LASER SAFETY FOR EU DEFENCE FORCES - E-LEARNING PLATFORM

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***Abstract**: With the development of laser sources in the last 60 years, the field of applications of lasers is developing as well. From vision correction to driving vehicles, from spaceflight to fusion, from material processing to presentation pointers, lasers are still finding their application in unexpected areas. Should be noted, that the lack of laser safety skills in the professions and sector bound up with lasers is already present and, unfortunately, reality. With the development of laser sources in the last 60 years, the field of application of lasers has been developing. From vision correction to driving vehicles, from spaceflight to synthesis, from material processing to presentation pointers, lasers are still being used in unexpected areas. It should be noted that the lack of laser safety skills in the professions and sector related to lasers is already present and, unfortunately, a reality.*
This article presents the highlights and results of a European project in the field of laser safety in several European countries. The project "Laser models for web safety for vocational education / training" is aimed at improving professional skills in the field of laser safety by developing, testing and validating innovative web-based training modules in accordance with the norms and standards of the European Union.

***Keywords**: Laser Safety, Laser Technology, e-learning platform, VET, Lasers in the Military*

Introduction

Laser is an electronically optic system which produces artificial, coherent, highly monochromatic electromagnetic radiation with ability to reach extremely high energy densities. The applications of lasers in our lives are extremely versatile and extensive[1 – 3]. In general, we can define the application of the laser in 4 groups, see Figure 1.

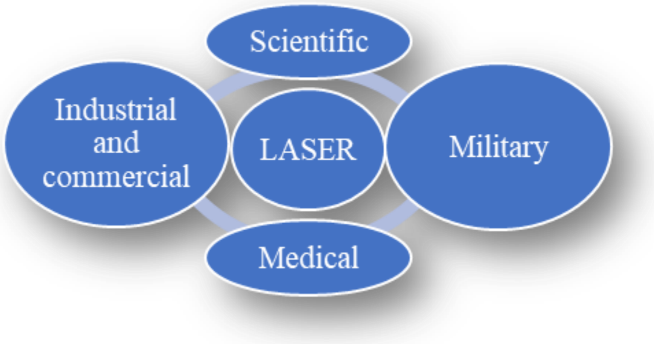

Figure 1 General areas of the Laser applications

Photonics and laser technology are now a priority of the Europe's defence ministries and an essential to enhance the combat capabilities of NATO-led armies, as stated in the documents and strategies. The introduction of new and different laser sources and weapons in the military sectors requires the development of new skills and competencies of the military and command staff of the army subdivisions in the field of laser safety. According to NATO (North Atlantic Treaty Organization), a number of significant technology-related trends – including the development of laser weapons, electronic warfare and technologies, that impede access to space – appear self-possessed to have major global effects that will impact on NATO military planning and operations. In addition, the photonics and laser technologies sector is an essential contributor to the European defensive economy and, that its advancement is vital to the development of other digital technologies and flagship programmes and indispensable to European security and defensive.

In the past years European Norms and Standards in this area „Laser Safety" have become obligatory for all European countries. But, the lack of laser safety skills in the sector is already in place and, unfortunately, traditional military institutions cannot meet this demand. The dangers of laser radiation can be diverse and at the same time devastating for the health and fitness of army.

The purpose of this report is to provide useful information about the purpose and results of a European project developed by us with a civic focus in the field of laser safety for the needs of vocational training. Our desire is for this attempt to serve as a basis and bridge to the creation of training modules for training in the military.

1. Erasmus+ Laser Safety Project

The project aims to improve professional skills for laser safety through online training in vocational education and training in small and medium enterprises. Details of the project can be found in Table 1.

Table 1 Details of the project

Title:	Web-Based Laser Safety Modules For Vocational Education/Training
Project No.:	2018-1-LV01-KA202-056957
Programme:	Erasmus+
Key Action:	Cooperation for innovation and the exchange of good practices
Action:	Strategic Partnerships
Project Start Date:	01-09-2018
Project Total Duration:	24 months
Applicant Organisation:	Rezekne Academy of Technologies, Latvia
Webpage:	lasersafety.rta.lv

Project has gathered partners from five European Union countries: Bulgaria, Germany, Hungary, Latvia, Romania.

Organizations involved:

- Rezekne Academy of Technologies, Latvia;
- iTStudy Hungary Kft., Hungary;
- SWA Bildungsakademie GmbH, Germany;
- Universitatea Din Pitesti, Romania;
- European Center for Science and Innovation in Education, Bulgaria;
- University of Ruse Angel Kanchev, Bulgaria;

- Veda Consult, Bulgaria.

Profile of participants includes three universities with their own research institutes (including photonics and laser technology), one NGO, two VET centers and an ICT company. The project team aims to develop, test and validate four innovative training modules (Figure 2) in line with the needs of the European photonics and laser technology field. Using the right environment, learning modules will be web-based and accessible to students, laser workers / operators and all other players related to the fields of photonics and laser technologies.

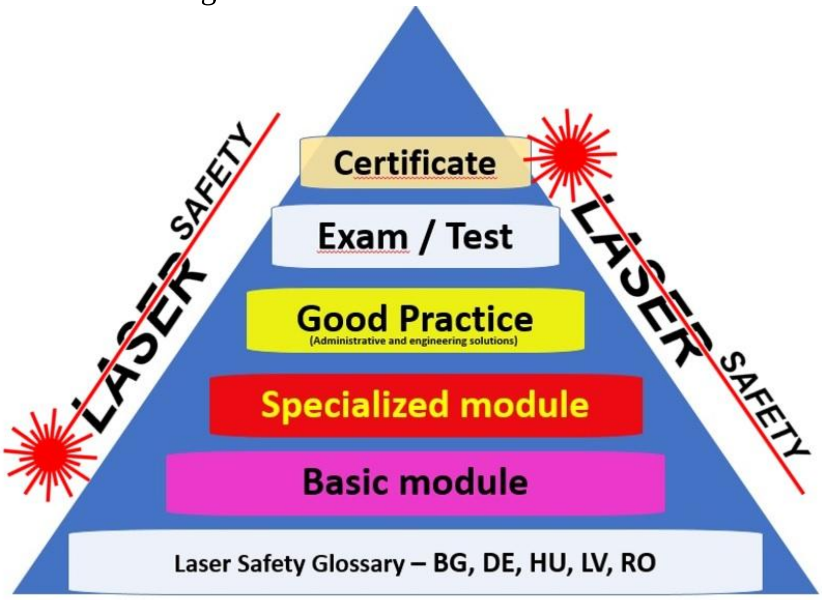

Figure 2. Innovative training modules in Laser Safety

The Laser Safety Course will be free of charge translated into 5 languages and web based and interactive. In substantive terms, it will comply with EU Directive 2006/25 / EC. It will give an opportunity to those who want to improve their knowledge and get a European certificate in Laser Safety.

The final results that will be expected to be obtained during the development of the project and its dissemination are:

- Improvement of vocational education and training in the field of laser safety by using new interactive methods.
- Enhancing the professional skills of photonics and laser technology specialists by enhancing their knowledge of laser safety.
- Creating specialists with skills and competencies in the field of laser safety.
- Support for the development and implementation of European laser safety norms and standards in the project partner countries.
- Improving the employability of the European labor market.
- Increasing the motivation of young people for vocational training and work in the field of innovative photonics and laser technology.
- Changing people's thinking about the dangers of laser radiation and creating safe working conditions when operating with laser, laser systems and complexes.

The educational product for e-learning that is created under this project is built on the basis of:

- analysis of existing VET programs and ongoing training in the laser safety sector in the partner countries;
- identification of the needs of workers related to the use of laser in 5 partner countries.

The survey and analysis methodology is based on special questionnaires. The team of participating project partners developed two sets of questionnaires. They are designed to provide the necessary information for:

- the current state of the laser safety problem;
- specific proposals for new skills needs for training modules.

After approval of the survey questions by the project partners, the questionnaires were translated from English into the national languages of the participating project partners: Latvian, Bulgarian, Romanian, Hungarian and German. The project partners then surveyed each in their country on (5) companies related to the use of lasers and the laser system and on (25) workers / operators.

Today, a number of SMEs are working successfully to produce new competitive products based on photonics and laser technology. Distributors of laser equipment are required under European laws to warn of the dangers inherent in their product. In turn, the laser operators and other laser technology consumers are required to examine in detail the operating instructions supplied with the safety instructions before putting the laser device into service.

This study showed that in some countries such as Bulgaria, Romania and Hungary in the years before the transition there was a system for control and training on laser safety, but in the years of transition due to the great administrative and economic changes in these countries these good practices are lost. Since 2006, with the adoption of the European Directive, the necessary administrative control structures for monitoring have not yet been deployed, and there are no professional training centers offering certified Laser Safety courses.

Another difficulty that would impede the widespread and rapid implementation of the directive is that it will require the removal of employees from their direct work responsibilities, which impedes employers and disrupts the pace of work in the enterprise. The activities and results of this European project "Creating Laser Safety Modules for Training / Training" will contribute to solving this problem. At the same time, it has saved both time and money for both trainees and employers.

The methodology offered to work on the project is a mixed model of training that could help achieve the project goals in the most appropriate way. Combined learning as a method of learning includes elements of distance learning and attendance training, optimally combining the strengths and benefits of each. The use of combined learning is intended to partially address the main task of modern education - with a limited number of teachers to help a large number of learners get the skills they need in the shortest possible time.

- Combined learning is a flexible technology that combines virtual and direct communication, in which discussions, debates, exchanges of experiences and practices, deep self analysis of parts of the matter through online technologies are held. These allow you to save time actively exercising and learning certain skills and habits in the classroom.
- Combined Learning develops critical thinking and creates skills for independent learning and work, relevant information (exploration, analysis and selection of materials) is used in training and career development.
- In combined learning, training materials are provided not only in print but also in accessible electronic text and / or media option, which allows students to choose individual mode of learning (access to the materials as many times as they need at a convenient time and place).
- Combined learning is interactive, it provides the opportunity for communication "teacher-learner" and "learner-learner", expression of personal opinion and perspective, exchange of opinions and possibility of changing topic directions in the studied material.

- In combined learning, individual psychological characteristics of the trainee are taken into account, because the combination of various forms of work enable students to express themselves with their different temperament and speed of absorption of matter. Thus, combined learning fits and supports the ideas of personality-oriented approach to training.

The complexity, versatility and multifactoriness of the learning process in learning contexts dictates the need for a methodologically new approach to learning from the standpoint of individualisation of learning. The use of combined learning nowadays is associated with solving the problem of the individualization of learning, its intensification and optimization. The ability of the online environment to individualize learning, enables a new way to approach the possibilities of using combined learning in the educational process.

EU Workplace Safety Regulations oblige each company to take all necessary safety and health measures at work, document them and periodically monitor for compliance, but on the other hand there is big problem about monitoring enterprises whose are related with laser beam use, because there is insufficient information about the laser systems purchased and implemented in the countries under study. This and many other problems will be solved if more people will have experience and knowledge in the field of laser safety after completing a full training course in accordance with European norms and standards, as well as obtaining a laser safety certificate.

The activities and content of the modules developed under this project will enable the students to receive knowledge and the opportunity to apply for Laser Safety Officer position in companies related with lasers, that would be monitored on national level by “Safety work environment” institutions in every EU country.

2. Lasers in the military

The use of lasers by the military continues to increase. Many armies of different countries are using a wide variety of lasers in many different ways. Traditional troops, such as infantry, artillery, naval and airborne subdivisions, now recognize the laser as an essential teaching element for increasing the accuracy and effectiveness of combat (Fig.3).

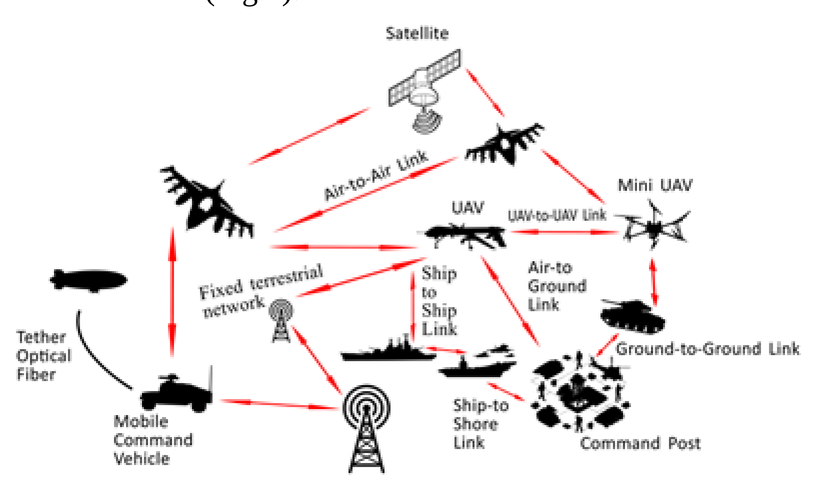

Figure 3. Illustration of military laser applications and their technological diversity

Lasers are also an element in a number of trainings related to the educational process of the Army staff.

How much exposure to laser light is hazardous? To answer this question, you have to take into account the output characteristics of the laser.

Those characteristics include wavelength, output energy and power, size of the irradiated area, and duration of exposure. If you’re using a pulsed laser, you also must consider the pulse repetition rate.

The output power of modern day military lasers ranges from milliwatts to megawatts (in cases where they deliver continuous output power), or even petawatts (10^{15} W) for short pulse lasers. In military terms, lasers with continuous output powers greater than 20 kW are classified as High Energy Lasers (HEL). Output powers in the range of kilowatts or even megawatts allow the creation of laser beams with potential harmful intensity over distances of up to several hundred kilometres. These beams can be used to heat up targets,which then may lead to structural failure of the target object.

The sensitivity to a given wavelength of laser radiation varies considerably from person to person. Maximum exposure limits (MPEs) show the highest exposure that most people can tolerate without injury.

Table2 gives the maximum allowable eye exposure for different lasers operating at different radiation levels.

Table 2. Maximum perssimible exposure limits (MPe) level W.cm^{-2}

	0,25 s	10, s	10, min	500, min
CO_2 (CW) λ = 10,6 µm	-	100. 10^{-3}	-	100. 10^{-3}
Nd:YAG (CW) λ = 1,33 µm	-	5,1. 10^{-3}	-	1,6. 10^{-3}
Nd:YAG (CW) λ = 1,064 µm	-	5,1. 10^{-3}	-	1,6. 10^{-3}
Nd:YAG (Q swiched) λ = 1,064 µm	-	17,0. 10^{-6}	-	5,1. 10^{-6}
GaAs Diode CW λ = 0,840µm	-	1,9. 10^{-3}	-	610,0. 10^{-6}
HeNe (CW) λ = 0,633 µm	2,5. 10^{-3}	-	-	17,6. 10^{-6}
Krypton-(CW) λ = 0,647; 0,568; 0,530 µm	2,5. 10^{-3} 31. 10^{-6} 16,7. 10^{-6}		364. 10^{-6} 2,5. 10^{-3} 2,5. 10^{-3}	28,5. 10^{-6} 18,6. 10^{-6} 1,0. 10^{-6}
Argon (CW) λ = 0,514 µm	2,5. 10^{-3}		16,7. 10^{-6}	1,0. 10^{-6}
XeFl-(Eximer CW) λ = 0,351 µm	-	-	-	33,3. 10^{-6}
Xel-(Eximer CW) λ = 0,308 µm	-	-	-	1,3. 10^{-6}

The hazard evaluation procedure used is based on the ability of the laser beam to cause biological damage to the eye or skin during intended use, and is related to the classification of the laser or laser system from Class 1, considered to be nonhazardous, to Class 4, very hazardous. Lasers or laser systems are certified by the manufacturer for the specific hazard class in accordance with the EU standard of laser products.

The classification of lasers is based on the concept of accessible emission limit (**AEL**); these are defined for each laser class. AEL takes into account not only the output of the laser product but human access to the laser emission. Lasers are grouped into seven classes: the higher the class, the bigger the potential to cause harm (Fig.4). The risk could be greatly reduced by additional user-protective measures, including additional engineering controls such as enclosures.

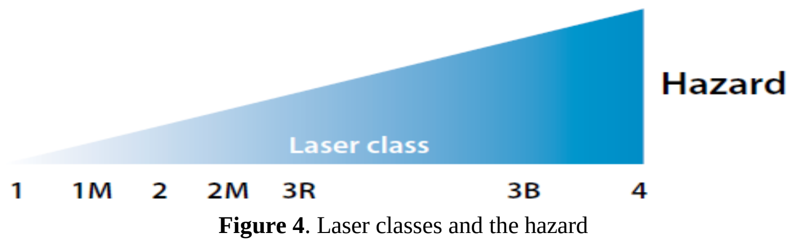

Figure 4. Laser classes and the hazard

Class 1

Laser products that are considered safe during use, including long-term direct intrabeam viewing, even when using optical viewing instruments (eye loupes or binoculars). Users of Class 1 laser products are generally exempt from optical radiation hazard controls during normal operation. During user maintenance or service, a higher level of radiation might become accessible.

Class 1M

Safe for the naked eye under reasonably foreseeable conditions of operation, but may be hazardous if the user employs optics (e.g. loupes or telescopes) within the beam.

Class 2

Laser products that emit visible radiation and are safe for momentary exposures, even when using optical viewing instruments, but can be hazardous for deliberate staring into the beam. Class 2 laser products are not inherently safe for the eyes, but protection is assumed to be adequate by natural aversion responses, including head movement and the blink reflex.

Class 2M

Laser products that emit visible laser beams and are safe for short time exposure only for the naked eye; possible eye injury for exposures when using loupes or telescopes. Eye protection is normally provided by aversion responses, including the blink reflex.

Class 3R

Direct intra-beam viewing is potentially hazardous but practically the risk of injury in most cases is relatively low for short and unintentional exposure; however, may be dangerous for improper use by untrained persons. The risk is limited because of natural aversion behaviour for exposure to bright light for the case of visible radiation and by the response to heating of the cornea for far infrared radiation.
Lasers should only be used where direct intra-beam viewing is unlikely.

Class 3A lasers—rated in power from 1 milliwatt to 5 milliwatts—cannot injure a normal person when viewed with the unaided eye but may cause injury when the energy is collected and put into the eye as with binoculars. Most laser pointers fall into this category. A danger or caution sign must label the device, depending on its irradiance.

Class 3B

Hazardous for the eyes if exposed to the direct beam within the nominal ocular hazard distance (NOHD). Viewing diffuse reflections is normally safe, provided the eye is no closer than 13 cm from the diffusing surface and the exposure duration is less than 10 s. Class 3B lasers which approach the upper limit for the class may produce minor skin injuries or even pose a risk of igniting flammable materials. Lasers from 5 milliwatts to 500 milliwatts can produce eye injury when viewed without eye protection. This class of laser requires a danger label and could have dangerous specular reflections. Eye protection is required.

Class 4

Laser products for which direct viewing and skin exposure is hazardous within the hazard distance and for which the viewing of diffuse reflections may be hazardous. These lasers also often represent a fire hazard. Lasers above 500 milliwatts in power can injure you if viewed directly or by viewing both the specular and diffuse reflections of the beam. A danger sign will label this laser. These lasers can also present a fire hazard. Eye and skin protection is required

Artificial optical radiation sources are widely used by the military: Searchlights; Lighting at military airfields; Infrared communication systems; Laser target designators; High Energy Lasers and others. During combat operations, commanders may need to take decisions on the cost/benefit of courses of action to weigh the small risk of real injury if the exposure limits are exceeded against the risk of serious injury or death from other hazards. Military uses of artificial optical radiation may include:

In order to use laser beams as weapons, a significant amount of laser output power is necessary. The output power depends heavily on the actual target. For the so-called soft targets, the minimum power to cause harm can be very low. Blinding lasers, for example, are designed to blind the human eye temporarily or permanently [4]. As the eye is very sensitive, these weapons require only a small amount of output power. Blindness can be caused in several ways: apart from burning the retina, a laser pulse can also break blood vessels inside the eye or cause a process of slow decline of the retina. At a distance of some meters, even an output power of a few milliwatts can damage the eye because the ocular focuses the beam onto the retina. This dramatically increases the intensity of the beam. Blinding lasers were used in the Falklands conflict and in the Iran/Iraq war of 1980s [5]. However, in 1995, these weapons were officially banned under International Humanitarian Law. If the aim is to destroy hard targets rather than to blind the enemy, however, the laser requires an output power which is many orders of magnitude higher than that of blinding lasers.

As mentioned above in this article, many countries and research institutes develop and test lasers with continuous output power over 20 kW or impulse power over 1 kJ [6]. As stated above, the use of blinding laser weapons is illegal under International Humanitarian Law. In particular, these weapons violate the Fourth Protocol (1995) to the Convention on Prohibitions or Restriction on the Use of Certain Conventional Weapons Which May be Deemed to be Excessively Injurious or to Have Indiscriminate Effects. This protocol outlaws the use and transfer of laser weapons which are intended to cause blindness. Additionally, the signatories are obliged to take the necessary steps to prevent blindness caused by other laser weapon engagements [7]. However, the protocol is not applicable if collateral blinding occurs as a result of military laser applications that are otherwise considered legitimate. As a consequence, the protocol might be applicable to High Energy Lasers (HEL) weapons only, if they are especially designed for blinding purposes. Nevertheless, the protocol seems to have had some positive effects so far. The protocol the first step towards a comprehensive ban of all laser weapons. This would be the first step towards preventive arms control, a concept which was developed to ban the introduction of new destabilising weapon systems [8]. Whether and to what extent a complete ban is realistically achievable is obviously another question.

Acknowledgments

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