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LASER SAFETY IN ARMY EDUCATION

Lyubomir LAZOV
Rezekne Academy of Technologies, Rezekne, Latvia
lyubomir.lazov@rta.lv

Nikolay Iliyanov PADAREV
"Vasil Levski" National Military University, Veliko Tarnovo, Bulgaria
nipadarevnvu@gmail.com

ABSTRACT

Studies have been made on the development of military science and it has been established that for the modernization of the army and the defense industry it is necessary to develop and search for new innovative technological solutions in the field of laser technology and photonics. According to the trends in the use of laser technologies for military applications, the need to acquire knowledge in the field of "Laser Safety" has also been proven. The report substantiates the need to train cadets and students in a military university. A curriculum on "Laser Safety" is proposed and what knowledge and skills future officers should acquire are indicated.

KEYWORDS: laser safety, education, armed forces, laser technology, security, innovative

1. Introduction

The trends in maintaining a high level of training of the armed forces are predetermined by the requirements for responses threats to national security arising from the specifics of the modern security environment and new modern technologies for military purposes. The main trends for development of the armed forces are characterized by implementation of new technologies, increasing level of compatibility with NATO and European Union member states, and increasing readiness to fulfil the missions of the armed forces and tasks arising from them (Shwartz, 2002).

The destructive power and accuracy of today's conventional and unconventional weapon systems threaten the survivability of NATO forces. Defeating these increasingly lethal threats will require new and revolutionary capabilities for our armed forces. The Army believes that high energy laser weapons can be effectively employed in a variety of mission areas, providing unique or complementary capabilities to other weapon systems, and resolving several existing capability gaps identified by the soldier in the field (Lavan, 2009).

Increasing capabilities of the military is achieved with properly training and education, an optimal structure, modernization, rearmament, on which we should focus our efforts.

Several important trends related to technology, including the development of laser weapons, radio electronic warfare, can have significant consequences for the development of military operations. The unforeseen challenges of the XXI century offer the phenomenon of war a new form, as well as new contexts, processes and means of conducting. It will have to consider the theoretical coordinates of the experts in military issues who argue that this change is due to the application of high-tech

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technologies and a new doctrine in the organization and execution of military operations, in the field of information management, remote detection sensors, full sensor-puller link automation and laser devices.

Several documents related to laser safety in the military are found in the standardization agreements (ARSP-4 – Laser Safety for Military use, 2017).

- STANAG 3606 – Evaluation and Control of Laser Hazards on Military Ranges, 1991. The aim of this agreement is to establish the criteria for the evaluation and control of laser hazards.
- STANAG 3606 – Laser Safety Evaluation for Outdoor Military Environments, 2012. The aim of this NATO standardization agreement (STANAG) is to respond to the following interoperability requirements.
- STANAG 3606 – Laser Safety for Military Use, 2016. The aim of this NATO standardization agreement (STANAG) is to respond to the following interoperability requirements, to provide an allied standard for laser.

Laser safety training can be provided using the handbook written by the USA Department of Defense, as well as courses and programmes found on the internet, such as: Canada – DAOD 2050-1, Laser Safety Programme (n.d.), USA – 047 Laser & Radio Frequency Hazards Course (n.d.), Laser Safety Officer Online Course (n.d.), United Kingdom – Protecting Defense personnel and operational capability through effective and independent HS&EP regulation, assurance, enforcement and investigation (n.d.), Denmark – Laser Safety Training Course (n.d.), Germany – Laser protection training (n.d.).

2. Laser Safety Needs to Be Studied in the Military

Now, the sources show us that the latest technologies are the so-called "swarms" of mini-drones that perfectly mimic the behavior of insects. They are scheduled to carry out surveillance and reconnaissance operations (intelligence, surveillance, and reconnaissance – ISR) in the battlefield. They give us real-time important information for decision-making processes aimed at coordinating some subunits of the armed forces during the attacks. What is genuinely beneficial is that all these new functionalities and technologies of the military system can be exploited without endangering the lives of the men who operate them remotely. Processing by means of lasers is based on the effect generated upon contact with a surface or with a substance that is in the vicinity of a laser beam with appropriate characteristics and focused with the help of a system of mirrors or optical lenses.

All these new technologies that have emerged are based on how the beam from the laser device interacts with the material in question. This interaction can be achieved by different processes, whether linear or nonlinear, with thermal effects or resonant processes, all depending on the parameters that characterize the laser beam, power, brightness, duration, frequency, repetition rate, band, intensity distribution, polarization, beam quality, fluctuation, temporal coherence, and spatial coherence.

In relation to any qualitative or quantitative changes suffered by the semi-finished material on which laser beam is applied, we distinguish different material processing processes such as cutting, drilling, marking, and engraving. Other processes with small quantitative changes in the material are annealing or ironing, processes performed through a series of heat treatments with the laser beam. There are also several processes based on adding material such as welding, coating, or superficial micro alloys, etc.

Lasers, as the source of light or radiation energy, were described by Theodore Maiman (1960). Until today, along with its applications in the service of human progress, the active work on its implementation as an effective combat tool for hitting various types

of targets has not stopped. Scientists from the USA, Russia, China, India and Israel are the most active in the race for the combat use of "death rays". Their colleagues from Great Britain, Japan, South Korea, Germany, and Iran are also working on this.

The laser weapon works almost instantly, such as the Russian laser complex "Сжатие" (Figure no. 1) (Copolovici, 2017).

The electromagnetic laser pulse travels at a speed close to that of light (about 300,000 km/sec). This creates conditions for successful and accurate shooting at fast moving targets. Their destruction takes place in a few seconds. The emitted pulse hits a section of the target with great accuracy without hitting surrounding objects. This is extremely important when shooting at fleeing fighters, moving combat vehicles, and flying objects (airplanes, helicopters, drones and missiles). Its striking effect on living targets can lead to temporary or permanent blinding of a person, and on combat technique - mechanical destruction (melting or vaporization of the body of the struck object). A significant advantage of the laser weapon is absence of unmasking factors characteristic of other types of weapons – fire, smoke and loud sound. A "shot" lacks the unpleasant recoil. The "ammunition" depends exclusively on the power source, being connected to it without running out.



Figure no. 1: *Russian laser complex "Сжатие"*
(Source: https://www.19fortyfive.com/2021/11/russia-wanted-laser-weapons-to-kill-us-nuclear-missiles/)



Figure no. 2: *Airborne Laser System (ABL) YAL 1A*
(Source: Airborne Laser System (ABL) YAL 1A, n.d.)

One of the most popular American laser projects is designated YAL-1A, located on a Boeing-747-400F aircraft. Its main purpose is to destroy the enemy's ballistic missiles in the section of their active trajectory. The maximum range of the YAL-1A system is about 200-250 km. The problem with its use is that at such a distance, the Boeing-747 is an easy target for enemy air defense equipment (Airborne Laser System (ABL) YAL 1A, n.d.). Nautilus and Skyguard form the basis of the 1-megawatt THEL chemical laser. The creators claim that it can be used to defeat cruise missiles, rockets, short-range ballistic missiles, and drones (Mobile/Tactical High Energy Laser (M-THEL) Technology Demonstration Program, n.d.).

Anti-missile lasers are actively being developed in Israel. The Qassam rockets that the Palestinians use are causing extremely unpleasant problems for the Israelis (HAMAS Rockets, n.d.). Successful countermeasure is quite costly to taxpayers, and the development of a laser anti-missile system seems like a very attractive alternative. This is how the laser anti-missile defense system Nautilus appeared, as a joint development agreement between the American company Northrop Grumman and Israeli specialists. Before long, however, Israel withdrew from the project due to overwhelming skepticism from high-ranking Israeli military officials. In 2011, a new TLS defense system was shown, which included a laser device and a rapid-fire cannon. The companies Boeing and VAE Systems were engaged in its development. The system must be able to hit cruise missiles, helicopters, airplanes, drones, and surface targets at up to 5 km.

German arms company Rheinmetall is working on a promising project for a new tactical High Energy Laser (HEL) that can be mounted on a wheeled or tracked infantry fighting vehicle.

Combat lasers were also developed in the former USSR at the beginning of the 60's of the last century. The most famous Soviet projects in this area are the products of the "Terra" and "Omega" programs. The tests of combat lasers were carried out on the training grounds in Kazakhstan.

These and other examples of the application of lasers as a weapon in modern military operations show the need to study laser technology in military schools. In military curricula, both in Bulgaria and in other countries, training is observed according to a united curricula for civilian and military level. The civilian specialty is fundamental to military and must be closely related. There is an opportunity to teach individual disciplines of laser technology for the new officers. We believe that it is appropriate to study the discipline "Laser safety" under the specialization "Nuclear, chemical and biological protection and ecology". In this specialization, there are some physical disciplines, as well as ionizing radiation protection.

In fact, what are the similarities between radioactive radiation and laser radiation? Gamma rays, X-rays and ultraviolet rays have the highest frequency. Infrared, microwave radiation and radio waves occupy low frequencies of the spectrum. The laser produces a strong, focused beam of light. If directed, reflected, or focused on the object, beam is partially absorbed, raising temperature of the object's surface and interior, which can cause material to change or deform. In addition to radiation that has a thermal effect on tissues, laser radiation that causes a photochemical effect is dangerous. Its state is characterized by short wavelength i.e. ultraviolet or blue parts of the spectrum.

Optical radiation is absorbed by the outer layers of the body, and for this reason the biological consequences are primarily limited to skin and eyes, but consequences for the whole organism are also possible. Different wavelengths have different effects depending on which part of the skin or eye absorbs the radiation and the type of

interaction involved: photochemical effects predominate in the ultraviolet range of the spectrum and thermal effects in the infrared range. The laser radiation can cause additional consequences, characterized by a very rapid absorption of energy by tissue, being especially dangerous for the eyes, where the lenses can focus the beam. The biological effects can be broadly divided into acute (rapidly occurring) and chronic (occurring because of prolonged and repeated exposures over a long period of time). The general rule is that acute effects only occur if exposure exceeds a given threshold level, which usually varies from person to person. Most exposure limits are based on studies of acute effect thresholds and derived by statistical consideration of these thresholds. Therefore, exceeding the exposure limit does not necessarily lead to adverse health effects. The risk of adverse health effects will increase as exposure levels above exposure limits increase.

3. Results and Discussions

The "Laser safety" discipline has been introduced for the first time into the "Protection against dangerous substances and radiation" program of "Vasil Levski" National University. The specialty is unique and based on knowledge and skills in the field of protection against radiation, chemical and biological incidents, as well as radiation hazards in the visible and invisible spectrum of light. Students will be trained in a curriculum built around the concept of optimal harmonization of theoretical and practical training in order to obtain competencies in the field of workplace safety, storage and transportation of hazardous and radiation-emitting substances. The specialty will find application in the structures for the protection and prevention of dangerous substances and radiations and liquidation of the consequences of dangerous events. For master's degree the "Laser safety" discipline can be most suitable as a continuation of bachelors who have completed the military specialty *"Nuclear, chemical and biological protection and ecology"* and the additional civilian specialty *"Protection of the population and infrastructure"*, which is intended not only for cadets, but also for civilian students. The topics that will be studied in "Laser safety" are presented in Table no. 1.

Table no. 1

"Laser safety" Program

Topics	Lections	Practical exercise
Basics of laser safety	1	
Laser safety according to EU norm RL 2006/25/EG	1	
Basics of laser radiation	2	
Classification of technological lasers and their device	2	2
External optical systems of technological lasers	2	
Laser technology – Laser cutting	2	2
Laser technology – Laser welding	2	2
Laser technology – Laser marking	2	2
Laser technology – Laser surface treatment	2	2
Dangerous and harmful production factors for humans arising from work on laser machines	2	2
Biological effects of laser radiation (eyes/skin)	2	
Glasses for laser safety	2	
Technical guarantees, safety and protective measures	3	
Waste emission	2	

Topics	Lections	Practical exercise
Tasks and responsibilities of the responsible person and operator	2	
Examination	1	
Recapitulation	30	12

Obtaining professional competence:

To form an idea of typical technological processes of laser processing carried out in laser technological complexes.

Familiarize students with:

–Harmful and dangerous factors for humans, arising during the operation of laser installations, with the effect of laser radiation on biological objects;

–Lasers classification;

–Rules for laser equipment placement and necessary documents layouts (measurement protocol, sanitary passport, etc.), organization in workplaces and premises, regulatory documents;

–Protection measures against laser radiation and harmful substances formed during laser exposure;

–Laser hazard warning devices;

–Labour safety organization and laser equipment control.

To achieve the set goals, the theoretical knowledge obtained during lectures is confirmed by practical skills obtained during practical work and during production practice.

The students should know:

–Obtaining of laser radiation;

–Basic properties of laser radiation;

–Scopes of lasers;

–Classification of technological lasers and their design;

–Features of pumping systems for various types of lasers;

–Technological parameters of laser radiation;

–Principles of construction of external optical systems in laser technology;

–Operating principles and schemes of gas, solid-state and Fiber lasers;

–Principles of operation, types and features of optical fibers used in technological lasers;

–Main types of technological processes using laser radiation;

–Hybrid technologies of laser processing: laser-arc technologies, two-beam laser welding and cutting, laser-induction welding, laser-plasma cutting and welding;

–Possibility of performing technological processes of laser processing on modern laser equipment;

–Methods for determining the main parameters of laser processing;

–The possibility of performing technological processes of laser processing on modern laser equipment;

–General mechanisms of action of laser radiation on biological objects;

–Classification of laser products according to the degree of danger;

–Regulatory documents regulating the requirements for design and technical characteristics, rules for safe operation and methods of protection against laser radiation;

–Measures taken by the manufacturer of the laser system to ensure its safe operation.

The curriculum will provide not only knowledge in the field of “Laser safety”, but also in the field of “Laser technology”. We expect that the students’ interest in laser technologies will increase, and in subsequent accreditations of the specialization “Protection from dangerous substances and radiations” in the master’s degree, the discipline Laser technologies will be created. We envisage student satisfaction questionnaires for each discipline, which may lead to change in study disciplines and their content.

4. Conclusions

The report has proven the requirement of "Laser technology" specialty in the military study curriculum. Laser technologies are an integral part not only of the modernization in the Bulgarian army, but also of being NATO army's member. Nowadays, the university doesn't have qualified staff to teach in this scientific field, but steps have been taken in this direction. In addition, proven scientific professors in the field who are proven scientific professors in the field from Germany and Latvia.

As part of the approval process, the "Laser Technology" training in a Master's program with the discipline "Laser Safety" is preferred. In the next stage, it is planned to survey the trainees and improve the training.

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