Statement on ICNIRP guidelines on limits of exposure to incoherent optical radiation

1. Introduction

In April 2006 the European Parliament and the Council adopted the Directive 2006/25/EC [2], which lays down the minimum safety requirements regarding the exposure of workers to risks arising from artificial optical radiation. The Directive places a responsibility on employers to assess exposure levels, adopt preventive measures and arrange for the provision of information and training for their employees. Annexes I and II of the Directive provide Exposure Limit Values (ELVs) for incoherent optical radiation and laser radiation, respectively. These ELVs take account of the biological effectiveness of the optical radiation causing harm at different wavelengths, the duration of exposure and the optical characteristics of the target tissue. The ELVs[1] are based on the guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). While the ELVs for incoherent optical radiation are based on the "Guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation)" [7] published in 2004 and the "Guidelines on limits of exposure to broad-band incoherent optical radiation (0.38 to 3 μm)" [4] from 1997, the ELVs for laser radiation are based on the "Guidelines on limits of exposure to laser radiation of wavelengths between 180 nm and 1,000 μm" [3] published in 1996 and the "Revision of guidelines on limits of exposure to laser radiation of wavelengths between 400 nm and 1.4 μm" [5] from 2000.

Each European Union member state was required to implement the Directive by the end of April 2010. According to Article 12 of the Directive, "every five years Member States shall provide the Commission with a report on the practical implementation of this Directive, indicating the points of view of the social partners", and subsequently "the Commission shall inform the European Parliament, the Council, the European Economic and Social Committee and the Advisory Committee on Safety and Health at Work of the content of these reports, of its assessment of these reports, of

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1) The terms Exposure Limit Value (ELV) in the Directive 2006/25/EC and Exposure Limit (EL) in ICNIRP guidelines have the same meaning.

developments in the field in question and of any action that may be warranted in the light of new scientific knowledge."

In 2013 ICNIRP has published revisions of the guidelines for incoherent visible and infrared optical radiation ("Guidelines on limits of exposure to incoherent visible and infrared radiation" [9]) as well as the guidelines for laser radiation ("Guidelines on limits of exposure to laser radiation of wavelengths between 180 nm and 1,000 μm" [10]). According to the Non-binding guide to good practice for implementing Directive 2006/25/EC "Artificial Optical Radiation" [12] drawn up by the Commission, should the guidelines be altered by ICNIRP, "the ELVs in the Directive may subsequently be modified".

Against this background, a group of scientists, industry experts, experts of accident prevention and insurance associations, as well as experts responsible for developing regulations and recommendations to protect workers from the adverse effects of optical radiation has drawn up a statement on the ELVs on incoherent optical radiation currently in force and those of the ICNIRP guidelines. The majority of experts are members of the Working Group "Non Ionizing Radiation" (Arbeitskreis Nichtionisierende Strahlung - AKNIR) of the German-Swiss Association of Radiation Protection. This statement points out problems with the practical implementation of the current ELVs as well as of those of the new ICNIRP recommendations. Moreover, the statement draws up proposals in order to further improve safety and health at work.

Comparisons of the ELVs of the ICNIRP guidelines from 1997 [4] (and therefore also of the Directive 2006/25/EC [2]) and those of the new ICNIRP guidelines on incoherent visible and infrared radiation from 2013 [9] are shown in the Annex.

2. Reduction factors

In order to protect the eyes and the skin from optical radiation hazards, the ELVs are set to a level below the damage thresholds. Uncertainties inherent in the damage thresholds are compensated for by reduction factors [6]. Reduction factors (previously called safety factors) have to be sufficiently high in order to protect employees with an acceptable level of safety.

The ELVs of the new ICNIRP guidelines from 2013 on incoherent visible and infrared radiation [9] are strongly influenced by the ELVs of the ICNIRP guidelines on laser radiation from the same year [10]. Reduction factors in [10] vary between a value of two and two orders of magnitude, depending on wavelength, biological effect regarded, exposure duration, etc. It should be emphasized that a factor of 2 is much lower than reduction factors applied in other fields of safety. For example, reduction factors for the exposure to electromagnetic fields or ionizing radiation range between one and two orders of magnitude. Regarding the uncertainties of the experimental data (predominantly threshold values obtained from animal experiments) and the model calculations used to estimate ELVs, it is questionable whether a reduction factor of 2 (see [10]) will be sufficient to protect against optical radiation hazards and to prevent adverse effects under all circumstances. Since, as stated above, the ICNIRP guidelines on incoherent visible and infrared radiation are influenced by the ICNIRP guidelines on laser radiation, this question is also valid for the case of incoherent visible and infrared radiation exposures.

3. Missing ELVs in the ultraviolet region (100 nm to 400 nm)

The term optical radiation refers to electromagnetic radiation with wavelengths between 100 nm and 1 mm. It is divided into ultraviolet (UV) radiation with wavelengths between 100 nm and 400 nm, visible radiation (VIS) with wavelengths between 380 nm and 780 nm, and infrared (IR) radiation with wavelengths between 380 nm and 1 mm. Since the ICNIRP guidelines set ELVs only in the wavelength range between 180 nm and 3000 nm, the whole range of optical radiation is not covered.

Concerning the UV region, there was no change of ELVs for wavelengths between 180 nm and 400 nm. However, ELVs are not set in the wavelength range between 100 nm and 180 nm, because in most cases the absorption of short wavelength radiation in air is sufficient to protect the skin. There are, however, optical sources of incoherent UV radiation with wavelengths shorter than 180 nm (e. g. excimer lamps) which are used so close (e. g. few centimetres) to the human skin, that air absorption might be insufficient as a protective measure. Therefore, it is proposed to extend the existing ELVs to the UV region as follows:

a) For optical radiation between 100 nm and 180 nm, radiant exposure of $H = 2500\ J{\cdot}m^{-2}$, as already specified in [7] for λ = 180 nm.
b) For broadband optical radiation between 100 nm and 400 nm, effective radiant exposure of $H_{eff} = 30\ J{\cdot}m^{-2}$. In order to do so, the spectral weighting function $S(\lambda)$ should be extended to the wavelength range between 100 nm and 180 nm with a constant value of 0.012, i. e. the value of $S(\lambda)$ for λ = 180 nm.

4. ELVs for the protection against skin cancer (180 nm to 400 nm)

In prior IRPA/ICNIRP guidelines before 2004 the ELV for effective radiant exposure of $H_{eff} = 30\ J{\cdot}m^{-2}$ was set to protect against acute eye and skin injuries. Action spectra for acute eye and skin damage were combined in order to obtain the spectral weighting function $S(\lambda)$. The main justification for the same, unchanged ELV in the ICNIRP guidelines on UV radiation published in 2004 [7] was to protect against skin cancer. However, the action mechanism for skin cancer is very different, since it is a long term effect which differs fundamentally from the deterministic effects of acute eye and skin injuries. In [7], no detailed risk considerations for skin cancer have been made, including dose-response relationships and other relevant influences. Since the ELV of $H_{eff} = 30\ J{\cdot}m^{-2}$ was originally set in order to protect against acute eye and acute skin injuries, there is no justification to recommend the same ELV for the protection against skin cancer as well.

Protection against skin cancer needs specific risk considerations and therefore an additional ELV. Factors which determine the risk of causing non-melanoma skin cancer are: accumulated UV-dose, dose-response relationship, radiation spectrum, age, skin sensitivity, action spectra, size of exposed skin surface, etc. If those influences were known, it would be possible to set a specific UV ELV for the protection against skin cancer in addition to the daily ELV of $H_{eff} = 30\ J{\cdot}m^{-2}$. The UV ELV for the protection against skin cancer would have to be specified on a long term basis (preferably: annual) regarding the specific non-melanoma skin cancer action spectra, e. g. in the quantity H_{nmsc}(annual). Unfortunately, there is not enough scientific knowledge to date in order to set an appropriate ELV in this respect. Hence, for the time being, the only guidance for the reduction of the risk of such a long term effect is to reduce the UV-exposure as far as reasonably achievable (minimizing obligation).

5. ELVs for the protection against retinal thermal hazard (380 nm to 1400 nm)

ELVs for the protection against retinal thermal hazard are defined in the wavelength range between 380 nm and 1400 nm. While in the ICNIRP guidelines on broad-band incoherent optical radiation from 1997 [4] the retinal thermal hazard function $R(\lambda)$ was normalized to 10, in the new ICNIRP guidelines on incoherent visible and infrared radiation [9] $R(\lambda)$ is normalized to 1, and the recommended ELVs for the radiance and the radiance dose have been modified accordingly. For exposure durations between 10 μs and 0.25 s, the basic ELV has been raised by a factor of 2.5. For exposure durations shorter than 1 μs, contradictory formulations in the new ICNIRP guidelines and the notes of the Table 4 in [9] concerning constant radiance dose and constant radiance, respectively, might lead to two different ELVs. Ambiguities in this respect should be avoided in the guidelines.

If exposure to incoherent optical radiation of very short duration occurs, it is likely that it happens repeatedly. In this case, a recommendation on how to deal with such repetitive short term exposures should be given, for instance similar to the concept applied for repetitively pulsed or modulated laser radiation (see also chapter 11).

Figure A1 in the Annex shows the time dependence of the limiting angles α_{min} and α_{max}. ELVs of the new ICNIRP guidelines [9] for the protection against retinal thermal hazard for different angular subtenses are presented in Figure A2. Figure A3 represents a comparison between the ELVs of the new ICNIRP guidelines [9] for the protection against retinal thermal hazard and those of the Directive 2006/25/EC [2].

6. ELVs for the protection against retinal thermal hazard in case of a weak visual stimulus

The basic ELVs for the protection against retinal thermal hazard for an exposure longer than 0.25 s expressed in radiance (Table 4 in [9]) and the ELVs for the protection against retinal thermal hazard in case of a weak visual stimulus of a near infrared source (equation (9) in [9]) differ substantially. However, no explanation for this difference is given. It is questionable if the different refraction properties of visible and IR radiation in the eye solely explain the different ELVs.

It is recommended to specify the exact wavelength range from 780 nm to 1400 nm for the application of equations (8) and (9) in [9].

Figure A4 shows a comparison between the ELVs of the new ICNIRP guidelines [9] for the protection against retinal thermal hazard in case of a weak visual stimulus and those of the Directive 2006/25/EC [2].

7. Missing ELVs for the protection of the anterior segments of the eye against thermal hazard (380 nm to 1400 nm)

Concerning the anterior segments of the eye, the ICNIRP guidelines for incoherent visible and infrared radiation [9] state that "for exposures to intense pulsed light sources at close proximity to the eye, thermally induced damage of the iris is a concern" and that "for sources in contact with or in immediate proximity to the eyes, injury to the anterior segment of the eye cannot be excluded for short pulses and large sources at exposure levels approaching the retinal thermal exposure limits". In spite of that, the guidelines only set ELVs for the protection against thermal hazard of the retina. ELVs for the protection of the anterior segments of the eye against thermal hazard are missing, due to a lack of scientific knowledge.

ICNIRP recommends to apply the infrared ELVs for the anterior segments of the eye also in the visible spectral range, if necessary. However, it is not clear whether ELVs for wavelengths between 780 nm and 3 μm (equations (20) and (21) for the irradiance in [9]) are to be applied in the same manner for wavelengths between 380 nm and 780 nm. Therefore, it should be explained how the infrared ELVs for the anterior parts of the eye shall be applied to the visible spectral range.

8. ELVs for the protection against the blue-light photochemical retinal hazard (300 nm to 700 nm)

The new ICNIRP guidelines from 2013 [9] state that photochemical, rather than thermal effects, dominate for exposure times in excess of approximately 10 s and that for short durations, less than a few seconds, the damage is due to thermal injury. The ELVs for the protection against photochemical retinal hazard are specified for exposure durations longer than 0.25 s. However, there is some indication (for further information see [13, 14]) that even for exposure durations shorter than 0.25 s photochemical effects may occur. Additionally, due to the cumulative impact to the photochemical retinal injury, the repetition of exposures shorter than 0.25 s has also to be taken into account. Both arguments may apply especially in the wavelength range between 300 nm and 500 nm. Therefore, further research is needed in order to decide if ELVs for the protection against the blue-light photochemical retinal hazard for exposures below 0.25 s are required.

Concerning the photochemical retinal hazard, the ICNIRP guidelines for incoherent optical radiation [9] set ELVs between 300 nm and 700 nm, whereas in the ICNIRP guidelines for laser radiation [10], ELVs are specified between 300 nm and 600 nm. As long as there is no reason for this difference, the wavelength ranges for laser and incoherent radiation should be the same. Currently, there are no data reported on retinal damage caused by cumulative irradiation for wavelengths above 600 nm.

The lowest exposure duration for which ELVs for the protection against photochemical retinal hazard are recommended are different in the new ICNIRP guidelines on laser radiation from 2013 [10] ($t \geq 10$ s) and the ICNIRP guidelines on incoherent visible and infrared radiation [9] ($t \geq 0.25$ s). The reason for this difference is not explained. The specification for the lowest exposure duration should be the same for coherent and incoherent radiation.

Figure A5 in the Annex shows ELVs for the protection against blue-light photochemical retinal hazard for small sources, i. e. for sources where the angular subtense α of the apparent source is less than the averaging angle of acceptance γ_{ph} according to Table 5 in [9]. In this case the ELVs are expressed as irradiance.

9. ELVs for the protection against thermal injury of cornea and lens (780 nm to 3000 nm[2)])

Concerning ELVs for the protection of cornea and lens, a new action spectrum has been included in comparison to the ICNIRP guidelines on broad-band incoherent optical radiation from 1997 [4]. While in the wavelength range between 780 nm and 1000 nm the measured spectral irradiance has to be weighted by a factor of 0.3, in the wavelength range between 1000 nm and 3000 nm it remains unweighted (see Figure A6). As a consequence, the ELVs for the protection of cornea and lens in the wavelength range between 780 nm and 1000 nm have been raised by a factor of 3.3 compared to the ICNIRP guidelines from 1997 (see Figure A7). The new action spectrum should only be applied to non-thermal radiators such as infrared emitting diodes (IREDs), for other infrared sources no spectral weighting is necessary.

However, there is no physiological reason why the real action spectrum of the cornea and the lens would be a step function with discontinuity at 1000 nm (change of the weighting factor from 0.3 to 1) and there is also no rationale for different weighting of different types of sources, which results in different ELVs for IREDs and other sources of incoherent optical radiation. In order to protect exposed persons with sufficient, conservative safety margins, the spectral weighting of the measured irradiance between 780 nm and 1000 nm should be omitted and the unchanged ELVs of the prior ICNIRP guidelines from 1997 [4] should be applied.

Furthermore, it is arguable whether it is correct to apply one set of ELVs for the protection against two hazards, i. e. corneal burn and lens clouding. Prior ICNIRP

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2) There is an obvious mistake in the heading of the chapter “Cornea and lens (780 nm – 1 mm)” in [9]. According to equation (19) the correct wavelength range is 780 nm to 3000 nm.

recommendations had two different ELVs, one for the cornea and the other one for the lens. From a scientific point of view it is reasonable to set different ELVs for the protection against acute burning hazard of the cornea and the long term hazard of the lens (cataract), since the time ranges (seconds and minutes vs. years) and therefore the biological mechanisms are very different.

Thus, two separate ELVs are proposed:

a) ELV for the protection against acute burning hazard of the cornea for exposure durations t < 1000 s (according to equation (20) in [9]):

   $E_{IR}^{EL} = 18 \cdot 10^3 \, t^{-0.75} \, W \cdot m^{-2}$

   No ELV is needed for longer exposures. The wavelength range should be extended up to 20000 nm, since optical radiation with wavelengths between 3000 nm and 20000 nm can contribute to thermal injuries of the cornea as well (see the proposal for ELVs for the protection against skin burning in chapter 10).

b) ELV for the protection of the lens against long term damage (cataract) in the wavelength range between 780 nm and 3000 nm of

   $H_{IR}^{EL} = 3 \cdot 10^6 \, J \cdot m^{-2}$,

   with the radiant exposure H_{IR} defined as:

   $H_{IR} = \int E_{IR} \cdot dt$

   As clouding of the eye lens is a long term effect, which presumably results from the addition of many single exposures, the quantity radiant exposure H_{IR} best describes the influencing physical agent. It is a daily (24 hours) ELV and it applies to constant, as well as to intermittent and varying exposures.

10. ELVs for the protection against thermal injury of the skin (380 nm to 3000 nm)

10.1 Quantity for the characterization of the radiation exposure

The occurrence of the thermal injury of the skin exposed to the visible and/or IR radiation, i. e. skin burning, depends on the temperature of the skin. The time-dependent skin temperature is the result of a dynamic equilibrium between the incoming heat flow as a function of the irradiance level, the outgoing heat flow into the surrounding tissue and the radiation emitted into the surroundings. Therefore, the ELV for the protection against skin burning should be expressed in terms of the irradiance E_{skin}, which can be calculated from the radiant exposure H and the exposure duration t. Note: The ELV for the protection against the thermal injury of the cornea is also expressed in terms of irradiance.

10.2 Wavelength range

ICNIRP has not specified the lower wavelength limit for the recommended ELV, but it can be assumed, that the lower wavelength limit is 380 nm. The new ICNIRP guidelines [9] set the ELVs for the protection against skin burning for visible and infrared radiation in the wavelength range up to 3000 nm. Although the wavelength range above 3000 nm is addressed in the ICNIRP statement on far infrared radiation exposure published in 2006 [8], no ELVs were recommended for these wavelengths.

Since there are workplaces where radiation exposures of wavelengths above 3000 nm occur, the restriction to wavelengths less than 3000 nm is not justified. For example, a thermal radiator at a temperature of T = 1000 ºC (metal or glass melt) radiates 55% of the overall emission at wavelengths above 3000 nm. Therefore, these longer wavelengths can contribute to skin burn. So it is reasonable to extend the range regarded to wavelengths above 3000 nm. For practical applications it is sufficient to extent the wavelength range up to 20000 nm. According to the Planck's Radiation Law it can be shown that radiation exposures to wavelengths above 20000 nm from commonly used thermal radiators are low, and therefore no thermal skin injuries are to be expected. Therefore, it is proposed to specify ELVs for the protection against thermal injury of the skin in the wavelength range from 380 nm to 20000 nm.

10.3 Exposure duration

The irradiance level for the onset of skin burning strongly depends on the exposure duration (Figure 1). In the ICNIRP guidelines on incoherent visible and infrared radiation [9] the ELV for the protection against skin burn is restricted to exposure durations less than 10 s, since it has been assumed that normal avoidance behaviour imposes limits on duration of exposure. However, by the nature of his work an employee in front of, or close to a glass or metal melt, often won't be able to turn away and will therefore be exposed longer than 10 s. A pain sensation, if it occurs at all, is not always sufficient to prevent thermal injury by avoidance reactions. Thus, ELVs for exposure durations above 10 s are necessary.

10.4 Proposed ELVs for the protection against thermal injury of the skin

It is proposed to adopt the ELV for the protection against thermal injury of the skin from [9] (equation (22)), with the following modifications:

a) The ELV should be expressed in terms of irradiance E_{skin} according to $E_{skin} = H_{skin} / t$.

b) The extended wavelength range should be 380 nm - 20000 nm.

c) The exposure duration should be extended up to 1000 s.

The following ELVs are proposed:

$E_{skin} = 20000 \cdot t^{-0,75}\ W \cdot m^{-2}$ for $t < 10$ s (t in s)

$E_{skin} = 7700 \cdot t^{-0,34}\ W \cdot m^{-2}$ for $10\ s \leq t < 1000$ s (t in s)

Note: Figure 1 shows the time dependence of the proposed limit values. For t < 10 s the proposal follows exactly the ICNIRP recommendation from 2013 [9] when H_{skin} is converted into E_{skin}. For 10 s ≤ t < 1000 s the ICNIRP recommendation is extended, so that no pain sensation occurs. When pain sensation is avoided, normally no skin burn will occur, too. The data for the prevention of a pain sensation when the skin is irradiated by optical radiation are taken from [1]. With the aid of a mathematical model the pain sensation data are best approximated. The derivation of the proposed ELV for the protection against skin burn for exposure durations up to 1000 s is described in [11].

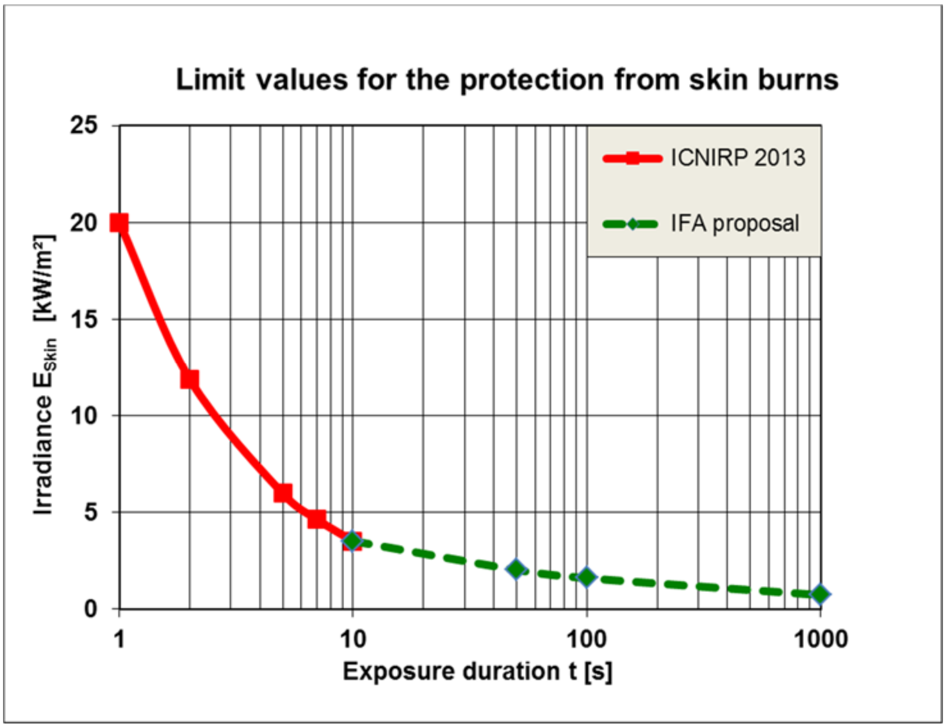

Figure 1: ELVs for the protection against skin burn from [9] and proposed extension of ELVs up to 1000 s [11].

In order to prevent a skin burn risk caused by visible and IR radiation, ELVs for exposures up to 1000 s are sufficient. The dominating hazard for exposure durations above 1000 s is not anymore skin burn, but heat stress of the entire body caused by high irradiance, high temperature and humidity. Therefore, at those exposure durations, climate limit values have to be applied [11].

11. Intermittent, repeated and varying exposures

In the new ICNIRP guidelines from 2013 [9] on incoherent visible and infrared radiation, intermittent, repeated and varying exposures are addressed in clause “Repetitive exposures”. The guidance could be improved if intermittent exposures are not treated in a summary chapter but in each chapter where ELVs for the protection of different effects and wavelengths are addressed. It should be described in detail (e. g. using formulas), which ELV or modifications thereof should be applied in these cases.

For the application of the ELVs for the protection against skin and corneal burn, necessary cooling times between two episodes of radiation exposures are not specified in [9]. In the context of heat stress, intervals of 5 min to 6 min without radiation exposure are often mentioned to reach the body temperature equilibrium. It is proposed to set 5 min as minimum interval for a cooling down phase.

Annex Comparison of the ELVs of the Directive 2006/25/EC and the ELVs of the ICNIRP guidelines from 2013

Figures A1 to A7 show the comparison of the ELVs of the prior ICNIRP guidelines published in 1997 [4] (and therefore also of the Directive 2006/25/EC [2]) and those of the new ICNIRP guidelines from 2013 [9].

A1 ELVs for the protection against retinal thermal hazard (380 nm to 1400 nm)

Angular subtense is the angle subtended by a source at the eye of an observer or at the point of measurement. Both prior [4] and new ICNIRP guidelines [9] distinguish between a "point source" and an "extended source". In [4], a source that subtends an angle of $\alpha_{min} \leq 1.7$ mrad is referred to as a point source. In the new ICNIRP guidelines, a source is considered a point source for an angular subtense $\alpha_{min} \leq 1.5$ mrad. In [9], large sources are defined as sources with $\alpha > \alpha_{max}$ with α_{max} being the retinal image size at which the retinal ELV expressed in retinal radiant exposure does not change with increasing angular subtense. In the new ICNIRP guidelines α_{max} is time dependent, while prior guidelines had a fixed value of α_{max} = 100 mrad.

Figures A2 and A3 show the ELVs for the protection against thermal retinal hazard expressed as radiance. The ELVs of the new ICNIRP guidelines for exposure durations shorter than 1 μs have been calculated taking into account constant radiance dose values from Table 4 in [9].

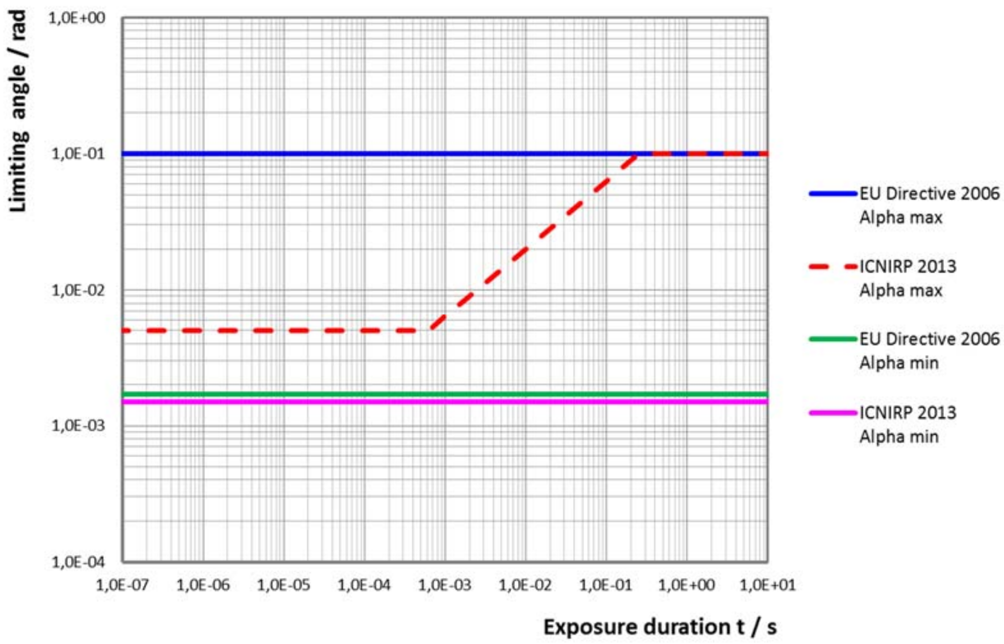

Figure A1: Limiting angles α_{min} and α_{max}

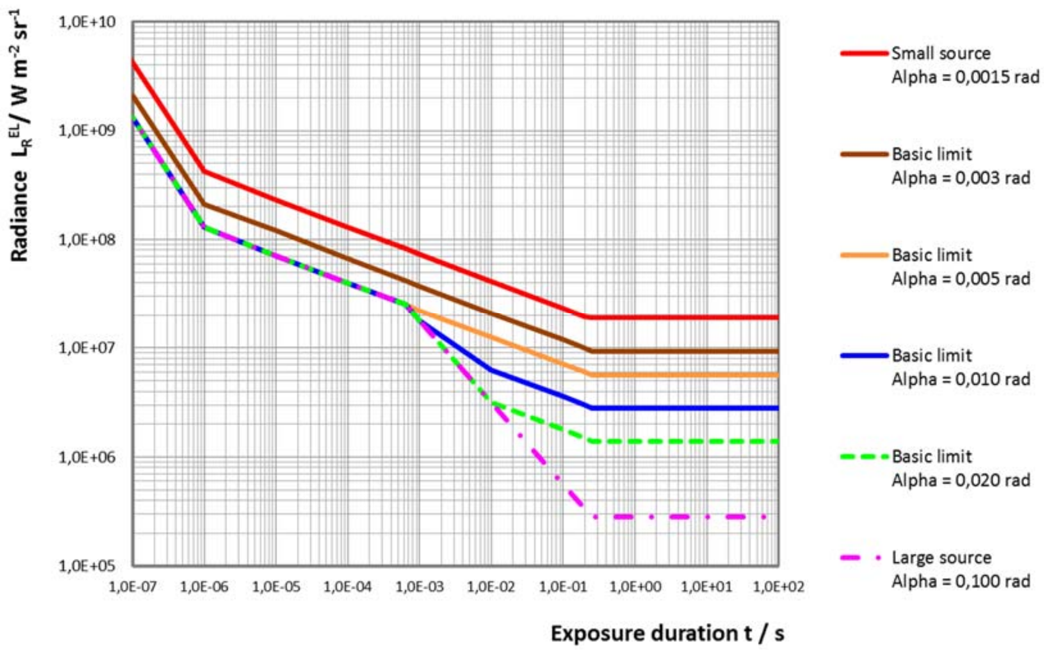

Figure A2: ELVs of the new ICNIRP guidelines [9] for the protection against retinal thermal hazard for different angular subtenses.

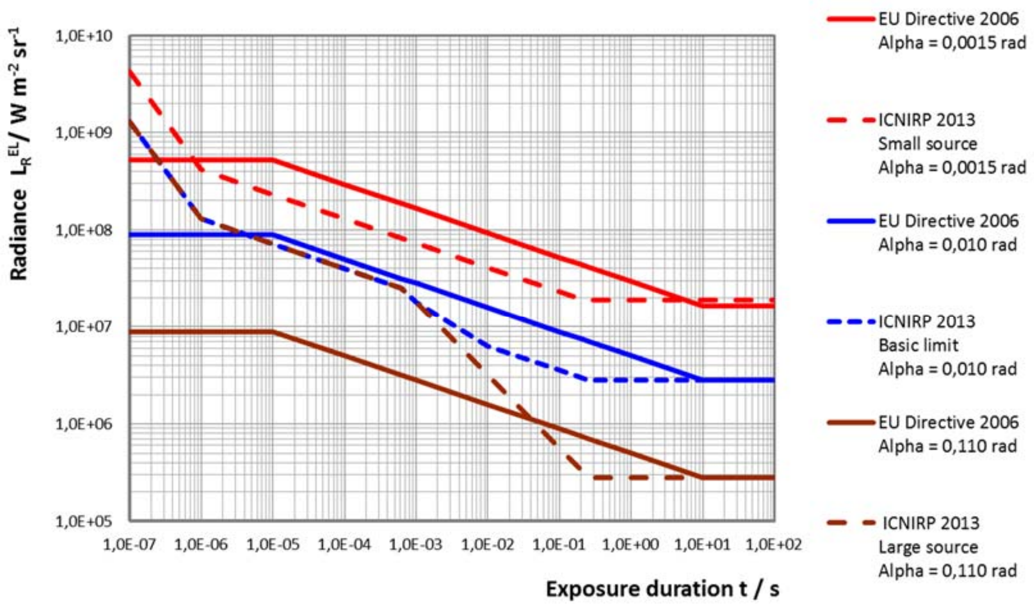

Figure A3: Comparison of the ELVs of the new ICNIRP guidelines [9] for the protection against retinal thermal hazard with those of the Directive 2006/25/EC [2].

A2 ELVs for the protection against retinal thermal hazard – weak visual stimulus

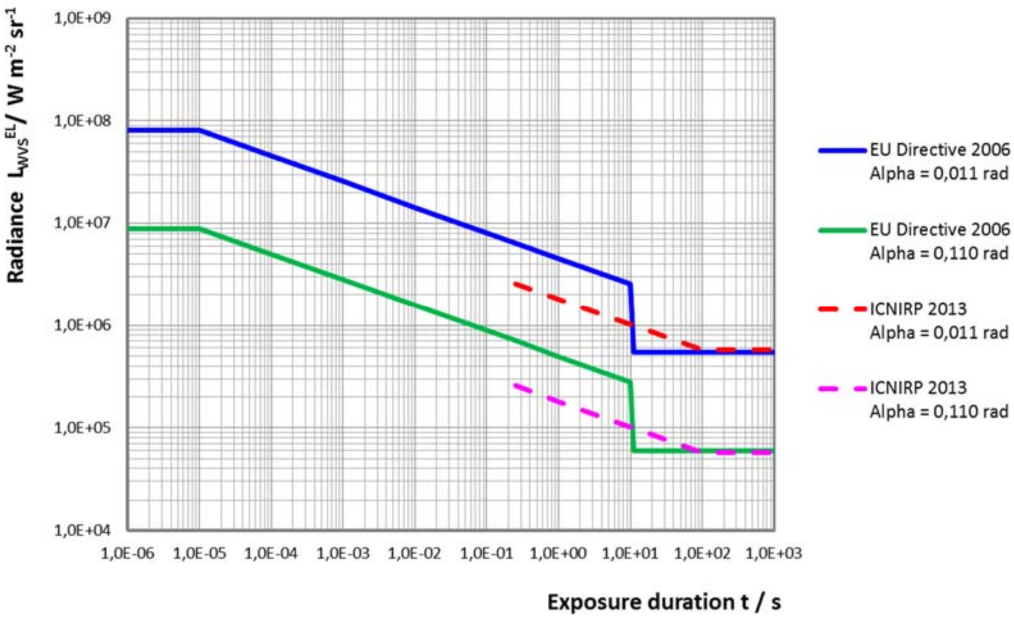

Figure A4: ELVs for the protection against retinal thermal hazard in the case of a weak visual stimulus

A3 ELVs for the protection against blue-light photochemical retinal hazard (300 nm to 700 nm)

ELVs for the protection against blue-light photochemical retinal hazard of the Directive 2006/25/EC and the new ICNIRP guidelines from 2013 [9] for sources with $\alpha \geq 11$ mrad and for exposures longer than 0.25 s do not differ. The ELVs are set as radiance doses. The ELVs of the Directive 2006/25/EC are set for exposure durations shorter than 10000 s without a specification of the lowest exposure duration limit, whereas the new ICNIRP guidelines from 2013 specify ELVs for exposure durations longer than 0.25 s.

According to the new ICNIRP guidelines [9], small sources are defined as sources with $\alpha < \gamma_{ph}$, where α is the angular subtense and γ_{ph} the angle of acceptance (Table 5 in [9]). In the Directive 2006/25/EC, small sources are sources with $\alpha \leq 11$ mrad. The ELVs for small sources are expressed as irradiance between 10000 s and 30000 s (Directive 2006/25/EC) and between 100 s and 30000 s (new ICNIRP Guidelines). For exposure durations below 100 s (Directive 2006/25/EC) and below 10000 s (new ICNIRP Guidelines), the ELVs are expressed as radiant exposure. Figure A5 shows the ELVs for the protection against blue-light photochemical retinal hazard for small sources expressed as irradiance.

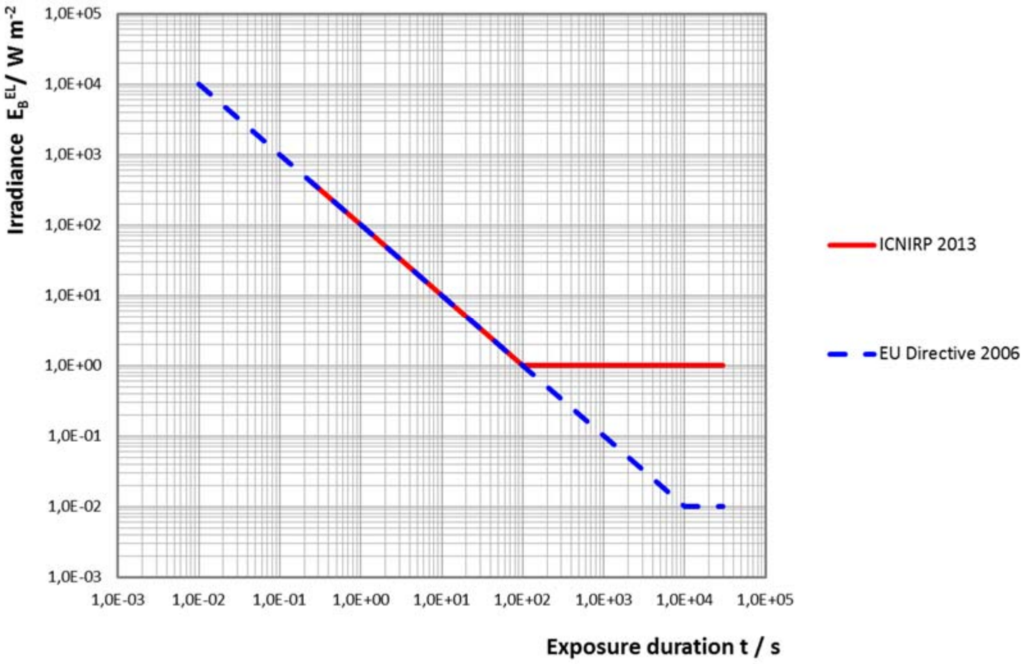

Figure A5: ELVs for the protection against blue-light photochemical retinal hazard for small sources

A4 ELVs for the protection against thermal injury of cornea and lens (780 nm to 3000 nm)

ELVs for the protection against thermal injury of cornea and lens in the wavelength range between 1000 nm and 3000 nm of the new ICNIRP guidelines [9] are the same as those in the Directive 2006/25/EC [2]. However, in the wavelength range between 780 nm and 1000 nm, the new ICNIRP guidelines introduce a weighting factor of 0.3 (see Figure A6). As a consequence, the ELVs for the protection of cornea and lens in this wavelength range have been raised by a factor of 3.3 compared to the Directive 2006/25/EC (see Figure A7).

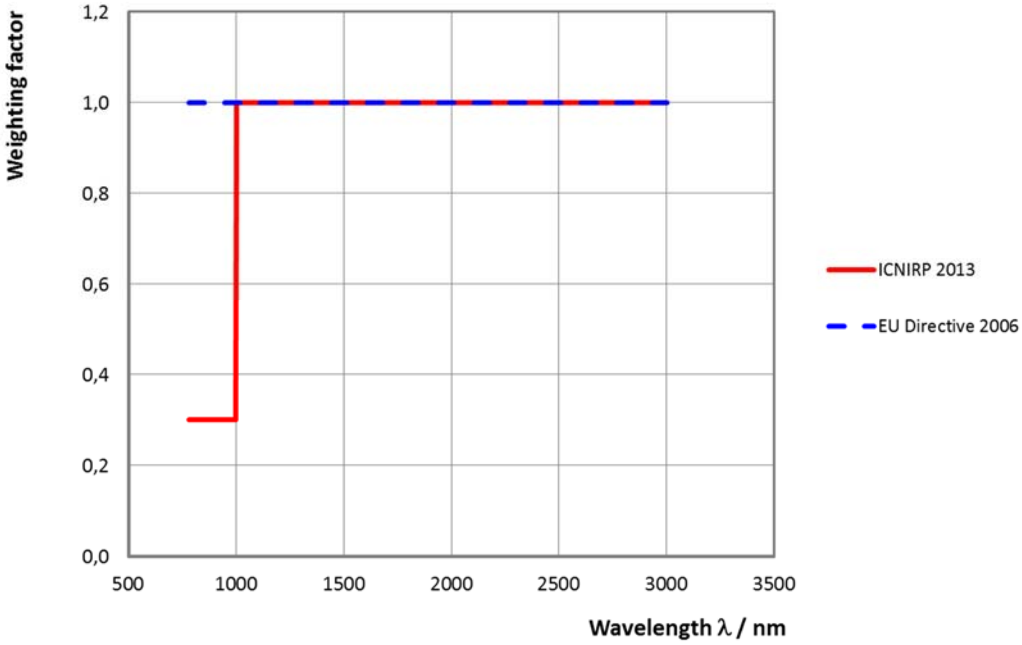

Figure A6: Weighting factor of the new ICNIRP guidelines [9] in the wavelength range between 780 nm and 1000 nm

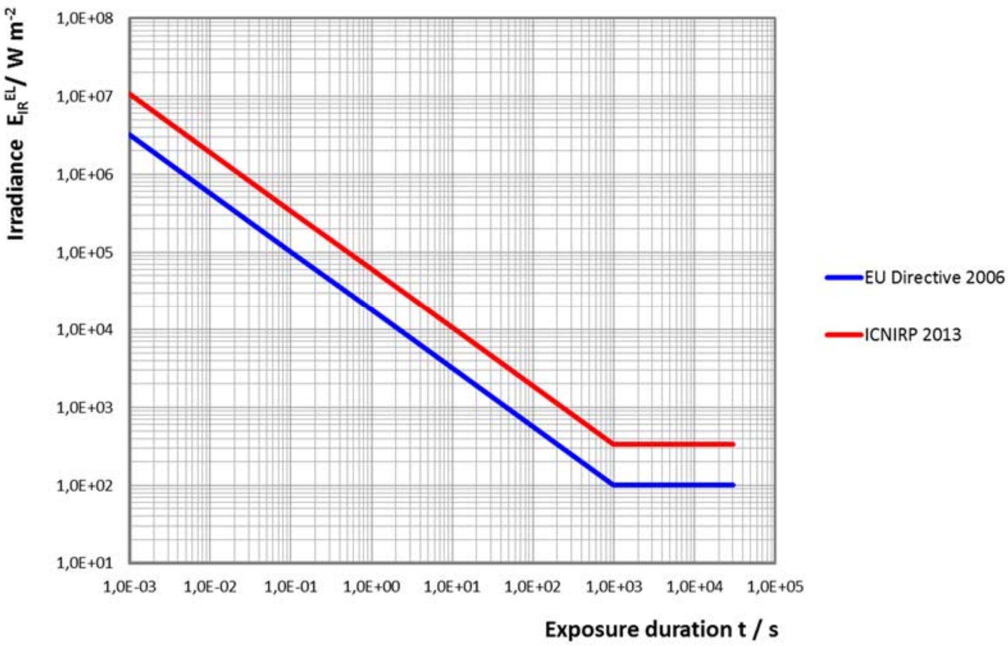

Figure A7: ELVs for the protection against thermal injury of cornea and lens for wavelengths between 780 nm and 1000 nm

References

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[2] 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)

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Ad-hoc-Gruppe des Arbeitskreises Nichtionisierende Strahlung (AKNIR)

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