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*Occupational Safety & Health ♦ Environmental Health ♦ Laboratory Safety ♦ Industrial
Hygiene ♦ Radiation Safety ♦ Hazardous Waste ♦ Pollution Prevention*

Laser Safety Manual

Administered by:

Environmental Health & Safety Office

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1. Glossary of Terms

Accessible Emission Limit (AEL): The maximum accessible emission level permitted within a particular laser hazard class.

Accessible Optical Radiation: Radiation to which the human eye or skin may be exposed for the condition (operation, maintenance, or service) specified.

Administrative Control: Methods of controlling employee exposures by job rotation, work assignments, or training in specific work practices designed to reduce the exposure.

ANSI: Acronym for *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 (LGAC's)*, fire and electrical hazards.

Attenuation: The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Aversion Response: Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. The aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 seconds or less.

Beam: A collection of light photons characterized by direction, diameter (or dimensions), and divergence (or convergence).

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

Diffuse Reflection: Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

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.

Enclosed Laser: A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removing of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place (an embedded laser is an example of one type of enclosed laser).

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: A device that produces an intense directional beam of light by stimulating electronic or molecular transitions to lower energy levels. Acronym for *Light Amplification by Stimulated Emission of Radiation*.

Laser Controlled Area: An area where the activities of those within are subject to control and supervision for the purpose of laser radiation hazard protection, e.g., the laboratory in which a laser is operated.

Laser Personnel: Persons who routinely work around hazardous laser beams. Such persons must be protected by engineering controls, administrative procedures, or both.

Laser Safety Committee: A group consisting of faculty, staff, or administrators that is responsible for overseeing conduct of the Laser Safety Program at Old Dominion University.

Laser Safety Officer: The individual who has the authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser System Supervisor: Generally, the Principal Investigator (PI) who oversees specific laser facilities, laser equipment, and protective equipment, and ensures that users of a specific laser system have received the appropriate training and approval to operate the laser system.

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 *maximum permissible exposure (MPE)*. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE. The NHZ may be a smaller area located within a laser controlled area, or it may consist of the entire laser controlled area. The NHZ should be clearly identifiable.

Nominal Ocular Hazard Distance (NOHD): The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure is not expected to exceed the applicable MPE.

Non-Beam Hazard: A class of hazards that result from factors other than direct human exposure to the laser beam.

Optical Density (OD): A measure of the amount of attenuation, either absorptive or reflective, provided by a medium.

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 Old Dominion University's *Laser Safety Manual*, *shall* means mandatory.

Should: In the context of Old Dominion University's *Laser Safety Manual*, *should* means advisory.

2. Introduction

Lasers are commonly employed in a wide variety of applications, including: non-destructive testing, communications, medical operations, research and development, etc. The purpose of a Laser Safety Program is to ensure appropriate control measures for lasers or laser systems are utilized, ensure personnel using lasers are properly trained, and to prevent accidents involving laser use. The vast majority of laser accidents fall into one or more of the following categories:¹

- 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.
- Improper restoration of equipment following service.

The *prevention* of laser accidents is the emphasis of Old Dominion University's Laser Safety Program. This manual outlines the policies and procedures for the conduct of the Laser Safety Program at Old Dominion University. The Laser Safety Program is based on the guidelines found in the American National Standard for Safe Use of Lasers, ANSI Z136.1, and applicable federal and state regulations. Special attention should be given to the use of the words *shall* and *should*. In accordance with ANSI Z136.1, *shall* is understood to mean mandatory and *should* is understood to mean advisory.

2.1. University Responsibilities

- 2.1.1. Old Dominion University's Administration is responsible for supporting the Laser Safety Program by providing adequate funding and management-level oversight.
- 2.1.2. Old Dominion University's Public Safety Office is responsible for providing the necessary notifications and responding to emergencies as necessary.
- 2.1.3. The Environmental Health & Safety Office is responsible for monitoring and enforcing the University's Laser Safety Program.

¹ Rockwell, Jr., R. James. Laser accidents: are they reported and what can be learned from them. Journal of Laser Applications 1989 1:4, 53-57.

3. Laser Safety Committee

The Laser Safety Committee is responsible for overseeing the conduct of the Laser Safety Program.

The Committee establishes and maintains policies and procedures for the control of laser hazards at Old Dominion University. Membership on the Committee is offered to employees of the University with expertise in laser use or in the assessment of laser hazards. Management representatives may also be included in membership.

Members of the Committee perform the following functions:

- Annual review of the conduct of the Laser Safety Program, 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 changes to the user's protocol.
- Recommend control measures to ensure the safe use of lasers.
- Consultation with laser users, as necessary.
- Review incidents involving the use of lasers, and recommend corrective actions to prevent reoccurrence of similar incidents.
- Provide administrative support to the Laser Safety Officer and the Laser Safety Program.
- Review applications for User status.

4. The Laser Safety Officer

The Laser Safety Officer (LSO) is granted, by virtue of his/her training and experience, the authority and responsibility for monitoring the use of lasers at Old Dominion University. The LSO is also responsible for the evaluation of laser hazards and, in concert with the Laser Safety Committee, establishment of appropriate control measures. Specific responsibilities of the LSO include:

- Develop and provide laser safety training, as necessary.
- Revise the Laser Safety Manual, as necessary.
- Maintain records of the Laser Safety Program, as required.
- Review and approve applications for User status.
- Investigate and document accidents and non-compliant conditions involving laser use.
- Ensure that corrective actions for unsafe or non-compliant conditions are performed in a timely and appropriate manner.
- In concert with the Laser System Supervisor, evaluate characteristics of a laser system to include:
 - Appropriate laser classification
 - Nominal hazard zones
 - Appropriate control measures
 - Required personal protective equipment, including laser eyewear
 - Required safety equipment, such as barriers and screens.
 - Appropriate signs and labels
- Periodically inspect laser work areas.
- Determine applicability of medical examinations for laser users, and recommend exams as necessary.
- Act as the contact point for regulatory agencies.

The LSO, with the approval of the Laser Safety Committee, reserves the right to terminate any activity involving the use of lasers if it is found to be detrimental to the health of University personnel, the property of Old Dominion University, or the health and/or property of an individual member of the public. Termination of laser activity will proceed as follows:

- The unsafe or non-compliant condition, once identified, is investigated and documented by the Laser Safety Officer. The Laser System Supervisor and Laser Safety Committee are provided with copies of this documentation.
- The Laser System Supervisor is provided the opportunity to respond, in a timely manner, to any findings to the Laser Safety Committee. Any response should include actions that will be taken to correct the unsafe or non-compliant condition.
- If corrective actions are deemed appropriate and satisfactory by the LSO and Laser

Safety Committee, no further action is required.

- If the Laser System Supervisor fails to respond to the LSO or Laser Safety Committee, or fails to take appropriate corrective actions, written warning that termination of laser activity will be considered shall be sent to the Laser System Supervisor and the appropriate department Chair. Copies shall be sent to all members of the Laser Safety Committee. The Laser System Supervisor must respond *within two business days* following receipt of the warning.
- Failure to correct unsafe or non-compliant conditions shall result in termination of all laser activities. Termination actions shall be reported to the Chair of the appropriate department.

5. Definitions of Laser Users

Users of lasers are classified according to their level of training, experience, and responsibility. There are three types of laser users: Laser System Supervisor, Qualified Operator, and Restricted Operator. User status is required prior to operating **Class 3B or Class 4 lasers**.

5.1. Laser System Supervisor/ Principal Investigator

Laser System Supervisor status is obtained by submitting form LSC-2, “*Application for Laser System Supervisor Status*” to the Laser Safety Officer (LSO). The LSO and Laser Safety Committee will review the application and request additional information if necessary. The LSO must approve the application before Laser System Supervisor status is granted.

In order to be approved as a Laser System Supervisor, the applicant must demonstrate, by combination of training and experience, sufficient knowledge of laser operation and safety requirements.

The Laser System Supervisor will be responsible for the following:

- Submitting the names and qualifications of potential operators to the LSO for approval prior to allowing individuals to operate the lasers.
- Ensuring that all operators of the laser have received adequate training for laser use, to include general laser safety training (provided by the Laser Safety Officer) and system specific training (provided by the Laser System Supervisor).
- Ensuring that adequate control measures are being properly implemented, including: entryway controls, beam enclosures, beam stops, window covering, etc.
- Ceasing the operation of the lasers if control measures are not being properly implemented.
- Notifying the LSO immediately following a laser accident or unusual occurrence involving the laser.
- Ensuring appropriate medical attention for a laser operator involved in a laser accident.
- Ensuring that form LSC-1, “*Application for the Operating of Lasers and Laser Systems*” is completed or amended prior to operating a new or modified laser.
- Developing standard operating procedures (SOPs) for laser alignment and/or maintenance. SOPs must be submitted to and approved by the Laser Safety Committee
- Not allowing any unauthorized individuals to operate a laser without direct supervision.
- Providing laser operators with appropriate personal protective equipment (e.g., appropriate eyewear).
- Identifying and mitigating ancillary hazards of laser operation.

- Ensuring areas where Class 3B and Class 4 lasers are operated are posted with appropriate signs and warning lights.
- Ensuring that grant proposal budgets include sufficient funding for compliance with this manual. Laser System Supervisors are responsible for purchasing required laser safety equipment

5.2. *Qualified Operators*

Qualified Operator status is achieved after successfully completed laser safety training (provided by the LSO) and passing a written examination with a score of 75% or better. 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 the applicant is deemed to have sufficient knowledge and experience to operate a laser independently.

A Qualified Operator will be responsible for the following:

- Maintaining familiarity with the applicable standard operating procedures (SOPs).
- Using appropriate engineering and administrative control measures while operating lasers.
- Wearing appropriate personal protective equipment.
- Notifying the Laser System Supervisor and LSO immediately following a laser accident or unusual occurrence involving the laser.
- Ceasing the operation of the laser immediately in the event of a safety malfunction of the laser system.
- Providing direct supervision over a Restricted Operator if directed to do so by the Laser System Supervisor.

5.3. *Restricted Operators*

A Restricted Operator is an individual that does not possess adequate training or experience to operator a laser independently. A Restricted Operator may operator a laser ONLY under the direct supervision of the Laser System Supervisor or a Qualified Operator. This user category is intended to allow new hires to start work involving lasers prior to attending laser safety training.

6. Application, Procedures, and General Criteria for Laser Use

Persons intending to operate a Class 3B or Class 4 laser must submit form LSC-1, “*Application for the Operation of Lasers and Laser Systems*”. The LSO and Laser Safety Committee will review the application and request additional information if necessary. The LSO must approve the application prior to operating the laser.

Applications for the use of a laser will be approved if the following requirements have been satisfied:

- The proposed facilities are adequate for the safe use of lasers.
- Engineering and administrative controls have been established to ensure the safety of the laser operators AND ancillary personnel.
- The appropriate personal protective equipment is available, if necessary.
- Effective standard operating procedures (SOPs) and emergency procedures have been established.
- Appropriate security measures for laser-controlled areas are in place.
- Non-beam and ancillary laser hazards have been identified and addressed.

The application for operation of lasers and laser systems do not require renewal. However, the application must be amended in the event the laser is relocated, or other significant changes to the set-up, operating procedures, control measures, or any other approved condition. The applicable Laser System Supervisor shall submit amendments in writing to the LSO.

7. Training Requirements

Training is **required** for any individual that operates a Class 3B or Class 4 laser at Old Dominion University. The level of training shall be commensurate with the potential hazard.

General laser safety training is provided by the LSO and includes completion of a written examination with a required score of 75% or better. System specific training is required for all Qualified Operators and is provided by the Laser System Supervisor. Previous training and experience may be accepted by the Laser Safety Committee, and should be listed on an individual's LSC-2 or LSC-3 application. Recommended training topics for Laser System Supervisors and Qualified Operators includes, but is not limited to, the following:

- The fundamentals of laser operation, including physical principles and basic laser construction.
- The known bioeffects of laser radiation, including optical and skin hazards.
- Properties 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 the Laser Safety Program, including administration and employee responsibilities.
- Medical surveillance recommendations.
- Emergency procedures.
- Laser terminology used in hazard analysis.
- The types of lasers including wavelengths, pulse shapes, operational modes and power/energy relationships.
- Definition of maximum permissible exposure (MPE).
- Calculations used in hazard analysis for laser safety.

8. Medical Surveillance

Any individual with an actual or suspected laser-induced eye injury should be evaluated by a medical professional as soon as possible after the exposure (usually within 48 hours). For laser-induced injury to the retina, medical evaluation shall be performed by an ophthalmologist. Potential skin injuries should be seen by a physician. Referral for medical examination shall be consistent with the symptoms and anticipated effects based on the associated laser system. Records of medical surveillance following a laser incident should be maintained by the Laser Safety Officer (LSO) for at least 30 years.

Any accident involving a laser shall be reported to the LSO. The LSO shall conduct an investigation, which will include interviews with all individuals involved, determination of causes and corrective actions, and documentation of findings.

9. Transfer and Disposal of Lasers

The Laser Safety Officer (LSO) maintains an inventory of Class 3B and Class 4 laser systems. This inventory is verified by the LSO annually. It is essential that the LSO is notified of receipt, transfer, and disposal of lasers.

Transfer or disposal of Class 3B and Class 4 lasers require certain precautionary measures and approval by the LSO. This ensures the safe and responsible disposition of lasers, and that the laser inventory is accurate.

The Laser System Supervisor, or responsible party, shall **contact** the **LSO** prior to the transfer or disposal of Class 3B and Class 4 laser equipment. The Laser System Supervisor is responsible for ensuring that precautions are taken to mitigate the risk of unauthorized removal or tampering of laser systems.

10. Laser Classification

The laser classification scheme outlined in this section is based on American National Standards Institute (ANSI), Z136.1-2014 “American National Standard for Safe Use of Lasers”. A laser system’s classification is generally designated by the manufacturer. For instances where a laser is not classified or is modified, a detailed hazard analysis shall be performed by the Laser System Supervisor or the Laser Safety Officer.

ANSI recognizes four broad classes of lasers, designated as Class 1, 2, 3, and 4. Each class has specific control measures that must be taken when the laser is operating. Laser classification is based on the beam’s ability to cause biological damage to the eyes or skin during use.

10.1. 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 the 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 higher powered laser that has been enclosed with a physical barrier to prevent direct viewing. If a Class 1 laser system incorporates a more dangerous class laser, the enclosed panel must be labeled with a warning to alert the user that hazardous exposure may occur if the panel is removed.

Class 1M lasers are considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope), and are exempt from any control measures other than to prevent potentially hazardous optically aided viewing.

10.2. Class 2 Lasers:

Class 2 lasers (“low-risk” or “low-power” lasers) are only hazardous if the viewer overcomes the 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 barcode scanner.

Class 2M lasers are potentially hazardous if viewed with collection optics (e.g., telescope).

10.3. Class 3 Lasers:

Class 3 lasers (“medium-risk” or “medium-power” lasers) are capable of causing injury to the eye faster than the natural aversion response. This class of lasers is not capable of causing serious skin injury or hazardous diffuse reflection hazards under normal conditions. There are two subclasses of Class 3 lasers: *Class 3R* and *Class 3B*.

Class 3R lasers are potentially hazardous only if the output is collected and focused into the eye, and the output is ≥ 5 times the output of the next lowest class. For example, with continuous wave lasers the output of a Class 3R 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 3R lasers but less than 500 mW. Class 3B lasers require control measures, training prior to operation, and engineering controls.

10.4. 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 and producing laser-generated air contaminants. All Class 4 lasers require control measures, training prior to operation, and engineering controls.

11. Control Measures

Engineering and administrative control measures are required to prevent exposure to laser radiation above the maximum permissible exposure limit. A laser controlled area shall be established for Class 3B and Class 4 laser system operations. The Laser System Supervisor is responsible for the evaluation and implementation of the control measures used in the laser controlled area. The Laser Safety Officer, with the support and guidance of the Laser Safety Committee, is responsible for monitoring and enforcing laser hazard control measures. Each user is responsible for employing those control measures approved by the Laser Safety Officer and Laser Safety Committee.

11.1. Area and Entryway Controls for Class 3B and Class 4 Lasers

- Lasers and laser systems shall be operated by authorized personnel only. Spectators *should* not be permitted access during operation of a Class 3B laser. Spectators *shall* not be permitted access during operation of a Class 4 laser.
- When possible, efforts should be made to fully or partially enclose the beam path with a protective housing. Protective housings shall include an interlock system to prevent access to laser radiation. If use of protective housing is not practicable protective laser barriers, such as curtains, should be used.
- Laser warning signs shall be posted conspicuously at all entrances to a laser controlled area.
- An audible or visible area warning device shall be installed at the entrance to a laser controlled area to alert individuals PRIOR to entering that the laser is operating.
- An audible or visible laser radiation emission warning shall be installed WITHIN the laser controlled area to ensure personnel inside of the area are aware that the laser is operating.
- The laser beam path shall be well-defined when operating. Any hazardous beams *should* be terminated in a beam stop of an appropriate material for Class 3B lasers. Any hazardous beams *shall* be terminated in a beam stop of an appropriate material for Class 4 lasers.
- Appropriate eye protection shall be supplied for personnel within a laser controlled area.
- Class 3B lasers *should* and Class 4 lasers *shall* be secured so that the exposed beam path is above or below eye level of an individual in a standing or seated position.
- All windows, doorways, and open portals should be covered or restricted.
- Class 3B lasers *should* and Class 4 lasers *shall* require storage or disabling (key-controlled access, lock-out/tag-out, etc.) when not in use to prevent unauthorized operation.
- Laser controlled areas shall allow for both rapid egress of laser personnel at all times, as well as admittance under emergency conditions.

- Ensure that only diffusely reflecting material is located in or near the beam path.

11.1.1. *Summary of Engineering Controls*

Engineering controls are the first measures to be employed to ensure laser radiation exposure does not exceed applicable MPEs. Engineering controls are preferred over administrative controls.

Engineering Control Measure	Classification						
	<i>1</i>	<i>1M</i>	<i>2</i>	<i>2M</i>	<i>3R</i>	<i>3B</i>	<i>4</i>
Protective Housing (hazard analysis required if housing is removed)	X	X	X	X	X	X	X
Interlocks on Housing	▼	▼	▼	▼	▼	X	X
Service Access Panel	▼	▼	▼	▼	▼	X	X
Key Control	-	-	-	-	-	●	●
Laser Radiation Emission Warning	-	-	-	-	-	●	X
Protective Barriers and Curtains	-	-	-	-	-	●	●
Entryway Controls	-	-	-	-	-	-	X
Viewing windows, display screens, and collecting optics are controlled by interlocks, filters, or attenuators.	X	X	X	X	X	X	X
Enclosed Beam Path	-	-	-	-	-	●	●
Emergency STOP Button	-	-	-	-	-	-	X

Legend: X Shall

● Should

- No requirement

▼ Shall if enclosed Class 3B or Class 4 laser

11.1.2. **Summary of Administrative Controls**

Administrative and procedural controls are instructions or work practices that mitigate the potential hazards associated with laser use. Administrative controls are required for the use of Class 3B and Class 4 lasers.

Administrative Control Measure	Classification						
	<i>1</i>	<i>1M</i>	<i>2</i>	<i>2M</i>	<i>3R</i>	<i>3B</i>	<i>4</i>
Standard Operating Procedures	-	-	-	-	-	●	X
Education and Training	-	●	●	●	●	X	X
Authorized Personnel	-	-	-	-	-	X	X
Laser Controlled Area	-	-	-	-	-	X	X
Personal Protective Equipment	-	-	-	-	-	●	X

Legend: X Shall
 ● Should
 - No requirement

11.2. **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:

11.2.1. **Compressed Gases**

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

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

11.2.2. **Exposure to Laser Generated Air Contaminants (LGACs)**

Adequate local exhaust ventilation shall be installed to control exposures when the potential for LGACs exists. Conditions for the design of a local exhaust system include:

- Exhaust ventilation shall ensure that all operators and ancillary personnel exposure to hazardous LGACs be maintained at or below the Permissible Exposure Limit (PEL) 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 American National Standards Institute (ANSI) specifications.
- Under no circumstances should there be recirculation of LGACs.

Respiratory protection may be provided to control exposures to LGACs or as an interim control measure until engineering and/or administrative controls are implemented.

Respiratory protection shall be utilized under the provisions of Old Dominion University's *Respiratory Protection Program*.

11.2.3. 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 the applicable provisions of Old Dominion University's *Chemical Hygiene Plan*:

- Safety Data Sheets (SDS) shall be provided to employees handling hazardous materials.
- Personal protective equipment (PPE), as described on the relevant SDS, shall be provided to each employee. The use of PPE, i.e., lab coats, gloves, and safety goggles, shall be mandatory when handling hazardous and potentially hazardous materials.

11.2.4. 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 Old Dominion University's *Chemical Hygiene Plan*:

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

11.2.5. Exposure to Excessive Noise

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

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

X-ray radiation may be generated by electronic components of the laser system. Laser systems with the potential to generate X-rays (e.g., high voltage vacuum tubes > 15 kV), or other ionizing radiation (e.g., pulsed laser beams with peak irradiance > 10^{18} W/cm²), shall be evaluated by the Environmental Health and Safety Office as necessary.

11.2.7. Non-Laser Radiation Hazards

In some cases, non-laser radiation resulting from laser use requires additional control measures. Radiation hazards associated with non-laser radiation are wavelength

dependent.

Collateral ultraviolet radiation emitted from laser discharge tubes and pump lamps shall be shielded so that personnel exposures are maintained within the applicable Threshold Limit Value (TLV) specified by the American Conference of Governmental Industrial Hygienists (ACGIH).

11.2.8. **Explosion Hazards**

Explosion hazards, such as high-pressure arc lamps, filament lamps, and capacitor banks, in laser equipment shall be enclosed in housing that is capable of withstanding an explosion. Target and optical elements that may shatter during laser operation shall be enclosed or protected to prevent injury to operators and spectators.

11.2.9. **Electrical Hazards**

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

- Metallic frames, enclosures, and other accessible parts of laser equipment shall be grounded by a continuous metallic connection with grounding conductor of the wiring system.
- Enclosures, barriers, and baffles of nonmetallic material shall comply with UL 746C: Polymeric Materials – Use in Electrical Equipment Evaluations.
- The implementation of lockout procedures during maintenance and servicing as specified in Old Dominion University’s *Lockout/ Tagout Program*.
- The use of written procedures and protocols for maintenance and service operations.
- Training for operators, maintenance, and service personnel, including current certification in cardiopulmonary resuscitation (CPR).
- The installation of interlock switches and/or “Emergency Power Off” switch to eliminate electrical hazards.
- 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.
- Additional controls as specified in OSHA regulations and the National Fire Protection Association (NFPA). These requirements include equipment connection to the electrical utilization system, electrical protection parameters, and specific safety training. OSHA requires additional control measures for those circuits operating at more than 50 volts (29CFR, Part 1910, Subpart S).

11.2.10. **Fire Hazards**

Class 4 lasers can generate beams powerful enough to burn the skin and/or ignite

flammable materials. Additionally, Class 4 lasers are a potential fire hazard if the material used to enclose an embedded laser is exposed to an irradiance level exceeding 10 W/cm², or beam power exceeding 0.5 W. Under some situations, fire hazards may exist from Class 3B lasers.

Other laser system components that are potential fire hazards include the electrical circuitry in the laser, certain laser gases, certain LGACs produced as the results of the beam's interaction with target material, and certain laser dyes and/or the solvents used to dissolve the dyes. The following precautions should be taken:

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

12. Signs and Labeling

Signs and warning label dimensions, letter size, font, layout, color, and content shall be in accordance with the American National Standards Specification for Accident Prevention Signs, ANSI Z535.2 “Environmental and Facility Safety Signs”.

All signs and labels shall be conspicuously displayed in locations where laser personnel and ancillary personnel will see them. Area warning signs are required for all Class 3B and Class 4 lasers. Signs and labels may be obtained from the Environmental Health and Safety Office.

Laser area Warning signs shall convey a rapid visual hazard-alerting message that includes a safety alert symbol (see Figure 1) and the laser radiation hazard safety symbol (see Figure 2).

For temporary laser controlled areas, the exterior boundary shall be posted with a Notice or Caution sign to warn persons entering the area and shall include the laser radiation hazard safety symbol (Figure 2).



Figure 1: Safety Alert Symbol
(ANSI Z535)



Figure 2: Laser Radiation
Hazard Safety Symbol
(ANSI Z535)

For laser area Caution signs, information should be included on the sign to include the laser class, type of laser, maximum output, optical density of eye protection required, and the name and contact information for the Laser System Supervisor. Additionally, precautionary statements may be added to the sign. Some examples include:

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

13. Eye and Skin Protection

13.1. Eye Protection

Eye protection against radiation *should* be worn during use of Class 3B lasers and *shall* be worn during use of Class 4 lasers within the Nominal Hazard Zone (NHZ) when administrative and engineering controls are impractical to eliminate potential exposures above the Maximum Permissible Exposure (MPE).

Laser eye protection shall be adequate to withstand either direct or diffuse scattered laser radiation under the circumstances of worst case exposure (typically, an exposure of 10 seconds). The selection of the proper filter for intrabeam viewing depends on the power input of the laser and the MPE for the wavelength of the laser in use.

Laser eyewear shall be designed to have an adequate Optical Density (OD) for a particular wavelength. OD can be expressed mathematically as:

$$OD_{\lambda} = \log_{10}(H_0/MPE_{\lambda})$$

Where: OD = Optical Density at wavelength λ
 H_0 = anticipated worst case exposure (W/cm^2 for continuous sources and J/cm^2 for pulsed sources)
 MPE_{λ} = maximum permissible exposure at wavelength λ

Laser eyewear shall be properly labeled with the OD of the lens and the specific wavelength it is intended to protect against.

For lasers with broad wavelength bands, eye protection may not be suitable. In this case, alternative protective measures may be appropriate, such as indirect viewing.

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

- Periodic cleaning in accordance with manufacturer recommendations.
- Inspection of the lenses for defects and the frame for mechanical integrity.
- Inspection of the eyewear for light leaks and coating damage.

13.2. Skin Protection

Skin protection may be required for Class 3B and Class 4 lasers if operating in the ultraviolet (UV) region (180 nm to 400 nm), if the anticipated exposure is chronic, and if exposure levels are at or near the applicable MPE for the skin.

Skin exposure shall be mitigated, if practicable, by employing administrative and/or engineering controls. If necessary, personal protective equipment (PPE) shall be worn, such as:

- 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.