	$C_C=1,0$
		1150-1200	$C_C=10^{0,018(\lambda - 1150)}$
		1200-1400	$C_C=8,0$
1.4.	T_1	$\lambda<450$	$T_1=10$ s
		450-500	$T_1 = 10 \, . \, [10^{0,02(\lambda - 450)}]$ s
		$\lambda>500$	$T_1=100$ s
2.	Parameter as listed in ICNIRP	Valid for biological effect	Correction value
2.1.	α_{min}	All thermal effects	$\alpha_{min} = 1,5$ mrad
3.	**Parameter as listed in ICNIRP**	**Valid angular range (mrad)**	**Correction value**
3.1.	C_E	$\alpha<\alpha_{min}$	$C_E=1,0$
		$\alpha_{min}<\alpha<100$	$C_E = \alpha/\alpha_{min}$
		$\alpha>100$	$C_E=\alpha^2/\alpha_{min} \, . \, \alpha_{max})$ mrad with $\alpha_{max}=100$ mrad

3.2.	T_2	$\alpha<1,5$	$T_2=10$ s
		$1,5<\alpha<100$	$T_2=10 \, . \, (10^{(\alpha-1,5)/98,5})$ s
		$\alpha>100$	$T_2=100$ s
4.	**Parameter as listed in ICNIRP**	**Valid exposure time range**	**Correction value**
4.1.	γ	$t\leq 100$	$\gamma=11$ [mrad]
		$100<t<10^4$	$\gamma = 1,1 \, t^{0,5}$ [mrad]
		$t>10^4$	$\gamma=11$ [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)	Correction value
T_{min}	$315<\lambda\leq 400$	$T_{min} = 10^{-9}$ s (= 1 ns)
	$400<\lambda\leq 1050$ 1050	$T_{min} = 18 \cdot 10^{-6}$ s (= 18 μs)
	$1050 <\lambda\leq 1400$ 1400	$T_{min} = 50 \cdot 10^{-6}$ s (= 50 μs)
	$1400<\lambda\leq 1500$ 1500	$T_{min} = 10^{-3}$ s (= 1 ms)
	$1500<\lambda\leq 1800$ 1800	$T_{min} = 10$ s
	$1800<\lambda\leq 2600$ 2600	$T_{min} = 10^{-3}$ s (= 1 ms)
	$2600<\lambda\leq 10^6$ 10^6	$T_{min} = 10^{-7}$ s (= 100 ns)

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