



UNIVERSITY *of* WEST FLORIDA

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UWF  
LASER SAFETY  
MANUAL

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**2019**

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**UWF Department of Environmental  
Health and Safety**

## Contents

Foreword.....	2
Glossary of Terms.....	2
Introduction.....	4
Responsibilities.....	5
UWF Administration: .....	5
The Environmental Health and Safety Office:.....	5
Laser Safety Committee (LSC):.....	5
Laser Safety Officer (LSO):.....	5
Laser System Supervisor, Qualified Operator & Restricted Operator. ....	7
Laser System Supervisor: .....	7
Qualified Operator: .....	8
Restricted Operator: .....	9
Public Safety Office: .....	9
Application, Procedures, and General Criteria for Approval of Laser Use.....	9
Training Requirements.....	10
Table 1: Suggested Training for Laser Operators.....	11
Laser Classification.....	11
Class 1 Lasers: .....	11
Class 2 Lasers: .....	11
Class 3 Lasers: .....	12
Class 4 Lasers: .....	12
Table 2: Accessible Emission Limits for Continuous Wave Small Source Lasers & Laser Systems <sup>(1)</sup> ..	12
Table 3: Accessible Emission Levels (Radiant Energy) for Single Pulsed Lasers <sup>(1)</sup> .....	13
Control Measures.....	13
Table 4: Summary of Engineering Controls <sup>(1)</sup> .....	14
Table 5: Summary of Administrative Controls <sup>(1)</sup> .....	14
Control Measures for Ancillary Hazards .....	15
Compressed Gases: .....	15
Exposure to Laser Generated Air Contaminants:.....	15
Exposure to Cryogenic Materials: .....	15
Exposure to Toxic and/or Carcinogenic Compounds: .....	15
Exposure to Excessive Noise: .....	16
Exposure to X-Rays Generated by High Voltage (> 15 kV) Power Supply Tubes: .....	16
Explosion Hazards: .....	16
Exposure to Optical (Non-Beam) Hazards: .....	16
Electrical Hazards: .....	16
Fire Hazards:.....	17
Eye and Skin Protection .....	17
Eye Protection:.....	17
Skin Protection: .....	18
Medical Surveillance .....	18
Signs and Labeling.....	19
References .....	19

## Foreword

The Laser Safety Manual represents University of West Florida's (UWF) commitment to provide a safe and productive workplace for employees whose work activities require the use of lasers and laser systems.

Just as the administration of UWF has committed to the safety of each one of its employees, the employee bears responsibility for his/her own safety and the safety of his/her coworkers. To this end, the administration welcomes the input from laser workers concerning the content and conduct of the **Laser Safety Program (LSP)**. Modifications in policies and procedures will be considered when there may be a substantial enhancement in the safety of the workplace without undo impedance to research and/or significant costs.

Information used to write The Laser Safety Manual was a collaboration from a number of resources, most notably "Laser Safety: Hazards, Inspection and Control" (Laser Institute of America, 1993). Applicable laser safety standards are found in American National Standards Institute's "American National Standard for the Safe Use of Lasers", ANSI Z136.1-2007.

All comments, questions and concerns should be addressed to the Laser Safety Officer, c/o the Environmental Health and Safety Office, 857-6221.

## Glossary of Terms

**Accessible Emission Limit (AEL):** The maximum laser output (as power or radiance) accessible to an operator for each class of laser. For example a Class 2 laser, accessible power exceeds the AEL for a Class 1 laser but is  $< 1$  mW.

**Accessible Radiation:** Radiation to which it is possible for the human eye or skin to be exposed in normal usage.

**Administrative Control:** Methods of controlling employee exposures by job rotation, work assignment time periods away from the hazard, or training in specific work practices designed to reduce the exposure.

**ANSI:** The American National Standards Institute.

**Ancillary (Non-Beam) Laser Hazard:** A hazard not directly associated with exposure of the human skin or eye to laser radiation itself. Ancillary hazards include laser generated air contaminants, fire and electrical hazards.

**Attenuator:** A material or medium used to absorb or scatter a beam for the purpose of decreasing the radiant flux

**Aversion Response:** Closure of the eyelid or movement of the head to avoid an exposure to a noxious stimulant or light. In ANSI Z136.1-1993, the aversion response to an exposure to laser radiation is assumed to occur within 0.25 seconds.

**Beam:** A collection of light photons that may be parallel, divergent or convergent.

***Defeatable Entryway Control:*** An interlock or control designed to limit entry into a laser controlled area. A defeatable control can be temporarily bypassed if it is clearly evident that there is no hazard at the point of entry.

***Diffuse Reflection:*** A beam of laser radiation that is reflected in many directions by a surface or by a medium. Diffuse reflection occurs when irregularities on a surface or medium are randomly oriented and are greater in size than the wavelength of the incident light.

***Embedded Laser:*** An enclosed laser with a higher laser classification than the system into which it is incorporated. The system's lower classification is appropriate due to engineering features that limit an operator's access to the embedded laser's emission. For example a Class 1 laser system with an embedded Class 4 laser, as in a flow cytometer.

***Engineering Control:*** A method of controlling employee exposures by incorporating controls into the laser system or design or by modifying the source.

***Incidental Personnel:*** Persons such as housekeepers, maintenance personnel, and emergency personnel who do not frequent areas in which lasers are operated but may have occasional exposure to laser radiation.

***Interlock:*** Typically a switch that, when activated, will interrupt the normal; operation of the laser by closing a shutter or de-energizing the system.

***Intrabeam Viewing:*** The viewing condition whereby the eye is exposed to all or part of a direct laser beam or specular reflection.

***Laser:*** Acronym for light amplification by stimulated emission of radiation. A device that produces an intense directional beam of light by stimulating electronic or molecular transitions to lower energy levels.

***Laser Controlled Area:*** An area where the activities of those within is subject to control and supervision for the purpose of laser radiation hazard protection.

***Laser Personnel:*** Persons such as Laser System Supervisors, Qualified Operators and Restricted Operators, as well as persons frequenting areas in which lasers are present, who have a reasonable opportunity to be exposed to laser radiation.

***Maximum Permissible Exposure (MPE):*** The level of laser radiation to which a person may be exposed without hazardous effects or adverse biological changes in the eye or skin. Factors that determine the MPE for a particular laser include the wavelength of the light, the exposure duration, and the power or radiance of the laser.

***Nominal Hazard Zone (NHZ):*** An area in which the level of direct, reflected or scattered laser radiation exceeds the applicable MPE.

**Optical Density (OD):** A measure of the amount of attenuation, either absorptive or reflective, provided by a medium. Optical density is expressed mathematically as:

$$OD_{\lambda} = \log_{10} \left( \frac{H_0}{MPE_{\lambda}} \right)$$

Where:  $OD_{\lambda}$  = optical density at wavelength  $\lambda$   
 $H_0$  = anticipated worse case exposure (W/cm<sup>2</sup> for continuous wave lasers and J/cm<sup>2</sup> for pulsed sources)

$MPE_{\lambda}$  = maximum permissible exposure at wavelength  $\lambda$

**Specular Reflection:** A mirror like reflection. Specular reflections occur when the size of surface irregularities or roughness is less than the wavelength of the incident light.

**Shall:** In the context of UWF's Laser Safety Manual and ANSI Z136.1-1993 shall means mandatory.

**Should:** In the context of UWF's Laser Safety Manual and ANSI Z136.1-1993 should means advisory.

## Introduction

The term "LASER" is an acronym that stands for "Light Amplification by Stimulated Emission Radiation". Lasers are commonly employed in a wide variety of applications including: non-destructive testing, biomedical research, surgery, communications, information handling systems, and research and development, to name a few.

Although there is no designated registry for laser accident data, R. James Rockwell, Jr., President, Rockwell Laser Industries (Cincinnati, Ohio) has information to suggest that the vast majority of laser accidents fall into one or more of the following categories:

- Unanticipated eye exposure during alignment.
- Available eye protection not used.
- Equipment malfunction.
- Improper methods of handling high voltage;
- Intentional exposure of unprotected personnel;
- Operators unfamiliar with laser equipment;
- Lack of protection for ancillary hazards; and,
- Improper restoration of equipment following service.

On the basis of this accident data, he concluded the emphasis of a laser safety program be placed on utilizing the appropriate control measures for the laser or laser system being used, and training of personnel, to prevent accidents. The *prevention* of laser accidents is the emphasis of UWF's Laser Safety Program.

This manual outlines policies and procedures for the conduct of UWF's Laser Safety Program. Special attention should be given to the use of the words shall and should. As with the American

National Standard for the Safe Use of Lasers, ANSI Z136.1-2007, shall is understood to mean mandatory, while *should* is understood to mean advisory.<sup>1</sup>Rockwell, Jr., R. James. "Laser Accidents: Are They Reported and What Can Be Learned From Them." Journal of Laser Applications. October 1989.

## Responsibilities

### UWF Administration:

- Support the **LSP** by providing adequate funding and management oversight.
- Provide information services (as needed) through the Public Relations Office.

### The Environmental Health and Safety Office:

- Provide support personnel for the LSP, including the Laser Safety Officer.
- Provide University employees laser safety training.
- Develop and update (as needed) the Laser Safety Manual.
- Provide technical assistance and consultation to University laser users.
- Maintain records concerning the LSP.
- Act as the contact point for regulatory agencies.
- In concert with the principal investigator inspect and assess laser hazards. Recommend control measures and corrective action(s) as necessary.
- Provide the Office for Institutional Advancement with information as needed.

### Laser Safety Committee (LSC):

The **Laser Safety Committee (LSC)** is responsible for overseeing conduct of the LSP.

The LSC establishes and maintains policies and procedures for the control of laser hazards at UWF. Membership on the Committee is offered to employees of the University, i.e., faculty, staff, and administrators with an interest in lasers and laser safety. Meetings are held as needed.

Members of the Committee perform the following:

- Annual review of the conduct of the LSP, including review of the provisions of the program, and the performance of the Laser Safety Officer.
- Initial reviews of protocols involving the use of lasers, and follow-up reviews if there are significant change(s) in the user's protocol.
- Recommend control measures to ensure the safe use of lasers.
- Consultation, as necessary, to all users of lasers.
- Review incidents involving the use of lasers and recommend corrective action(s) to prevent the reoccurrence of similar incident(s).
- Provide administrative support to the Laser Safety Officer and the LSP.
- Review applications for Laser System Supervisor status.

### Laser Safety Officer (LSO):

The **Laser Safety Officer (LSO)** is granted, by virtue of his/her training and experience, the authority and responsibility for monitoring use(s) of lasers at UWF. The LSO is also responsible for the evaluation of laser hazards and, in concert with the LSC, will establish appropriate controls. Specific responsibilities of the LSO include:

- Classification of lasers.

- Hazard evaluations in all laser work areas, and in areas adjacent to laser work areas, including the establishment of nominal hazard zones.
- Implementation of appropriate control measures to demonstrate compliance with ANSI Z136.1. Establishes alternate measures as necessary and ensures that the control measures taken are adequate.
- Approval of personal protective equipment such as eyewear and clothing.
- Approval of equipment such as barriers and screens. Ensures that the equipment is adequate and in good working order.
- Ensuring that appropriate signs and labels are posted in all laser work areas, and on lasers as required by ANSI Z136.1.
- Ensuring that laser workers receive adequate safety education and training, and that they understand their responsibilities.
- Determining the applicability of medical surveillance for laser workers, and recommends surveillance as necessary.
- Providing consultative services to laser users.
- Maintaining records of the LSP as required.
- Along with the principal investigator, periodically inspect laser work areas.
- Documenting instances of non-compliance and reporting them to the LSC for consideration.
- Ensuring that actions (as agreed upon by the LSC) to correct unsafe or non-compliant conditions are taken in a timely and appropriate manner.
- Performing investigations of accidents involving lasers and initiation the appropriate follow-up action(s).
- Reviewing applications for Laser System Supervisor and Qualified Operator status.

The LSO, with the approval of the LSC, reserves the right to terminate any activity, involving the use of lasers if it is found to be a threat to the health of the employees of UWF, the property of UWF, or the health and/or property of an individual member of the public. Termination would include immediate cessation of laser operation(s), closing of the laboratory or area, and/or confiscation of the laser. The administrative protocol for such termination is as follows:

1. The unsafe or non-compliant condition, once identified, is documented. The Laser System Supervisor and members of the LSC are provided with copies of the report.
2. The Laser System Supervisor is given the opportunity to respond (in a reasonable time period) to any findings to the LSO and members of the LSC. Any response should include actions that will be undertaken to correct the non-compliant or unsafe condition(s) and/or any arguments appealing the findings of the LSO.
3. If the corrective actions undertaken by the Laser System Supervisor are deemed appropriate, or if by the LSO and the LSC, on further actions will be taken.
4. If the Laser System Supervisor fails to respond to the LSO and LSC, or fails to undertake corrective actions, he/she is warned in writing that termination of all activities using the laser(s) will be considered. Copies of the warning shall be sent to the Chair or Head of the Laser System Supervisor's Department as well as members of the LSC. The Laser

System Supervisor will be expected to respond within 2 *working days* after he/she receives the warning.

5. Continued failure to correct non-compliant or unsafe conditions, or respond shall result in termination of all activities involving the laser(s). Termination actions shall be reported to the Chair or Head of the Laser System Supervisor's Department immediately after the action had been taken.

### Laser System Supervisor, Qualified Operator & Restricted Operator.

Users of lasers are classified according to their level of training, experience and responsibility. There are three classes of laser users: Laser System Supervisor, Qualified Operator, and Restricted Operator. *User status is required for operation of Class 3b and Class 4 lasers only.*

### Laser System Supervisor:

Laser System Supervisor status is obtained by application to the LSO using form LSC-2, "Application for Laser System Supervisor Status." The LSO must approve the applicant's LSC-2 before Laser System Supervisor status is granted. If the LSO does not grant approval of the applicant's LSC-2, the applicant may appeal to the LSC. The LSC's decision in matters pertaining to laser System Supervisor status is final.

To be approved by the LSC as a Laser System Supervisor, the applicant must demonstrate, by successful completion of training (and an exam) and/or a "challenge exam," his/her knowledge of the following:

- The fundamentals of laser operation and procedures and provisions relating to the safe operation of lasers.
- Known bioeffects on the eye and skin for the laser class he/she will be operating.
- The potential non-beam hazards associated with the operation of the laser or laser system.
- Laser classification and the potential hazards of all classes of lasers.
- Control measures required for the safe operation of all classes of lasers.
- Management and operator responsibilities, including the conduct of the LSP.
- Medical surveillance practices, including reporting requirements for accidents involving operation of their lasers.
- Education and training requirements for the class lasers he/she operates.

For those areas, systems, and employees under the Supervisor's authority, the Supervisor will be responsible for the following:

- Providing appropriate instruction and system specific training to all operators of the lasers.
- Ceasing the operation of the lasers if adequate control measures are not being implemented.
- Submitting the names, qualifications, training background and medical surveillance history of individuals to the LSO for approval prior to those individuals operating the lasers.
- Notifying the LSO (or other designated authority) immediately following the occurrence of a laser accident or unusual occurrence.
- Obtaining appropriate (and necessary) medical attention for a laser operator involved in a laser accident.



- Ensuring that the LSO has approved form LSC-1, “Application for the Operation of Lasers and Laser Systems,” prior to operating a new or modified laser.
- Not allowing a Restricted Operator or any other unauthorized individual to operate the lasers without direct supervision.
- Providing laser operators with appropriate personal protective equipment.
- Posting areas with appropriate warning labels/signs.
- Arranging medical surveillance for laser operators (if required).
- Ensuring that adequate funding is available for personnel protective equipment and medical surveillance.
- Including in grant proposal budgets, sufficient funding for compliance with this manual, as appropriate. Funding should include the cost of any training or medical evaluations.

### Qualified Operator:

Qualified Operator status is achieved after successfully completing laser safety training or passing a laser safety "challenge exam." Persons wishing to apply for Qualified Operator status must submit form LSC-3, *Application for Qualified Operator Status* to the LSO for approval. The LSO will approve the application if he/she is satisfied that the applicant has sufficient knowledge and experience to operate lasers independently of a Laser System Supervisor. If the LSO does not grant approval of the applicant's LSC-2, the applicant may appeal to the LSC. The LSC's decision in matters pertaining to Qualified Operator status is final.

To be approved as a Qualified Operator, the applicant must demonstrate his/her knowledge of the following:

- Fundamentals of laser operation and procedures and provisions relating to the safe operation of lasers.
- Known bioeffects on the eye and skin for the laser class he/she will be operating.
- The potential non-beam hazards associated with the operation of lasers.
- Laser classification and the potential hazards of all classes of lasers.
- Control measures required for the safe operation of all classes of lasers.
- Management and operator responsibilities, including the conduct of the LSP.
- Medical surveillance practices, including reporting requirements for accidents involving operation of their laser.

Once approved by the LSO (or LSC) as a Qualified Operator he/she will be responsible for the following:

- Being familiar with and following, the standard operating procedures established for lasers.
- Employing the appropriate engineering and administrative control measures while operating lasers.
- Using the appropriate personal protective equipment while operating lasers.
- Notifying the LSO or Laser System Supervisor immediately following the occurrence of an accident or unusual occurrence.
- Ceasing the operation of the laser immediately in case of imminent danger to an individual or property as the result of a malfunction in the system or system set-up.
- Direct supervision of a Restricted Operator if authorized and directed by the Laser System Supervisor or the LSO.

### Restricted Operator:

A Restricted Operator is an individual that does not have adequate training and/or experience to operate a laser except under the direct supervision of a Laser System Supervisor and/or a Qualified Operator. This category of laser user is intended to allow new hires to start working immediately upon employment and prior to attending the required training and/or successfully completing the written "challenge exam."

The LSO may approve individuals that have successfully completed the necessary training for Qualified User status.

### Public Safety Office:

Public Safety Office provides the necessary notification and communication services in the case of emergencies.

## Application, Procedures, and General Criteria for Approval of Laser Use

Persons intending to operate a Class 3b or 4 laser are required to have the approval of the LSO prior to operating that laser. Applicants must submit two forms to the LSO: LSC-1, "*Application for the Operation of Lasers and Laser Systems*," and LSC-2, "*Application for Laser System Supervisor Status*." Applications must be reviewed and approved by the LSO prior to operating the laser. All questions concerning the application must be resolved before final approval to operate the laser is granted. If the LSO does not grant approval of the applicant's LSC-1 or LSC-2, the applicant may appeal to the LSC. The LSC's decision in matters pertaining to laser use protocols is final.

Applications for the use of a laser will be approved if the LSO is satisfied that the applicant has:

- Adequate facilities to ensure the safe use of lasers.
- Established adequate engineering and administrative controls to ensure the safety of the laser operators and the general public.
- The appropriate personnel protective equipment available to augment engineering and administrative controls.
- Established safe and effective operating and emergency procedures.
- Provided for adequate and appropriate security for the laser-controlled areas.
- Adequate training and experience to operate lasers and supervise other operators in a safe manner.
- Provisions that maintain optical and ancillary hazards to the lowest levels possible.
- Obtained the appropriate medical surveillance.

Application approvals do not require renewal except as deemed necessary by the LSO. The application must be amended in cases where the laser or lasers are relocated, or if there are significant changes in the set-up, operating procedures, controls or any previously approved condition, including changes in personnel operating the lasers. The Laser System Supervisor shall submit amendments in writing to the LSO prior to any changes in the laser operations protocol. If the LSO does not grant approval of the amendments to their existing LSC-2, the

applicant may appeal to the LSC. The LSC's decision in matters pertaining to laser use protocols is final.

## Training Requirements

Training *shall* be provided to each employee routinely working in an area with, or operating a Class 3b or Class 4 laser. Persons who work in an area with, or who operate a Class 2 or Class 3a laser have the option of attending laser safety training; however, training is not required. The level of any training *shall* be commensurate with the level of the potential hazard.

Individuals who receive training must demonstrate their knowledge of lasers and laser safety by successful completion of a written examination. Those individuals who choose not to attend formal training may demonstrate their knowledge of lasers and laser safety by successfully completing a laser safety "challenge exam." Maintenance of training records and exam results will be the responsibility of the LSO. Suggested training topics for Laser System Supervisors and Qualified Operators might include, but are not limited to:

- The fundamentals of laser operation, including physical principles and basic laser construction.
- The known bioeffects of laser radiation, including optical and skin hazards.
- Relations of diffuse and specular reflections.
- Ancillary laser hazards.
- Laser classifications.
- Engineering and administrative control measures, and the proper use of personal protective equipment.
- Components of UWF's LSP including administration, and employee responsibilities.
- Medical surveillance practices.
- Emergency procedures.

Suggested topics for the LSO, and Program managers might include (but is not limited to) all topics listed above for Laser System Supervisors and Qualified Operators and:

- Laser terminology.
- Types of lasers, including wavelengths, pulse shapes, operational modes, and power / energy relationships.
- Radiometric units and measurement devices.
- MPE levels under all conditions for the eye and skin;
- Laser hazard evaluations; and,
- Calculations relating to lasers and laser safety.

Suggested topics for optional training of Class 2 and 3a laser users include:

- Basic explanation of the laser and laser operation;
- The basis for differentiation between Class 1 and Class 2 lasers;
- The human aversion response; and,
- The optical effects of intrabeam viewing of Class 2 lasers.

Table 1 summarizes suggested topics for the LSO, Laser System Supervisors, and Qualified Operators for each class of laser:

**Table 1: Suggested Training for Laser Operators**

	Laser System Supervisors / Qualified Operators Highest Class Laser						LSO
	1	2a	2	3a	3b	4	
Manufacturers Guide and Operating Manuals	R	R	SR	SR	SR	SR	n/a
Safety Guide Literature	n/a	n/a	R	R	SR	SR	SR
Audiovisual and/or Computer Based Instruction	n/a	n/a	R	R	SR	SR	SR
Laser Safety Orientation	n/a	n/a	n/a	n/a	R	SR	SR
Short-Term Course	n/a	n/a	n/a	n/a	n/a	R	SR
Review of Applicable Standards	n/a	n/a	n/a	n/a	n/a	n/a	SR

R = Recommended  
SR = Strongly recommended

## Laser Classification

The laser classification scheme outlined in this section is taken from ANSI, Z136.1-1993, “American National Standard for the Safe Use of Lasers.”

ANSI recognizes 4 broad classes of lasers, designated Class 1, 2, 3 and 4. Each class has specific control measures that must be taken when the laser is operated. In general:

### Class 1 Lasers:

Class 1 lasers are the lowest powered lasers normally limited to gallium-arsenide lasers and certain other enclosed lasers. These lasers are not considered hazardous even when its output is collected by collecting optics and concentrated into the pupil of the eye. Most lasers do not fall into Class 1 based on output, rather they are categorized Class 1 because the laser system has a high(er) powered laser that has been enclosed thereby offering a physical barrier to direct viewing. If a Class 1 laser system incorporates a more dangerous class laser the enclosure panel must be labeled with a warning to alert the user that hazardous exposure might occur if the panel is removed.

### Class 2 Lasers:

Class 2 lasers ("Low-Risk or Low-Power" lasers) are only hazardous if the viewer overcomes his/her natural aversion response to bright light and focuses the primary beam continuously into the eye for a long period. All lasers in this class are in the visible spectrum (400 to 700 nm). An example of a Class 2 laser is a supermarket checkout scanner.

A subclass of Class 2 lasers, Class 2a, is also recognized. Class 2a lasers are intended for specific use when viewing the laser output is not intended. The accessible output of a Class 2a laser does not exceed the Class 1 AEL for an exposure duration of  $\leq 1000$  seconds.

### Class 3 Lasers:

Class 3 lasers ("Medium-Risk" or "Medium-Power" lasers) are capable of causing injury from exposures shorter the natural aversion response time of 0.25 seconds, i.e., faster than the blink reflex. This class of lasers is not capable of causing serious skin injury or hazardous diffuse reflection hazards under normal conditions. There are 2 subclasses of Class 3 lasers, Class 3a and Class 3b.

Class 3a lasers are potentially hazardous only if the output is collected and focused into the eye, and have an output  $\geq 5$  times the output of the next lowest class. For example with continuous wave lasers the output of a Class 3a laser would be between 1 and 5 mW.

Class 3b lasers are capable of causing acute eye damage by either intrabeam viewing or specular reflections. For continuous wave lasers the output of a Class 3b laser would be greater than Class 3a lasers but less than 500 mW.

### Class 4 Lasers:

Class 4 lasers ("High-Risk" or "High-Power" lasers) are capable of causing serious eye and skin injury by exposure to the primary beam and by exposure to both specular and diffuse reflections. This class of lasers is also capable of igniting flammable materials.

Table 2 summarizes characteristics of each classification of continuous wave (cw) lasers based on the power output of the laser:

**Table 2: Accessible Emission Limits for Continuous Wave Small Source Lasers & Laser Systems <sup>(1)</sup>**

Wavelength Range ( $\mu\text{m}$ )	Emission Duration (s)	Class 1 (W)	Class 2 (W)	Class 3 <sup>(3)</sup> (W)	Class 4 (W)
Ultraviolet: 0.18 to 0.302	$3 \times 10^4$	$\leq 9.6 \times 10^{-9}$	—	>Class 1 but $\leq 0.5$	>0.5
0.302 to 0.4	$3 \times 10^4$	$\leq 3.2 \times 10^{-6}$	—	>Class 1 but $\leq 0.5$	>0.5
Visible: 0.4 to 0.7	$10^{(2)}$	$\leq 0.4 \times 10^{-3}$	>Class 1 but $\leq 1.0 \times 10^{-3}$	>Class 2 but $\leq 0.5$	>0.5
Near Infrared: 0.7 to 1.05	$\geq 10$	$\leq 0.4 \times 10^{-3}$ to $\leq 1.9 \times 10^{-3}$	—	>Class 1 but $\leq 0.5$	>0.5
1.05 to 1.15	$\geq 10$	$\leq 1.9 \times 10^{-3}$	—	>Class 1 but $\leq 0.5$	>0.5
1.15 to 1.2	$\geq 10$	$\leq 1.9 \times 10^{-3}$ to $\leq 1.5 \times 10^{-2}$	—	>Class 1 but $\leq 0.5$	>0.5
1.2 to 1.4	$\geq 10$	$\leq 1.5 \times 10^{-2}$	—	>Class 1 but $\leq 0.5$	>0.5
Far Infrared: 1.4 to 100	>10	$\leq 9.6 \times 10^{-3}$	—	>Class 1 but $\leq 0.5$	>0.5

Submillimeter: 10 <sup>2</sup> to 10 <sup>3</sup>	>10	≤9.5×10 <sup>-2</sup>	—	>Class 1 but ≤0.5	>0.5
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<sup>(1)</sup> From ANSI Z136.1-2000, Table 1. For emission durations ≥0.25 seconds.

<sup>(2)</sup> When the design or intended use of the laser or laser system ensures personnel exposures of less than 10<sup>4</sup> seconds in any 24 hour period, the limiting exposure duration may establish a higher exempt power level as described in ANSI Z136.1-2000 (§3.2.3).

<sup>(3)</sup> For 1 to 5 mW laser systems (Class 3a) see ANSI Z136.1-2000 (§3.3.3.1 and 3.3.3.2)

Table 3 summarizes characteristics of each classification of single pulsed lasers based on the radiant energy output of the laser:

**Table 3: Accessible Emission Levels (Radiant Energy) for Single Pulsed Lasers <sup>(1)</sup>**

Wavelength Range (μm)	Emission Duration (s)	Class 1 (J)	Class 3b (J)	Class 4 (J)
Ultraviolet: 0.18 to 0.302	10 <sup>-9</sup> to 0.25	≤2.4×10 <sup>-5</sup>	>Class 1 but ≤0.125	>0.125
0.302 to 0.4	10 <sup>-9</sup> to 0.25	≤2.4×10 <sup>-5</sup>	>Class 1 but ≤0.125	>0.125
		≤3.1×10 <sup>-3</sup>	>Class 1 but ≤0.125	>0.125
Visible: 0.4 to 0.7	10 <sup>-9</sup> to 0.25	≤0.2×10 <sup>-6</sup>	>Class 1 but ≤0.03	>0.03
		≤0.25×10 <sup>-3</sup>	>Class 1 but ≤0.03	>0.03
Near Infrared: 0.7 to 1.05	10 <sup>-9</sup> to 0.25	≤1.9×10 <sup>-7</sup> to 1.2×10 <sup>-3</sup>	>Class 1 but ≤0.03C <sub>A</sub>	>0.03C <sub>A</sub>
1.05 to 1.4	10 <sup>-9</sup> to 0.25	≤1.9×10 <sup>-6</sup> to 9.8×10 <sup>-3</sup>	>Class 1 but ≤0.125	>0.125
Far Infrared: 1.4 to 10 <sup>-2</sup>	10 <sup>-9</sup> to 0.25	≤79×10 <sup>-6</sup> to 7.9×10 <sup>-3</sup>	>Class 1 but ≤0.125	>0.125
Submillimeter: 10 <sup>2</sup> to 10 <sup>3</sup>	10 <sup>-9</sup> to 0.25	≤10×10 <sup>-3</sup>	>Class 1 but ≤0.125	>0.125
		≤0.4	>Class 1 but ≤0.125	>0.125

<sup>(1)</sup> From ANSI Z136.1-1993, Table 1. There are no Class 2 single-pulsed lasers.

<sup>(2)</sup> C<sub>A</sub> is a correction factor allowed by ANSI Z136.1-1993 that permits increased MPE values in the near infrared (IRA) spectrum, 700 to 1400 nm.

## Control Measures

The Laser System Supervisor is responsible for the evaluation of the control measures used in each laser application. The LSO, with the support and guidance of the LSC, is responsible for monitoring and enforcing laser hazard control measures. Each user is responsible to employ those control measures approved by the LSO and/or the LSC.

**Table 4: Summary of Engineering Controls<sup>(1)</sup>**

Control Measures	Laser Classification					
	1	2a	2	3a	3b	4
<i>Engineering Controls</i>						
Protective housing	●	●	●	●	●	●
Without protective housing	LSO shall establish alternate controls					
Interlocks on protective housing	■	■	■	■	●	●
Service access panel	■	■	■	■	●	●
Key control	—	—	—	—	▲	●
Viewing portals	—	—	MPE	MPE	MPE	MPE
Collecting optics	MPE	MPE	MPE	MPE	MPE	MPE
Totally open beam path	—	—	—	—	● (NHZ)	● (NHZ)
Limited open beam path	—	—	—	—	● (NHZ)	● (NHZ)
Enclosed beam path	None required if interlocked protective housing is provided					
Remote interlock connector	—	—	—	—	▲	●
Beam stop or attenuator	—	—	—	—	▲	●
Emission delay	—	—	—	—	—	●
Indoor laser controller area	—	—	—	—	● (NHZ)	● (NHZ)
Class 3b laser controlled area	—	—	—	—	●	—
Class 4 laser controlled area	—	—	—	—	—	●
Laser outdoor controls	—	—	—	—	● (NHZ)	● (NHZ)
Temporary laser controlled area	■ (MPE)	■ (MPE)	■ (MPE)	■ (MPE)	—	—
Remote firing and monitoring	—	—	—	—	—	λ
Labels	●	●	●	●	●	●
Area posting	—	—	—	▲	● (NHZ)	● (NHZ)

<sup>(1)</sup>From ANZI Z136.1-1993. Alternative controls may be substituted if ANSI Z136.1-1993 permits exceptions.

**Legend:**NHZ Nominal hazard zone analysis required—No requirement, MPE-Should if MPE is exceeded, ▲-Should, ■-Should if enclosed Class 3b or 4 laser, ●-Should

**Table 5: Summary of Administrative Controls<sup>(1)</sup>**

Control Measures	Laser Classification					
	1	2a	2	3a	3b	4
<i>Administrative Controls</i>						
Standard operating procedures	—	—	—	—	▲	●
Output emission limitations	—	—	—	LSO determination		
Education and training	—	—	▲	▲	●	●
Authorized personnel	—	—	—	—	●	●
Alignment procedures	—	—	●	●	●	●
Protective equipment	—	—	—	—	▲	●
Spectator	—	—	—	—	▲	●
Service personnel	■ (MPE)	■ (MPE)	■ (MPE)	■ (MPE)	●	●
Demonstration with general public	MPE (1)	—	●	●	●	●
Laser optical fiber systems	MPE	MPE	MPE	MPE	●	●
Laser robotic installations	—	—	—	—	● (NHZ)	● (NHZ)
Eye protection	—	—	—	—	▲ (MPE)	● (MPE)
Protective windows	—	—	—	—	● (NHZ)	● (NHZ)
Protective barriers and curtains	—	—	—	—	▲	▲
Skin protection	—	—	—	—	● (MPE)	● (MPE)
Other protective equipment	May be required					
Warning signs and labels (requirements)	—	—	▲	▲	● (NHZ)	● (NHZ)
Service and repairs	LSO and Laser System Supervisor determination					
Modification of laser system	LSO and Laser System Supervisor determination					

<sup>(1)</sup>From ANZI Z136.1-1993. Alternative controls may be substituted if ANSI Z136.1-1993 permits exceptions.

**Legend:** NHZ Nominal hazard zone analysis required-No requirement, MPE-Should if MPE is exceeded, ▲-Should, ■-Should if enclosed Class 3b or 4 laser, ●-Should

## Control Measures for Ancillary Hazards

The Laser System Supervisor shall consider control measures for ancillary hazards based on sound industrial hygiene and safety practices. Specific control measures for ancillary hazards may include but are not limited to the following:

### Compressed Gases:

Specific guidelines for the safe use and storage of compressed gases can be found in UWF's *Chemical Hygiene Plan*. General control measures include:

- Securing compressed gas cylinders at all times whether they are in use or not.
- Properly labeling all gas cylinders.
- Providing adequate ventilation when compressed gases are being used.

### Exposure to Laser Generated Air Contaminants:

Adequate local exhaust ventilation shall be installed to control exposures when potential for LGAC's exists. Principals for the design of a local exhaust system include:

- Exhaust ventilation shall ensure that all operators and spectators exposure to hazardous LGAC's be maintained at or below the Permissible Exposure Limits specified by the Occupational Health and Safety Administration (OSHA);
- Ventilation systems should be designed and built in accordance with acceptable criteria, i.e., the American Society of Heating and Air Conditioning Engineers (ASHRAE) and the ANSI specifications; and,
- Under no circumstances should there be re-circulation of LGAC's.

Respiratory protection may be provided to control exposures to LGAC's or as an interim control measure until engineering and/or administrative controls can be implemented. Respiratory protection shall be utilized under the provisions of UWF's Respiratory Protection Program.

### Exposure to Cryogenic Materials:

Cryogenic materials, dyes and other hazardous materials shall be handled in accordance with the instructions provided by the manufacturer or importer, and applicable provisions of UWF's *Chemical Hygiene Plan*:

- Safety data sheets (SDS's) shall be provided to employees handling hazardous materials.
- Personal protective equipment (PPE), as described on the respective MSDS shall be provided to each employee. The use of PPE, i.e., lab coats, gloves, and safety goggles shall be mandatory when manipulating hazardous and potentially hazardous materials.

### Exposure to Toxic and/or Carcinogenic Compounds:

Toxic and carcinogenic materials in dyes and/or the solvents used to dissolve them shall be handled in accordance with the instructions provided by the manufacturer or importer, and applicable provisions of UWF's *Chemical Hygiene Plan*:

- Safety data sheets (SDS's) shall be provided to employees handling toxic and/or carcinogenic materials.
- Personal protective equipment (PPE), as described on the respective MSDS shall be provided to each employee. The use of PPE, i.e., lab coats, gloves, and safety goggles shall be mandatory when manipulating toxic and/or carcinogenic materials.



### Exposure to Excessive Noise:

Hearing protection shall be provided in accordance with OSHA's Occupational Noise Exposure Standard.

### Exposure to X-Rays Generated by High Voltage (> 15 kV) Power Supply Tubes:

The Radiation Safety Office shall evaluate the potential for x-ray exposure, and provide for radiological surveys of lasers and laser systems as necessary.

### Explosion Hazards:

- High-pressure arc lamps, filament lamps and capacitor banks shall be housed in enclosures capable of withstanding an explosion.
- Target and optical elements capable of shattering shall be protected so as to prevent injury to the operator and spectators.

### Exposure to Optical (Non-Beam) Hazards:

Included in this category of ancillary hazards are exposures to ultraviolet radiation emitted from laser discharge tubes and pumping lamps, exposures to visible and near-infrared radiation emitted from pumping systems and exposures to ultraviolet and/or blue radiation emitted from materials testing and processing:

Ultraviolet radiation emitted from discharge tubes, pumping lamps shall be shielded in such a manner so as to maintain exposures to within the applicable Threshold Limit Value (TLV) specified by the American Conference of Government Industrial Hygienists (ACGIH).

### Electrical Hazards:

Potential electrical hazards may occur during the course of laser installation, maintenance and service. A barrier system should be employed as primary protection against electrical hazards. Other specific control measures to prevent electrical hazards include:

- The use of metallic enclosures, barriers or baffles. Any system of enclosures, barriers and/or baffles shall comply with Underwriters Laboratories (UL) Standard 746C.
- If appreciable capacitance is associated with the laser circuitry, components with peak potentials of  $\geq 2500$  V shall be adequately covered, insulated or enclosed:
  - Electrical terminals shall be covered and properly insulated.
  - All accessible non-current carrying metallic parts of laser equipment shall be grounded by a continuous metallic connection with grounding conductor of the wiring system.
- The implementation of lockout procedures during maintenance and servicing as specified in UWF's Lockout/Tagout Program.
- The use of written protocols for maintenance and service operations.
- Training for operators, maintenance and service personnel, and current certification in cardiopulmonary resuscitation (CPR).
- The installation of interlock switches (or equivalent) to remove voltage from accessible live components;
- The installation of bleeder resistors to discharge capacitors;

- The use of a solid metal grounding bar to complete the discharge of capacitor banks when the laser has been serviced less than 24 hours after voltage was applied. A resistor-grounding rod may be used first to protect circuit components; however, a solid metal cannot be replaced when discharging the system.
- Additional controls as specified in OSHA regulations and the National Fire Protection Association (NFPA).

### Fire Hazards:

Class 4 lasers can generate beams powerful enough to burn the skin and/or to ignite flammable materials. In addition, Class 4 lasers are a potential fire hazard if the material used to enclose an embedded laser is exposed to irradiance exceeding 10 W/cm<sup>2</sup>, or beam powers exceeding 0.5 W. Other laser system components that are potential fire hazards include the electrical circuitry in the laser, certain laser gases, certain LGAC's produced as the result of the beam's interaction with a target material, and certain laser dyes and/or the solvents used to dissolve the dyes:

- Flame retardant materials should be used to enclose Class 4 lasers and laser systems.
- Flammable materials (e.g., wire insulation, tubing, laboratory chemicals, etc.) should be protected from the direct beam, and specular and diffuse reflections from Class 4 lasers.

## Eye and Skin Protection

### Eye Protection:

Eye protection should be used (and its use enforced) only where administrative and engineering controls are impractical to eliminate potential exposures above the applicable MPE for the laser. For Class 3b lasers, the use of protective eye protection should be administratively required and its use enforced when controls are inadequate to eliminate potential exposures in excess of the applicable MPE for the laser. In the case of Class 4 lasers, the use of protective eyewear shall be administratively required and its use enforced when controls are inadequate to eliminate potential exposures in excess of the applicable MPE for the laser.

The eyewear selected shall be adequate to withstand either direct or diffusely scattered laser radiation under the circumstances of worst case exposure, i.e., typically an exposure of 10 seconds. The selection of proper filter for intrabeam viewing depends on the power output of the laser and the MPE for the wavelength of the laser in question. The unit of interest is *optical density (OD)*, expressed mathematically:

$$OD_{\lambda} = \log_{10} \left( \frac{H_o}{MPE_{\lambda}} \right)$$

Where:	OD <sub>λ</sub>	=	optical density
	H <sub>o</sub>	=	anticipated worst case exposure (W/cm <sup>2</sup> for continuous wave lasers and J/cm <sup>2</sup> for pulsed sources)
	MPE <sub>λ</sub>	=	maximum permissible exposure at wavelength λ

All protective eyewear *shall* be properly labeled with the following information:

- Optical density of the lenses; and,
- Wavelength for which protection is afforded.

Protective eyewear shall be cleaned and inspected periodically. Eyewear that is defective shall be removed from service immediately. An inspection record should be kept for each set of eyewear. Maintenance of eyewear shall include:

- Periodic cleaning recommended by the manufacturer.
- Inspection of the lenses for defects and the frame for mechanical integrity; and,
- Inspection of the eyewear for light leaks and coating damage.

### Skin Protection:

Skin protection may be required for Class 3b and 4 lasers, particularly lasers operating in the region from 180 nm to 400 nm (the ultraviolet region), if the anticipated exposures are chronic, and the exposures are at levels at or near the applicable MPE limits for the skin.

As with eye exposure, skin exposure shall be controlled by first employing administrative and engineering controls. If administrative and engineering controls are impractical, personal protective equipment shall be employed:

- Gloves, especially those made with tightly woven fabrics, and opaque materials offer protection against hand exposure.
- Creams that block ultraviolet radiation (200 nm to 400 nm) may also be used for protection against chronic exposures.
- Laboratory coats to protect the arms.

### Medical Surveillance

Medical examinations are not required for Class 1, 2, 2a, or 3a lasers; however, examinations for Class 3b and 4 lasers shall be required. Except in the case of acute exposure, or a suspected exposure to laser radiation, preemployment (baseline) medical examinations are the only examinations required.

The purpose of the preemployment examination is to establish a baseline against which any damage caused by an acute or chronic exposures can be measured; and identify employees who might be at special risk from chronic exposure to laser radiation.

An ophthalmologist, or optometrist or an otherwise qualified physician shall perform examinations. The extent of the examination will depend on the category of personnel:

The LSO will determine the need for medical evaluation of “incidental personnel.” Incidental personnel include those persons whose work makes it possible, but not likely, to be exposed to laser radiation of sufficient energy to damage their eyes. Examples of incidental personnel include: custodial and maintenance workers, laboratory personnel not directly involved with lasers but share the common area, and other staff members who frequent laser areas. For these persons, the examination shall consist of a visual acuity test.

For “laser personnel,” i.e., Laser System Supervisors, Qualified Operators, and Restricted Operators who operate either Class 3b, or 4 lasers, the medical examination shall include the following:

- An ocular history.
- A visual acuity test.
- An Amsler Grid test.
- Color vision test.

If the responses to these tests are normal, no further tests are required. If there is an abnormal response to any one of the tests, further examination may be conducted by the physician or optometrist at his/her discretion.

## Signs and Labeling

Signs and warning labels’ dimensions, letter size, color and content shall be in accordance with American National Standards Specification for Accident Prevention Signs, ANSI Z535.

All signs and labels shall be conspicuously displayed in locations where both laser personnel and incidental personnel will see them.

In temporary laser controlled area a notice sign shall be posted outside the controlled area so as to warn persons entering the area. When a controlled area is created, the area outside is assumed to be a Class 1 area, while the area within is assumed to be either a Class 3b or 4 area.

The word “Radiation” on signs and labels may be replaced with the word “Light” for lasers operating in the visible spectrum, i.e., 400 nm to 700 nm. For lasers operating outside the visible spectrum, i.e., less than 400 nm and more than 700 nm the word “Invisible” shall be placed in front of the word “Radiation” or “Light.”

In addition to the precautionary instructions required, a precautionary action statement or statements may be added to the sign. Some examples of precautionary statements include:

- “Invisible Laser Radiation”
- “Knock Before Entering”
- “Do Not Enter When Light is On”
- “Restricted Area”

## References

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