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Eye protection from laser radiation hazard

Mirjana Nikolić, MSc (Eng)[1)]

The laser radiation, depending on the choice of parameters, can be very healthy, but on the other hand, very dangerous for the eye and skin, in case of inadequate application. In this paper, the relevant parameters defining the hazard levels are explained in a very popular way. Also, the numerical calculation of hazard parameters on the basis of International European Convention IEC 825-1 is shown. The choice of appropriate protective goggles should ensure the safety of work

Key words: **lasers, laser radiation, radiation safety, eye protection, reflection, standards.**

Abbreviations and symbols

The following is a list of the abbreviations and symbols and their meaning, used in this paper.

MPE – Maximum Permissible Exposure (J/m^2)
OD – Optical Density
NOHA – Nominal Hazard Area
NOHD – Nominal Hazard Distance
NHZ – Nominal Hazard Zone
E_i – The incident beam irradiance (W/m^2)
E_t – The transmitted beam irradiance (W/m^2)
λ – The radiation wavelength (nm)
P – The peak pulsed power (W)
Q_E – The energy per pulse (J)
f – The pulse repetition frequency (Hz)
a – The diameter of the beam output aperture (m)
θ – The beam divergence angle (mrad)
t – The radiation exposure duration (s)
N – The pulse number
H – The radiant exposure (J/m^2)
α – The opposite angle (mrad)
$\alpha_{\min}$ – The limiting opposite angle (mrad)
d – The laser spot diameter on the diffuse target (m)
r – The distance from the observer to the diffuse target (m)

Introduction

LASER have been a revelation for the modern technology and engineering from the outset. Lasers, as individual devices, but also as constituent element of other devices, are applied in practice in both the civilian (medicine, physics, chemistry, biology, geology, engineering), and military domain. In the cases of inadequate application of laser radiation, not knowing the laser radiation characteristics and disregarding protective measures from laser hazard, lasers can produce eye and skin injuries, both indoors (surgery, operating theatre, laboratory), and outdoors (military field training site). Contact with the laser radiation is done in direct and indirect way. For that reason, the aim of this paper is to show in a simple and user-friendly way, the importance of protection from the laser radiation hazard and explain the crucial parameters for calculating the laser hazard level applying the international standard for the safe use of lasers in health care facilities.

Laser radiation hazard

Lasers have become widely applied and important tools. The He-Ne laser is commonly used for optical elements alignment; the GaAs family of the laser diodes are used in communication; Nd:YAG and CO_2 lasers are increasingly used in material processing in industries. The argon laser as medical laser is still the most widespread one for surgical purposes. In recent times, the Q-switched pulsed Nd:YAG laser is used as medical laser, and the CO_2 and continuous-wave Nd:YAG are being increasingly used as surgical lasers [1]. Powerful Nd:YAG and CO_2 lasers are also used in the military as rangefinders, designators and lidar systems.

The laser produces monochromatic, highly coherent and directional beam of light. The laser radiation directly falling onto the object surface, will be partially reflected, partially absorbed, and partially transmitted through the object body. Depending on the characteristics of the object and radiation, some of the mentioned phenomena will be dominant. The absorbed part of light energy raises the temperature of the surface, potentially causing an alternation or deformation of the material. These properties have been applied in laser surgery and material processing in the industry.

In addition to these obvious thermal effects on the tissue, there can also be photochemical effects [2] when the wavelength of the laser radiation is sufficiently short, i.e., in the ultraviolet or blue region of the spectrum. The human body is vulnerable to the wavelength of certain lasers, and under certain circumstances, exposure can result in damage to the eye and skin. Research relating to injury thresholds of

1) Military Technical Institute (VTI), Ratka Resanovića 1, 11132 Belgrade

the eye and skin has been performed in order to understand the biological hazards of laser radiation. It is now widely accepted that the human eye is more vulnerable to injury than human skin. In order to illustrate the influence of the laser radiation on some parts of the human eye, the eye cross section is shown in Fig.1, and the eye injuries in the function of laser radiation wavelength are presented in Table 1 [1,3]. The cornea, unlike the skin, does not have an external layer of dead cells to protect it from the environment. In the far infrared (IR) region of the spectrum (1400 nm ÷ 10000 nm), the cornea absorbs the laser energy and may be injured. The retina is sensitive in the waveband from 400 nm to 1400 nm, and it is most sensitive in the region of the near IR radiation (780 nm÷1400 nm). Some biological effects produce the transient injuries which are repaired and the tissue is normal within a number of days or weeks (e.g., photokeratitis is a painful inflammatory response of the cornea, but due to the rapid repair of the corneal epithelium, the signs and symptoms disappear within a day or two after exposure). By contrast, retinal injury is normally permanent, although a certain degree of tissue repair will reduce the degree of initial visual loss. The worst-case exposure condition will occur when a collimated beam is focused or regularly reflected (specular reflection) onto the eye [3,1].

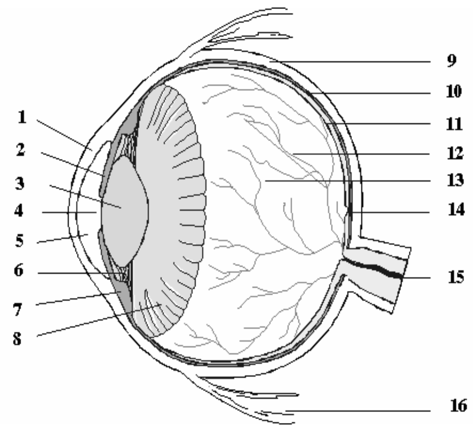

Figure 1. The cross-section of the human eye (1– cornea, 2 – iris, 3– lens, 4 – pupil, 5 – aqueous humour, 6 – suspensory ligaments, 7 – ciliary muscle, 8 – ciliary body, 9 – sclera, 10 – choroid, 11 – retina, 12 – arteries and veins, 13 – vitreous humour, 14 – fovea, 15 – optic nerv, 16 – eye muscle).

Table 1. Eye injuries in function of the radiation wavelength.

Wavelength	Absorbing structure	Radiation effects
180nm-315nm	Cornea	Photokeratitis
315nm-400nm	Eye lens	Cataract
400nm-780nm	Retina	Retinal lesion
780nm-1.4μm	Eye lens and retina	Cataract, retinal lesion
1.4μm-3.0μm	Cornea and eye lens	Thermal damage
3.0μm-1.0mm	Cornea	Thermal damage

Exposure to the Q-switched Nd:YAG laser beam (1064nm) is especially hazardous and may initially go undetected, because the beam is invisible and the retina lacks pain sensory nerves. Visual disorientation due to retinal damage may not be apparent until considerable thermal damage has occurred. For that reason, the maximal care should be taken to provide protection for all persons in the laser suite, including the patients, laser operator, assistants, and accidental observers [4].

In Fig.2, the typical retinal injuries as the results of the effect of the military Nd:YAG laser are shown. The large arrow shows the superior lesion and the small arrow shows the retinal hemorrhage [5].

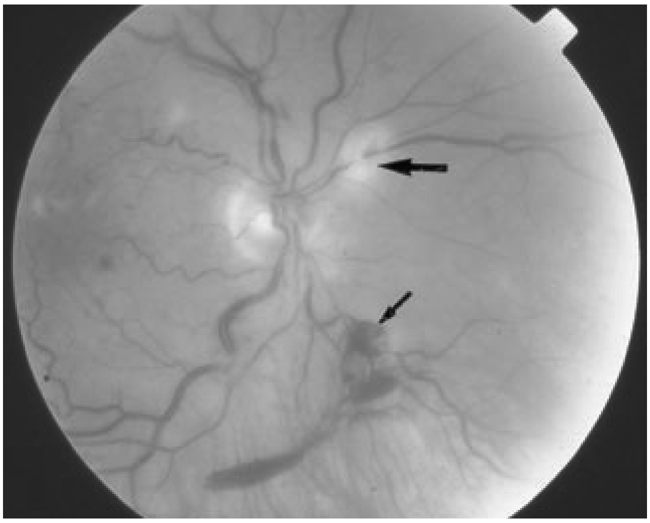

Figure 2. The effects of the Nd:YAG laser used in the military applications on the retinal tissue.

Classification of lasers

For correct application of protection from the laser radiation hazard, it is necessary to know the laser classification. Lasers are divided into a number of classes, depending on the power or energy of the beam [1,2,6,7]. Laser classification is based on the laser's potential for causing immediate injury to the eye and skin and/or potential for causing fires from direct exposure to the beam or from reflections from either specular or diffuse reflective surfaces. Lasers are classified using physical parameters of the laser: the laser power (in the case of pulse mode, the power is presented by the peak pulsed power), the laser radiation wavelength, and the laser exposure duration.

Class 1 lasers: Class 1 lasers are considered to be incapable of producing damaging radiation levels, and are therefore exempt from most control measures or other forms of surveillance. Semiconductor diode lasers, laser printers, CD players, optical-fiber communication systems, and certain laboratory chemical assay instruments (such as commercial Raman spectrophotometers) fall into this class.

Class 2 lasers: Class 2 lasers emit radiation in the visible region of the spectrum, and protection is normally provided by normal human aversion response (blink reflex) to bright radiant sources. In general, the human eye blinks within 0.25 s when exposed to class 2 laser light. Although class 2 lasers emit laser radiation in the visible region, they are capable of creating eye damage through chronic exposure. Laser pointers, surveying lasers, lasers used in industry and medicine for alignment or to mark the path of an invisible laser beam, belong to this class.

Class 2a lasers are special-purpose lasers. Their output power is less than 1 mW. This class of lasers causes eye injury only when viewed directly for more than 1000 s, which can be extended to an 8 hour period in case of not continuous exposure. Many bar-code readers fall into this category.

Class 3a lasers normally would not produce injury if viewed only momentarily by unaided eye. They may present a hazard if viewed using collecting optics, e.g., telescopes, microscopes, or binoculars. He-Ne lasers above

1 mW but not exceeding 5 mW radiant power and some pocket laser pointers fall into this class.

Class 3b laser light will cause injury upon direct viewing of the beam and regular specular reflections. He-Ne lasers above 5 mW but not exceeding 500 mW radiant power, belong to this class.

Class 4 lasers: Class 4 lasers include all lasers with power levels greater than 500 mW radiant power. They provoke eye hazards, skin hazards and fire hazards. Viewing of the beam and specular reflection or exposure to diffuse reflection can cause eye and skin injuries. All of the control measures explained in the international standards for laser safety must be implemented. Most of very high powered Q-switched crystal lasers such as the ruby and Nd:YAG lasers, are included in this class. Generally, any laser with an average power exceeding 0.5 W, will fall into class 4. Most material processing and surgical lasers and also most Q-switched lasers (military lasers) are class 4 laser products.

The skin protection is carried out according to regulations of safety standards [8,9,10], and all protective clothing worn should be made from suitable flame and heat-resistant materials.

Table 2 shows the maximum permissible exposure values (**MPE** level) for the most frequently used lasers with the typical parameters range considered in the hazard calculation in the case of direct intrabeam viewing [10-Table 6]. For the lasers working in the pulsed mode, **MPE** level is assessed for one pulse.

Table 2. The **MPE** levels for the most frequently used lasers.

Laser	λ [nm]	Mode	Exposure duration or pulse duration [s]	MPE level [J/m^2]
He-Cd	325	Continual	0.1	$3.15\cdot10^{3}$
Argon	488	Pulsed	10^{-8}	$5\cdot10^{-3}$
He-Ne	633	Continual	10	100
Ruby	694	Pulsed	10^{-3}	0.1
GaAs	905	Pulsed	10^{-7}	$12.9\cdot10^{-3}$
Nd:YAG	1064	Pulsed	$30\cdot10^{-9}$	$5\cdot10^{-2}$

Since it is precisely the Q-switched pulsed, very powerful Nd:YAG class 4 laser, that is used for the military purposes, a more detailed eye protection from this type of lasers will be presented in this paper.

Numerical approach to laser hazards for Nd:YAG laser

In this paper, the crucial parameters defining the laser hazard level are calculated on the bases of relations and definitions incorporated in the International European Convention IEC 825-1 Standard, which has been translated into Serbian language [10]. To begin with, it is necessary to define the primary values and definitions. The used values are marked in the same way as in the Standard [10].

MPE (Maximum Permissible Exposure): The maximum permissible exposure is the level of laser radiation to which persons may be exposed without harmful consequences. In other words, the **MPE** levels represent the largest radiation level to which the eye and skin may be exposed without hazardous effects, in the form of immediate or delayed injuries. The **MPE** levels are determined as a function of: laser radiation wavelength, laser work mode, pulse duration or exposure time, pulse repetition frequency, exposed tissue, and in the case of visible and near IR radiation (400 nm÷1400 nm), the image size on the retina plays an important role. The **MPE** levels are usually expressed either in terms of irradiance in W/m^2 or as radiant exposure in J/m^2.

OD (Optical Density): Optical Density refers to the ability of a material to reduce laser energy of a specific wavelength to a safe level below the **MPE** level. It can be expressed by the following formula [4]:

$$OD = \log_{10}\left(\frac{E_i}{E_t}\right) \tag{1}$$

where: E_i is the incident beam irradiance (W/m^2) for the worst case exposure, E_t is the transmitted beam irradiance (**MPE** limit in W/m^2).

NOHA (Nominal Hazard Area): The nominal hazard area is the physical space in which the beam irradiance is smaller than **MPE** level for cornea.

NOHD (Nominal Hazard Distance): The nominal hazard distance is the distance within which the beam irradiance is equal to the **MPE** level.

The modified example A.5-6 [10], which refers to the laser with characteristics adequate military use, is presented here.

The laser radiation from Q-switched Nd:YAG laser rangefinder with following characteristics is analysed:

- Laser radiation wavelength: $\lambda = 1060$ nm;
- Peak pulsed power: $P = 1.5$ MW;
- Pulse energy: $Q_E = 45$ mJ;
- Pulse repetition frequency: $f = 12$ pulses/min;
- Diameter of the beam output aperture: $a - 10$ mm;
- Beam divergence angle: $\theta = 1$ mrad;

It is necessary to perform the **NOHD** calculation for viewing with unaided eye and in the case of beam viewing through the optics with diameter of 50 mm. The effects of the atmospheric extinction are neglected in these calculations. At the end of these calculations, the **OD** factor will be calculated in order to define a safety level for the safety eyewear material.

a) Viewing with the unaided eye

Since the laser energy per pulse and also the peak pulsed power are known, the pulse duration is calculated as $t_p = \frac{Q_E}{P} = \frac{45\cdot10^{-3}\,J}{1.5\cdot10^{6}\,W} = 30\text{ ns}$, and the pulse repetition frequency is $f = 12\text{ pulses/min} = 0.2\,Hz$. If the direct viewing of the beam does not exist, it is assumed, on the basis of the Standard [10], that the estimated time of radiation exposure is $t = 100\,s$, so that the total number of pulses in this time period is $N = f\cdot t = 20$.

The **MPE** level for one pulse is calculated as follows. From Table 6 [10], for $t_p = 30$ ns and $\lambda = 1060$ nm, the radiant exposure is calculated as: $H_{pulse} = 5\cdot10^{-2}C_6C_7\ J/m^2$, where C_6 and C_7 are the coefficients taken from Table 4 [10]. On condition that the laser beam is stared at, C_6 is 1, and C_7 is 1 in the waveband from 1050 nm to 1150 nm. Having substituted the mentioned coefficients, for the radiant exposure for one pulse, the value $H_{pulse} = 5\cdot10^{-2}$ J/m^2 is obtained.

The radiant exposure for total exposure time $(t = 100\,s)$ is calculated from Table 6 [10], as:

$$H_t = 90 \cdot t^{0.75} C_6 C_7 \text{ J/m}^2 = 2846 \text{ J/m}^2 .$$

Since there are N pulses in the given time interval, the average radiant exposure for one pulse can be calculated as:

$$H_{av,\text{pulse}} = \frac{H_t}{N} = 142 \text{ J/m}^2 .$$

Having had the case of pulse repetition, the criteria for treating this radiation demands that the exposure for one pulse has to be reduced by a factor of $N^{-1/4}$, so that the radiant exposure of pulse train is expressed as $H_{\text{train}} = H_{\text{pulse}} \cdot N^{-1/4} = 2.36 \cdot 10^{-2}$ J/m^2, that is the most rigorous criterion, so that the **MPE** level is $MPE = H_{\text{train}} = 2.36 \cdot 10^{-2}$ J/m^2.

The distance on which the **MPE** threshold is exceded is calculated as [10]:

$$r_{NOHD} = \frac{1}{\theta}\left(\sqrt{\frac{4 \cdot 2.5 \cdot Q_E}{\pi \cdot H_{train}}} - a\right) \quad (2)$$

Factor 2.5 is added when the repeated exposures to the radiation are expected, which is the case explained in this example. Substituting all the values in the above equation, $r_{NOHD} = 2454$ m is obtained.

b) Viewing with binoculars

By using the collecting optics with diameter of 50 mm for intrabeam viewing in the described example, the value for **NOHD** is increased, because the maximal permissible radiant exposure is reduced by a gain factor G^{-2} (G is the quotient of the lens diameter or optical instrument's aperture and the theoretical pupil diameter). Since the aperture diameter for the eye (pupil) is about 7 mm in the waveband from 400 nm to 1400 nm (Table 7 [10]), the gain factor is

$$G^{-2} = \left(\frac{7 \text{ mm}}{50 \text{ mm}}\right)^2 = 1.96 \cdot 10^{-2} .$$

The distance r_{NOHD} is then:

$$r_{NOHD} = \frac{1}{\theta}\left(\sqrt{\frac{4 \cdot 2.5 \cdot Q_E}{\pi \cdot G^{-2} \cdot H_{train}}} - a\right) = 17587 \text{ m} ,$$

so that at the distances smaller than r_{NOHD} a serious danger for the eye occurs. In order to enable adequate eye protection, it is necessary to choose the appropriate laser safety goggles with defined **OD** factor.

c) **OD** factor calculation

To determine the adequacy of the eye protector, the worst case of exposure is assumed, i.e., the case when the entire energy of the laser pulse train falls into the eye. When repeated exposure levels are anticipated, the **MPE** level must be reduced by a factor of 2.5, and the equation (1) is rearranged in this case as:

$$OD = \log_{10}\left(\frac{H_i \cdot 2.5}{MPE}\right) \quad (3)$$

where H_i is the radiant exposure of the incident beam in the worst case exposure. The pupil diameter in the waveband from 400 nm to 1400 nm is 7 mm, the pupil area (if it is assumed that the pupil is approximately the circumference) is $A = 3.85 \cdot 10^{-5}$ m^2. The radiant exposure is given as $H_i = \frac{Q_E}{A} = 1169$ J/m^2, so that the **OD** factor for the eyewear is:

$$OD = \log_{10}\left(\frac{H_i \cdot 2.5}{MPE}\right) = \log_{10}\left(\frac{H_i \cdot 2.5}{H_{train}}\right) = 5 \quad (4)$$

Then it is necessary to choose the appropriate eye goggles from the catalogues of the renowned laser safety eyewear manufacturers (Glendale, Edmund Optics, Trinity Technologies, Phillips Safety Products, Melles Griot) [11]. The laser safety eyewear, chosen on the bases of the calculated safety parameters for the specified laser radiation wavelength and exposure duration, should be very comfortable in order to provide safe and undisturbed work. In Fig.3, some models of the laser safety eyewear are shown.

Figure 3. Some models of the laser safety eyewear.

The so called extended source viewing normally refers to viewing laser radiation after reflection from a diffusing screen (the false source) and where the image formed on the retina by the reflected radiation, is greater than a certain minimum value defined by the limiting opposite angle $\alpha_{\min}$ (the angle subtended at the observer's eye by the laser source or diffuse image). The limiting angular subtense $\alpha_{\min}$ is a function of the exposure time and at the distance greater than 100 mm with regards to the false source is measured.

The example A.3-1 from [10], gives a scope of the **MPE** level calculation in case of diffuse reflection. Radiation from a Q-switched Nd:YAG laser ($\lambda = 1064$ nm, $t = 10^{-8}$ s), expanded into a beam 2 cm in diameter before being reflected from a perfect diffuser, is analyzed. It is necessary to calculate: a) the final distance from the diffuser at which the conditions for extended source viewing exist and б) **MPE** level at the distance 2.5 m from the diffuser.

a) The opposite angle (the viewing angle of the false source (including the diffuse reflections) subtended at the observer's eye or at the measure point, by an extended source) is defined by the relation:

$$\alpha = 2 \cdot \arctan\left(\frac{d/2}{r}\right) \quad (5)$$

where *d* is the laser spot diameter on the diffuser, and *r* is the distance from the observer to the diffuser.

In the limiting case, $\alpha = \alpha_{\min}$ (according to the theory proposed in [10], $\alpha_{\min} = 1.5$ mrad for $t < 0.7$ s), and it is equal to:

$$\alpha = \alpha_{\min} = \frac{d}{r_{\max}}$$

and

$$r_{\max} = \frac{d}{\alpha_{\min}} = \frac{2 \cdot 10^{-2}\ m}{1.5 \cdot 10^{-3}\ rad} = 13.3\ \mathrm{m}$$

so it can be concluded that at distances greater than 13 m, conditions for viewing a point source exist.

From Table 6 [10], the **MPE** level for the defined exposure time *t*, is calculated as:

$$H_{MPE} = 5 \cdot 10^{-2} C_6 C_7\ \ \mathrm{J/m^2}$$

where $C_7 = 1$ for λ=1064 nm [10]. In case of viewing the point source [10], $C_6 = 1$ in the case when $\alpha \le \alpha_{\min}$ in the waveband $\lambda = $ (400 nm ÷1400 nm), the **MPE** level is:

$$H_{MPE} = 5 \cdot 10^{-2}\ \ \mathrm{J/m^2}$$

b) For the distances smaller than $r_{\max} = 13\ \mathrm{m}$, the conditions for viewing the expanded source are applied, and when $\alpha_{\min} < \alpha \le \alpha_{\max}$, the factor C_6 is expressed as $C_6 = \alpha / \alpha_{\min}$. The value of the opposite angle of the false source above which the **MPE** level does not depend on the source size, is marked as $\alpha_{\max}$ and according to [10], $\alpha_{\max} = 0.1\ \mathrm{rad}$.

At the distance $r_1 = 2.5\ \mathrm{m}$, the necessary parameters are calculated in the following manner:

$$\alpha = \frac{d}{r_1} = \frac{2 \cdot 10^{-2}}{2.5} = 8 \cdot 10^{-3}\ \mathrm{rad}$$

$$C_6 = \frac{\alpha}{\alpha_{\min}} = \frac{8 \cdot 10^{-3}}{1.5 \cdot 10^{-3}} = 5.33$$

The ***MPE*** level for viewing the expanded source at the distance $r_1 = 2.5\ \mathrm{m}$ is:

$$H_{MPE} = 5 \cdot 10^{-2} C_6 C_7\ \ \mathrm{J/m^2}$$

$$H_{MPE} = 5 \cdot 10^{-2} \cdot 5.33 \cdot 1\ \mathrm{J/m^2}$$

$$H_{MPE} = 0.27\ \ \mathrm{J/m^2}\ .$$

LAZAN computer software

Rockwell Laser Industries (USA) [12] offers the exclusive LAZAN (LAser haZard ANalysis) computer software, that is the most powerful software for evaluating laser hazards available today. LAZAN version 3.6.4 is based on the laser hazard analysis requirements and specifications as defined in the most recently released ANSI Z136.1 (2000) national standard published by the American National Standards Institute (ANSI) [8]. It should be stressed that the LAZAN software program is intended for educational, instructional and informational purposes and is considered an additional means of training for Laser Safety Operators, with duties and responsibilities as defined in the ANSI Z136.1 [8].

LAZAN reduces the tedious process of laser hazard analysis. The input parameters of this program are the crucial parameters presented earlier in this paper, defining a safety level:

- Laser beam wavelength;
- Beam average power (or pulse energy);
- Beam divergence;
- Exposure time (or laser pulse length, pulse repetition frequency and pulse time envelope);
- Beam shape and dimensions.

Additional Nominal Hazard Zone (**NHZ**) parameters can also be entered:

- Lens focal length;
- Diffuse reflection coefficient;
- Viewing angle;
- Diffuser – observer distance;
- Spot size on diffuse target;
- Fiber Optics mode;
- Beam waist or numerical aperture;
- Distance from radiation source (laser) to diffuser or to observer.

The LAZAN software performs more than fifty hazard analysis computations almost instantaneously. Some of the most important calculations are:

- Maximum Permissible Exposure (MPE) computations for continuous wave pulsed and/or repetitively pulsed laser sources.
- Optical Densities (OD) calculations for the intrabeam laser eye-protection for "worst case" exposure (all of the beam fall into the eye).
- Optical Densities (OD) calculations for the intrabeam exposures at a specified range from the laser where the beam energy/power entering the eye is a function of the laser spot (beam size) at the specified range.
- Eye-protection Optical Densities calculations for viewing either small source (point) and/or extended source (diffuse) viewing.
- Nominal Hazard Zone calculations for direct, diffuse and lens-on-laser cases.

All the calculation results are summarized in the electronic form of the LAZAN report option, suitable for printing. In addition, the detailed "HELP FILES" are included in LAZAN, providing valuable assistance in the operation of the program.

Conclusion

Safe work with the laser radiation sources calls for qualified and trained employees in the research laboratory, medical centres and on the military field training site. All persons dealing with the high energy laser radiation (Class 3b and 4 lasers), research personnel, medical personnel, or patients, have to be adequately protected in accordance with the rigorous requirements and regulations defined in the Laser Safety Standards. At the entrance to the area when the laser is operating, a proper warning indication has to exist.

Protective goggles are necessary in laser environments with Class 3b and 4 lasers, if the person is exposed to direct, reflected, or scattered laser beam. Research laboratories have to be equipped according to laser safety standards.

A qualified laser operator must meet the operational qualifications established by radiation safety standards. The laser operator is responsible for ensuring that all persons, who work in the areas where Class 3b or 4 lasers are used, are provided with appropriate training and written safety instructions (work rules), so that the workers can properly use laser equipment and observe the safety procedures.

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Zaštita oka od laserskog zračenja

Lasersko zračenje zavisno od izbora parametara koji ga karakterišu može da leči ali i da s druge strane ošteti oči i kožu, ako se nepravilno koristi. Na veoma popularan način, objašnjeni su relevantni parametri koji definišu stepen hazardnosti određenog laserskog zračenja. Po važećem standardu IEC 825-1, dat je njihov proračun u cilju odabira odgovarajućeg zaštitnog sredstva. Izbor odgovarajućeg zaštitnog sredstva (zaštitne naočare) treba da obezbedi siguran rad korisnika.

Ključne reči: Laseri, zračenje lasera, zaštita od zračenja, zaštita oka, refleksija, standardi.

Защита глаза от лазерного излучения

В зависимости от выбора характеризирующих параметров лазерное излучение может вылечить, но с другой стороны может повредить глаза и кожу, если им неправильно пользуются. В настоящей работе очень популярным способом растолкованы все существенные параметры, которые определяют ступень риска определённого лазерного излучения. По действительном стандарте ИЕЦ 825-1 (Международная Европейская Конвенция) приведён их предварительный расчёт с целью выбора соответствующего защитного средства. Выбор соответствующего защитного средства (защитные очки) нужен обеспечить надёжную работу пользующего.

Ключевые слова: лазеры, лазерное излучение, защита от излучения, защита глаза, отражение, стандарты.

Protection de l’oeil contre la radiation de laser

La radiation de laser, selon le choix des paramètres qui le caractérisent, peut servir à soigner mais, de l’autre côté, est capable de provoquer les dégats de la peau et des yeux, quand il est employé incorrectement. D’une manière très populaire, on a expliqué les paramètres qui définissent le degré du hasard chez la radiation laser déterminée. Selon la norme en usage IEC 825-1, on a donné le calcul numérique dans le but de choisir les moyens de protection appropriés. Le choix du moyen de protection appropriée (lunettes protectives), doit assurer le travail sûr des usagers.

***Mots clés*: lasers, radiation de laser, protection contre la radiation, protection de l’oeil, reflexion, normes.**