

Central Michigan University
Office of Laboratory & Field Safety (OLFS)
Laser Safety Manual

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Executive Summary

All Central Michigan University (CMU) personnel who actively use Class 3B or Class 4 lasers must comply with the requirements contained in this manual.

For Class 3B and Class 4 open beam lasers, the following are minimum requirements:

- Laser registration
- Laser safety training
- Standard Operating Procedures (SOP's)
- Protective laser eyewear
- Laser signage on the door

For equipment with embedded Class 3B or Class 4 lasers with reasonable expectation of beam exposure due to maintenance or similar activities, the following are minimum requirements:

- Laser/equipment registration

I. Introduction

The purpose of this manual is to ensure the safe use of lasers in research and instructional laboratories at Central Michigan University. To achieve this goal, the University has adopted the American National Standard for Safe Use of Lasers, ANSI Z136.1-2014 and the American National Standard for Safe Use of Lasers in Research, Development, or Testing, ANSI Z136.8-2012.

Most lasers are capable of causing eye injury from the direct beam and specular reflections. Class 4 lasers are also capable of causing eye injury from diffuse reflections, burning exposed skin, igniting flammable materials and generating hazardous air contaminants. Equipment used to produce the lasing action and control and direct the laser beam introduce additional hazards associated with high voltage, high pressure, cryogenics, noise, radiation and toxic gases.

A. Scope

This program applies to all lasers used in research and instructional laboratories at Central Michigan University.

B. Responsibilities

1. **Principal Investigators (PI)** are responsible for:

- Supervising laser use in the laboratory.
- Implementing and enforcing the safety recommendations and requirements outlined in this manual.
- Developing standard operating procedures (SOPs) for the laboratory.
- Providing laser operators with training in operating, administrative and alignment procedures.
- Ensuring that all lasers in the laboratory are properly classified and labeled.
- Ensuring that the proper signs are posted at the entrance(s) to the laboratory.
- Registering all lasers with the Laser Safety Officer (LSO).
- Completing laser safety training.
- Notifying the LSO immediately in the event of an exposure to a Class 3B or Class 4 laser beam or reflection.

2. **Laser Operators (LO)** are responsible for:

- Following laboratory standard operating procedures (SOPs).
- Informing the Principal Investigator of any departure from the SOPs.
- Notifying the Principal Investigator in the event of an exposure incident.
- Completing laser safety training.

3. **Laser Safety Officer (LSO)** is responsible for:

- Conducting safety audits of all laser laboratories.
- Providing assistance in evaluating and controlling hazards.
- Updating the Laser Safety Manual.

- Maintaining records of all lasers and laser operators.
- Providing laser safety training for all personnel working with lasers.
- Participating in accident investigations involving lasers.

C. Elements of the Laser Safety Program

Laser Safety Committee - The safe use of lasers and laser systems requires coordinated management. The Laser Safety Committee will work to ensure that design, installation, service, maintenance, training and medical evaluations are implemented as needed. Individual committee members must have training appropriate to their role on the Laser Safety Committee (LSC).

Laser Hazard Identification - To adequately protect employees all beam and non- beam hazards associated with laser systems must be identified. This identification includes establishment of laser Nominal Hazard Zones (NHZ), laser Maximum Permissible Exposure (MPE), electrical hazards and potential contaminant generation.

Laser System Control Measures - Hazards associated with lasers must be controlled to minimize the risk to the worker. These controls include beam and beam path enclosures, system interlocks, warning labels, personal protective equipment, administrative controls, energy controls, appropriate lockout procedures and laser energy measurement systems.

New Laser Implementation Procedures - New laser systems must meet established design criteria when installed in a Central Michigan University lab or facility. These criteria are validated at the design and installation phases and must be completed prior to laser system commissioning. The laser system manufacturer or integrator must provide detailed information to the Laser Safety Committee including nominal hazard zone, system safety feature identification, and safe operating procedures.

Laser System Maintenance - The laser system manufacturer or integrator must identify all required maintenance and service tasks to be performed on a laser system and establish safe operating procedures for each task. Due to the specialized skills and potential hazards associated with maintenance and service activities, a determination must be made as to which tasks will be performed by campus personnel, laser supplier technicians or other approved third parties. For each task a list of hazards encountered doing the task and method/procedures to control the hazards will be identified.

Information and Training - Those workers designated as "Laser Personnel" and those designated as "Incidental Personnel" must be trained appropriately.

Laser Classification - Laser systems must be appropriately classified based on the hazard presented. Additionally, these systems must have the labels and hazard communication warnings appropriate for the systems.

Accidents and Near Miss Incidents- Known or suspected accidents or near miss incidents must be immediately reported to the LSO. The LSO will lead an investigation of the incident and initiate appropriate action.

II. Training and Qualifications

- A. Only qualified personnel are permitted to operate a laser. The Principal Investigator (PI) will identify qualified personnel based on departmental training, technical training and other appropriate learning experience.
- B. All staff and students operating Class 3B and Class 4 lasers are required to complete laser safety training prior to working with lasers.
- C. Before operating a Class 3B or 4 laser, staff and students shall:
 - 1. Review the Laser Safety Manual
 - 2. Receive training from the Principal Investigator or laboratory supervisor covering safe operation of the laser to be used, administrative procedures, alignment procedures and other applicable SOPs.
 - 3. Review the operating and safety instructions furnished by the manufacturer.
- D. Laser safety training for Class 3B and 4 lasers includes the following:
 - 1. Laser Operation
 - 2. Biological Effects of Lasers
 - 3. Non-Beam Hazards of Lasers
 - 4. Standard/Safe Operating Procedures
 - 5. Engineering and Administrative Controls
 - 6. Personal Protective Equipment
 - 7. Signs and Labels
 - 8. Reporting Incidents and Emergency Procedures

III. Laser Classification

The basis of the hazard classification scheme is the ability of the laser beam to cause biological damage to the eye or skin during use.

Laser classifications are contained in ANSI Z136.1-2014. OSHA references the ANSI Z136.1 standard. The Center for Devices and Radiological Health (CDRH), a part of the Food and Drug Administration (FDA) enforce 21 CFR 1040.10 and 1040.11. The FDA requires the manufacturer to classify and appropriately label lasers prior to sale. All lasers or laser systems owned or purchased by Central Michigan University (CMU) shall have these labels to ensure they are legally sold products in the United States. For custom-built lasers these labels are not required and the Laser Safety Officer (LSO) shall be made aware of such systems and verify the classification with the Principal Investigator (PI). The PI shall contact the LSO to determine and label the class of any modified laser or laser system. The LSO must verify the classification of manufactured or custom-built lasers and laser systems.

Class 1 laser systems are incapable of producing damaging radiation levels during normal operation and are exempt from any control measures. Class 1 laser systems may contain higher class lasers and may produce laser hazards if operated with interlocks defeated. The interlocked service panels or portions of the protective housing are only intended to be accessed or removed by authorized service personnel. The LSO shall be notified if repairs or adjustments are needed that require defeating the interlocks to ensure program requirements are met.

Class 1M laser systems are incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with optical instruments.

Class 2 laser systems emit visible light only at a power level equal to 1 milliwatt or less. The normal aversion response to bright light is adequate protection. Staring into the beam of a Class 2 laser is hazardous.

Class 2M laser systems emit visible light only. The normal aversion response to bright light is adequate protection for unaided viewing. However, viewing the beam with optical aids is potentially hazardous.

Class 3R laser systems have a power level greater than Class 1 or 2 but equal to or less than 5 milliwatts, are potentially hazardous under some viewing conditions, but the probability of an actual injury is small, and the control measures for safe use are straightforward. Most laser pointers fall in this class (Most lasers previously classified as class 3a fall in this category). For pulsed lasers outside of the retinal hazard region (i.e., < 400 nm or > 1400 nm), review the ANSI Z136.1 definition for Class 3R lasers.

Class 3B laser systems have a power level greater than Class 1 or Class 2 and equal to or less than 500 milliwatts, are eye hazards for intrabeam viewing and specular reflections, even for momentary exposures, but diffuse reflections are not usually hazardous. Class 3B laser systems shall be operated only in laser controlled areas by authorized operators. Operators of class 3B laser systems shall receive approved laser safety training. For pulsed lasers outside of the retinal

hazard region (i.e., < 400 nm or > 1400 nm), review the ANSI Z136.1 definition for Class 3B lasers.

Class 4 laser systems have a power level greater than 500 milliwatts, are eye hazards and skin hazards for intrabeam exposures, specular reflections, and diffuse reflections. They are also fire hazards and may produce laser generated air contaminants. Class 4 laser systems shall be operated only in laser controlled areas by authorized operators. Operators of Class 4 laser systems shall receive approved laser safety training. For pulsed lasers outside of the retinal hazard region (i.e., < 400 nm or > 1400 nm), review the ANSI Z136.1 definition for Class 4 lasers.

A written Standard Operating Procedure (SOP) is required for Class 3B and 4 laser operation. All requirements of the CMU Laser Safety Program apply to Class 3B and Class 4 lasers or laser systems, unless documented equivalent procedures and control measures have been approved by the LSO.

IV. Laser Hazards

Most lasers are capable of causing eye injury to anyone who looks directly into the beam or specular reflections for a sufficient duration. In addition, diffuse reflection of a high-power laser beam can produce permanent eye damage. Class 4 laser beams can burn exposed skin, ignite flammable materials and activate toxic chemicals that release hazardous fumes, gases, debris and radiation. The equipment and optical apparatus required to produce the lasing action and control and direct the laser beam also introduce potential hazards associated with high voltage, high pressure, cryogenics, noise, radiation and toxic gases.

All hazards associated with the laser system must be identified and controlled. The hazards associated with laser systems fall into the two broad categories of "Beam-Related Hazards" and "Non-Beam Related Hazards".

Although less frequent, the potential for injuries resulting from skin exposure to a laser beam should be treated just as strictly as the potential for eye injuries. In certain situations where eye protection is worn, skin exposure could represent the more significant hazard.

A. Beam-Related Hazards

Beam related hazards are those hazards that arise from exposure to direct or reflected laser beams. Assessment of the laser and/or laser system must be made to determine hazards associated with exposure to the laser beam and methods of hazard mitigation.

1. Eye and Skin Hazards

Hazardous effects can occur to various parts of the eye depending on the wavelength of the laser radiation. The injuries can vary due to the variance in how tissues absorb energy. The following are some examples of hazards that can affect the eye:

- a. Radiation at the visible and near-infrared wavelengths is absorbed and can have hazardous effects on the retina.
- b. Radiation at the near-ultraviolet and middle infrared wavelengths is absorbed and can injure the lens.
- c. Corneal absorption and associated effects can occur with far-infrared and middle ultraviolet wavelengths.
- d. Corneal lesions and retinal lesions can occur from the heat resulting from the energy absorption and from photochemical reactions.
- e. Some transitional wavelength zones can result in both corneal and retinal damages.

2. The assessment of the beam-related hazards must address the following elements:

- a. Potential exposure to laser radiation, either direct or reflected, to the eyes and skin.
- b. Potential fire hazards from direct or reflected laser radiation.

- c. Determination of the Maximum Permissible Exposure (MPE) for the laser based on wavelength and exposure duration. This must consider both eye and skin exposure and include diffuse viewing, intrabeam viewing, and lens-on-laser, situations as appropriate.
- d. Determination of the Nominal Hazard Zone (NHZ) for the laser based on the MPE. This must include eye and skin exposure and must take into account diffuse intrabeam viewing, and lens-on-laser situations as appropriate. The NHZ shall be identified for all operation, maintenance and service tasks.
- e. The use of optical viewing aids (e.g., cameras, telescopes, microscopes, etc.) to view laser beams may increase the eye hazard. All collecting optics must incorporate suitable means such as interlocks, filters, or attenuators to prevent eye exposures above the MPE.

B. Non-Beam Hazards

Although eye and skin exposure to laser radiation represent the primary hazard associated with laser use, ancillary hazards associated with the use of lasers can be significant. Electrical shock, fire, injuries from cryogenics and chemicals are all potential hazards associated with laser use.

1. **Electrical Hazards:** Next to skin and eye exposure, electrical shock represents the highest potential for injuries from laser use, especially with the newer, high-powered lasers. The potential for electrical hazards most commonly results from inappropriate electrical installation, grounding, or handling of the high voltage associated with many lasers. Any University department responsible for the operation of any laser shall ensure the necessary protective electrical circuit design. The laser resonator and electro-optical elements should also be designed so that no exposed metallic element is above ground potential. All electrical installations must comply with the National Electric Code (NEC).
2. **Fire and Explosion Hazards:** High-pressure arc lamps, filament lamps, and associated optics can shatter or explode during laser operation. These components must be enclosed in housings that can withstand the maximum explosive pressures. The proper installation of the electrical power supply discussed in the above section is also important to reduce the potential for electrical fire. Any enclosures, barriers or baffles must comply with "Polymeric Materials for Use in Electrical Equipment," Underwriters Laboratories Standard, UL 746C.
3. **Other Associated Hazards:** Consideration should be given to other hazards that may be associated with laser use, including the presence of compressed gases (excimer gas lasers require the installation of vented cabinets, with an alarm, to capture the release of poisonous gas), dyes, cryogenic liquids, toxic fumes and gases, ionizing radiation, and toxic materials. Consideration should also be given to the proper disposal of any hazardous materials in accordance with the appropriate CMU policies.

V. Control Measures for all Laser Classes

The purpose of control measures is to prevent exposure to laser radiation above the MPE. Use engineering controls whenever possible. When engineering controls are not able to reduce exposure below the MPE, administrative controls and personal protective equipment should be used.

A. General Safety Procedures

1. Do not work with or near a laser unless you have been authorized to do so.
2. Do not enter a room or area where a laser is being energized unless authorized to do so.
3. Before energizing a laser, verify that prescribed safety devices for the unit are being properly employed. These may include opaque shielding, non-reflecting and/or fire-resistant surfaces, goggles and/or face shields, door interlocks, and ventilation for toxic material.
4. Make sure that a pulsed laser unit cannot be energized inadvertently. Discharge capacitors and turn off power before leaving the laser unit unattended.
5. Don't stare directly into the laser beam. Use appropriate eyewear during beam alignment and laser operation. Beam alignment procedures should be performed at the lowest practical power levels.
6. Control the access to the laser facility. This can be done by clearly designating those who have access to the laser room. Implement access control by locking the door and installing warning lights and signs on the outside door.
7. Never leave the laser unattended when it is in operation.
8. Remove jewelry to avoid inadvertent reflections.

B. Protective Housing

1. Place lasers in protective housings whenever practical. When protective housings are not practical, the LSO shall perform a hazard analysis to ensure that control measures are implemented to ensure safe operation.
2. Protective housings or service panels enclosing embedded Class 3B and 4 lasers shall be interlocked or fastened closed requiring special tools for removal.
3. When it is necessary to remove protective housings or service panels, a temporary laser controlled area shall be established. A temporary laser controlled area will not have the built-in protective features that are part of a laser-controlled area, but shall provide all safety requirements to protect personnel within and outside the area. Requirements for the temporary laser controlled area include, but are not limited to:
 - a. Restricted access to the area.
 - b. Control of the beam to prevent the beam and reflections from extending beyond the area.
 - c. Removal of reflective materials in and near the beam path.
 - d. Appropriate laser eye protection if there is a possibility of exposure to laser radiation above the MPE.
 - e. A warning sign posted outside the area. (See Section XIX for the warning sign requirements.)

C. Collecting Optics

Collecting optics used to view the laser beam or its interaction with a material shall have permanently attached attenuators, filters or shutters to prevent hazardous levels of radiation from entering the eye.

D. Beam Control

1. Ensure the beam height is not at the normal eye position of a person in a standing or seated position.
2. Position the laser so that the beam is not directed toward doorways or aisles.
3. Securely mount the laser system to maintain the beam in a fixed position during operation and limit beam movements during adjustments.
4. Ensure beam path is well defined and controlled.
5. Terminate the beam at the end of its useful path.
6. Confine beams and reflections to the optical table. The addition of beam-stopping panels to the sides of the optical table is recommended.
7. If the beam path extends beyond the optical table, a physical barrier shall be used to prevent accidental exposure.
8. Have only diffusely reflecting materials in or near the beam path, where feasible.
9. Absorb unwanted reflections. Scatter is not permitted.

E. A Class 1 laser system is exempt from any control measures for laser radiation.

F. A Class 1M laser system is exempt from any control measures except for conditions of:

1. Optically-aided direct viewing of the beam is expected and/or
2. Unattended operation where the beam is directed into a location where it can be directly viewed by the general public and/or personnel that may be uninformed about the hazards

G. A Class 2 laser system is exempt from any control measures except for conditions of:

1. Intentional direct viewing of the beam

H. A Class 2M laser system is exempt from any control measures except for conditions of:

1. Intentional direct viewing of the beam and/or
2. Potentially hazardous optically aided viewing

I. A Class 3R laser system is exempt from any control measures or other forms of surveillance except for conditions of:

1. Direct viewing of the beam or its specular reflection
2. Unattended operation with the beam directed into a location where it can be directly viewed either by the general public or other personnel who may be uninformed about its hazards

J. A Class 3B laser system requires the approval of appropriate control measures by the LSO in order to reduce the risk of a hazardous exposure to the eye from a direct or specularly reflected beam. In some cases control measures may also be required to prevent access to hazards from a diffuse reflection or fire hazard.

K. A Class 4 laser system requires the approval of appropriate control measures by the LSO in order to reduce the risk of a hazardous exposure to the eye or skin from a direct, specularly reflected, or diffusely reflected beam. Control measures may also be required for potential fire hazards and other non-beam hazards.

VI. Control Measures for Class 3B and Class 4 Lasers and Laser Systems

All of the control measures outlined in Section V must be met. The following are additional requirements for Class 3B and Class 4 lasers and laser systems.

A. Nominal Hazard Zone (NHZ)

A NHZ shall be established for Class 3B and Class 4 laser applications which require an open beam. The NHZ is the area in which the level of direct, reflected or scattered laser radiation exceeds the MPE. The LSO can assist in defining the NHZ.

B. Laser-Controlled Area

A laser-controlled area shall be established for Class 3B and Class 4 lasers. The laser-controlled area will contain the NHZ, if needed. The walls, ceiling and floor of the room often define the laser-controlled area.

1. Class 3B Laser Controlled Area

- a. Only personnel trained in the operation of the laser and laser safety shall be permitted to operate the laser or laser system.
- b. An individual knowledgeable in laser safety shall directly supervise the laser-controlled area.
- c. The area shall be posted with the appropriate warning signs. (See Section XIV.)
- d. Restrict access to the laser controlled area.
- e. Control the beam to prevent any misdirected beams or reflections.
- f. Provide eye protection for all personnel working in the laser-controlled area. (See Section XIII.)
- g. Cover all windows and other openings to prevent laser radiation from extending beyond the laser-controlled area

2. Class 4 Laser-Controlled Area

All of the requirements for a Class 3B laser-controlled area must be met. In addition, one of the following entryway controls must be incorporated into a Class 4 laser controlled area.

- a. **Non-Defeatable Entryway Safety Controls:** Non-defeatable safety latches or interlocks that deactivate the laser or reduce the output to levels below the MPE in the event of unexpected entry are the preferred method of entryway control.
- b. **Defeatable Entryway Safety Controls:** If non-defeatable controls limit the intended use of the laser, defeatable entryway safety controls may be used. Defeatable entryway controls allow authorized personnel to override the controls. Defeatable entryway controls may be used only if there is no laser radiation hazard at the point of entry. Personnel must be properly trained and provided with adequate personal protective equipment.

- c. Procedural Entryway Controls: If safety latches or interlocks are not feasible, procedural entryway controls may be used. When procedural entryway controls are used, the following conditions must be met:
 - All authorized personnel shall be adequately trained.
 - Personal protective equipment shall be provided.
 - A door, barrier, screen or curtains shall be used to block or attenuate the laser radiation below the MPE at the entryway.
 - The entryway shall be equipped with a lighted laser warning sign that indicates the laser is operating

C. Permanently Attached Beam Stop or Attenuator

Some lasers or laser systems have long warm-up times, and it may not be practical to turn the power off to the laser when the laser is not in use. In these cases, Class 3B lasers should be equipped with a permanently attached beam stop or attenuator and Class 4 lasers shall be equipped with a permanently attached beam stop or attenuator. The beam stop or attenuator must limit accessible laser radiation to below the MPE and be employed when the laser is not in use. For lasers that do not require warm-up time, turn the power off to the laser when not in use.

D. Standard Operating Procedures

1. Written Standard Operating Procedures (SOPs) are required for operating, alignment, maintenance and service activities. The SOPs shall be written by the Principal Investigator and available to the LSO for review. SOPs shall be reviewed with all laser personnel and be posted in the area of the laser or laser system.
2. The manufacturer's operating manual is not a substitute for an SOP.
3. SOPs must include (See Appendix B for a SOP form):
 - a. Laser data
 - b. Contact information
 - c. Laser application
 - d. Control measures
 - e. Personal protective equipment
 - f. Start up and shut down procedures
 - g. Experimental procedures
 - h. Emergency procedures
 - i. Storage
 - j. Non-beam hazards

E. Output Emission Limitations

Operate the laser or laser system at the lowest level of power or radiant energy required for the application.

F. Key Control

Class 3B or Class 4 lasers or laser systems should be provided with a master switch. This master switch shall effect beam termination and/or system shutoff and shall be operated by a key or by a coded access (such as a computer code). As an alternative, the master switch can be designed to allow system activation using a momentary switch action (or alternative) that initiates system operation with the option that the key (or alternative) can be removed after operation commences. In this mode, if the system ceases to operate, the key switch (or alternative) must again be used to restart the laser or laser system.

A single master switch on a main control unit shall be acceptable for multiple laser installations where the operational controls have been integrated.

VII. Laser Hazard Evaluation / Standard Operating Procedures

- A. A laser hazard evaluation shall be performed to identify all hazards associated with a laser or laser system and to determine the necessary control measures. The LSO can provide assistance in performing the hazard evaluation/standard operating procedures (SOPs). A form for developing SOPs is available in Appendix B.

- B. The hazard evaluation will take into account the following aspects:
 - 1. The laser or laser system's capability of injuring personnel or interfering with task performance.
 - 2. The environment in which the laser is used, including access to the beam path (considering enclosures, baffle, beam, etc.).
 - 3. The personnel who may use or be exposed to laser radiation.

VIII. Exposure Incidents

In the event that a worker suspects they have been exposed to excessive levels of laser radiation, the following steps should be taken:

For paid workers:

1. Notify Principle Investigator and/or Laser Safety Officer
2. Report the incident to Workers' Compensation and request an eye exam

For unpaid workers:

1. Notify Principle Investigator and/or Laser Safety Officer
2. Complete the Accidental Personal Injury Report (APIR) form and submit to Risk Management
3. Seek medical treatment

Following an exposure or suspected exposure, the Standard Operating Procedures for the laser involved in the incident should be reviewed. The Laser Safety Officer must be contacted and a thorough review of the incident performed.

IX. Operation, Maintenance and Service

It is important to distinguish between operation, maintenance and service when considering control measures. Lasers and laser systems are classified based on the level of accessible laser radiation during normal operation. Maintenance tasks are performed to support routine performance of the laser or laser system, such as cleaning and replenishing expendables. Maintenance tasks may or may not involve access to the beam. Service occurs less frequently than maintenance and often requires access to the beam. Service tasks include replacing laser resonator mirrors and replacing or repairing faulty components.

Extensive training and thorough familiarity with lasers and laser systems is required to safely perform maintenance activities where exposure to laser radiation is possible. For this reason maintenance activities associated with lasers and laser systems is divided into the groups of equipment service and laser service.

A. Equipment Maintenance

Equipment service encompasses all activities associated with servicing the laser or laser system in which only the ancillary components of the laser system are disturbed. These ancillary components may be equipment such as local exhaust ventilation and other equipment exterior to the laser.

B. Laser Service

Laser service encompasses all activities associated with servicing the laser itself. These activities include items such as:

1. Any activity associated with a Class 3B or Class 4 laser.
2. Any activity that requires opening the housing and accessing internal components of all Classes of lasers
3. Mechanical or electrical maintenance of the laser or any of its associated control components.
4. Beam aiming or alignment

C. Training of Maintenance Employees

Personnel performing maintenance on lasers or laser systems may only work at their level of competence as specified in the following section.

1. Equipment Maintenance Training

Maintenance activities conducted on laser systems may only be performed by competent personnel. Competence is verified for personnel with appropriate documented training for the task that they are assigned to perform. This may include training in the following topics:

- a. Lockout and hazardous energy control

- b. Electrical safety
- c. Hazard Communication
- d. Equipment specific safety training including Safe Operating Procedures for the equipment.
- e. Equipment specific maintenance training

2. Laser Service Training

Maintenance activities conducted on the laser itself may only be performed by personnel trained by the laser manufacturer. If training from the manufacturer is not feasible (e.g., because the system is no longer supported or the manufacturer is out of business) then training must be conducted by expert personnel or another source. The training must be specific in nature as to the laser installed and must be equivalent to that given to the manufacturer's field service personnel. Individuals trained by the manufacturer must maintain current knowledge of all technical updates for the specific laser system and be as proficient on the specific laser system as the manufacturer's field service representative.

X. Registration of Lasers

All Class 3B and Class 4 lasers must be registered with the Office of Laboratory and Field Safety (OLFS). Equipment with embedded Class 3B or Class 4 lasers with reasonable expectation of beam exposure due to maintenance or similar activities shall be registered with OLFS. The registry shall be updated when lasers are taken out of service or new lasers are purchased. The Laser Registration Form is available in Appendix C. This form must be sent to the LSO and a copy retained with the laser.

Registrants must be faculty or staff of CMU. Lasers may not be used until Standard Operating Procedures (SOPs) are in place and the registration process is completed.

XI. Medical Examinations

Medical examinations shall be performed as soon as possible (usually within 48 hours) when a suspected injury or adverse effect from a laser exposure occurs. In addition to the acute symptoms, consideration shall be given to the exposure wavelength, emission characteristics and exposure situation to ensure appropriate medical referral. Appendix F in ANSI Z136.1-2014 contains recommended examination protocol commensurate with the observed symptoms and laser system. For injury to the eye from lasers operating in the retinal hazard region, examinations shall be performed by an ophthalmologist.

XII. Non-Beam Hazards and Controls

Non-beam hazards (NBH) are all hazards arising from the presence of a laser system, excluding direct exposure of the eyes or skin to a laser beam. NBH include physical, chemical, and biological agents. NBH may occur when a material is exposed to a laser beam (e.g., fire or airborne contaminants), when materials used to generate the beam (e.g., flow-through gases, dyes and solvents) are released into the atmosphere, or when individuals contact system components (e.g., electrocution). Some NBH can be life threatening (e.g., electrocution, fire), and may require use of more stringent control measures.

All written SOPs shall address NBH as well as beam hazards.

XIII. Personal Protective Equipment

The use of engineering and administrative controls are the preferred methods of protecting employees and students from lasers. This may be impractical in a university setting, therefore personal protective equipment shall be worn in the NHZ for all Class 3B and 4 lasers.

A. Eye Protection

1. Conditions of Use

All Class 3B and 4 lasers require eye protection.

A maximum permissible exposure limit (MPE) is the limit set to prevent injury from a laser beam based on beam power, wavelength, and time of exposure. Laser protective eyewear shall be worn whenever MPE levels may be exceeded. See Laser Safety Officer if you have questions. Eyewear provides protection over a narrow range of the laser spectrum and must be selected for specific laser use. Laser protective eyewear must be approved by the American National Standards Institute (ANSI) and clearly labeled with optical densities and wavelengths for which protection is afforded.

The energy emitted from lasers is highly concentrated and can cause permanent eye injury. The eyewear should be matched to the wavelength emitted and for the laser intensity. Laser safety eyewear must be clearly marked with the optical density of the lens and for which protection is provided. The following factors should be considered when purchasing laser protective eyewear (Note: These websites can help with the calculation to select eyewear – <http://rli.com/Products/eyewear/eyewear.aspx> and <https://www.lia.org/evaluator/od.php/>).

- **Wavelength:** The wavelength of the laser output must be known. If the laser emits more than one wavelength, each wavelength must be considered.
- **Optical Density:** The attenuation of laser light by protective goggles is given by its optical density (OD). The OD must be sufficient to reduce the laser light to safe levels while transmitting sufficient ambient light for safe visibility. The required OD is determined from the maximum intensity to which an individual could be exposed.
- **Laser Beam Intensity:** The maximum irradiance in watts/cm² for CW lasers and the maximum radiant exposure in joules/cm² for pulsed lasers must be known.
- **Luminous Transmittance:** When considering laser safety goggles the visible or luminous transmission must be considered along with the optical density. Luminous transmission is given in percent transmission of visible light. Laser goggles with a lower luminous transmittance than required may result in eye fatigue and accidents. However, proper optical density should not be sacrificed for increased luminous transmission.
- **Damage Threshold:** The resistance of the lenses to damage from the laser beam must be considered. The damage can take the form of bubbling,

melting, or shattering. The lens must be capable of absorbing the amount of energy under the most severe operating conditions without suffering changes in the light transmission characteristics. Laser goggles should be inspected periodically for pitting, cracking, discoloration and deterioration in the mountings.

- **Comfort:** Laser safety eyewear should be comfortable and provide a good fit. Spectacle type frames generally are more comfortable than goggles but do not fit as tightly and may allow unattenuated laser radiation to reach the eyes. However, the increased comfort of spectacle type frames may increase user acceptance.
- **Lenses:** Lenses in laser safety eyewear can be made of reflective glass or plastic, absorptive glass filters, or absorptive polymeric filters. No lens material is useful for all wavelengths and for all radiant exposures.

2. Eyewear Maintenance and Inspection

Eyewear must be inspected periodically by the user for pitting and cracking of the attenuating material, for mechanical integrity of the eye protection, and for light leaks in the frame.

B. Skin Protection

Skin protection can best be achieved through engineering controls. If potential skin damaging exposures exist, skin covers and or “sun screen” creams are required. Minimize exposure to UV radiation by using beam shields and clothing (opaque gloves, tightly woven fabrics, lab coat) which attenuate the radiation to levels below the MPE for specific UV wavelengths. Consider flame-retardant materials for Class 4 lasers. Special attention must be given to the possibility of producing undesirable reactions in the presence of UV radiation (formation of skin sensitizing agents, ozone, etc.).

XIV. Warning Signs and Labels

Warning signs and labels shall be in accordance with ANSI Standards. Signs and labels shall be conspicuously displayed on equipment and on access doors where applicable.

A. Signs

Laser controlled areas must be posted with the appropriate warning signs at the entryway(s) and within the laser controlled area.

NOTICE – The signal word “Notice” must be used on signs posted outside a temporary laser controlled area.

CAUTION – The signal word “Caution” shall be used with all signs and labels associated with Class 2 and Class 2M lasers and laser systems that do not exceed the applicable MPE for irradiance.

WARNING – The signal word “Warning” shall be used on laser area warning signs associated with lasers and laser systems whose output exceeds the applicable MPE for irradiance, including all Class 3B and most Class 4 lasers and laser systems.

DANGER – The signal word “Danger” indicates that death or serious injury will occur if necessary control measures are not implemented to mitigate the hazards within the laser controlled area. This signal word shall be restricted to those Class 4 lasers with high (e.g., multi-kilowatt) output power or pulse energies with exposed beams.

For CAUTION, WARNING, and DANGER signs, adequate space shall be available within the message panel to allow for the inclusion of pertinent information. Such information may be included during the printing of the sign or may be handwritten in a legible manner, and shall include the following:

1. The hazard class of the laser controlled area.
2. Special precautionary instructions or protective action that may be applicable. For example:
 - a. Laser Eye Protection Required
 - b. Invisible Laser Radiation
 - c. Knock Before Entering
 - d. Do Not Enter When Light is Illuminated
 - e. Restricted Area, Authorized Personnel Only
3. The highest hazard class of the laser or lasers within the laser controlled area. Additional information such as type of laser, pulse duration (as appropriate), and maximum output may be included.
4. The optical density of laser eye protection to be worn within the area.
5. The name and contact information for the LSO.

B. Labels

All equipment warning labels shall be conspicuously displayed in locations on the equipment where they best will serve to warn onlookers. Lasers and laser systems shall have an equipment label that includes the following information:

1. The class of the laser or laser system.
2. The emitted wavelength, pulse duration (if appropriate), and maximum output power.
3. A precautionary statement for users such as:
 - a. For Class 2 lasers and laser systems, “Laser Radiation – Do Not Stare into Beam”
 - b. For Class 2M lasers and laser systems, “Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments”
 - c. For Class 3R lasers and laser systems, “Laser Radiation – Avoid Direct Eye Exposure to Beam”
 - d. For Class 3B and Class 4 lasers and laser systems, “Laser Radiation – Avoid Eye Exposure to Direct or Scattered Radiation; Avoid Skin Exposure to Direct Radiation”

APPENDIX A: Definitions

ABSORB - To transform radiant energy into a different form, with a resultant rise in temperature.

ABSORPTION - Transformation of radiant energy to a different form of energy by the interaction of matter, depending on temperature and wavelength.

ABSORPTION COEFFICIENT - Factor describing light's ability to be absorbed per unit of path length.

ACCESSIBLE EMISSION LIMIT (AEL)- The maximum accessible emission level permitted within a particular laser hazard class.

ACTIVE MEDIUM - Collection of atoms or molecules capable of undergoing stimulated emission at a given wavelength.

AIMING BEAM - A laser (or other light source) used as a guide light. Used coaxially with infrared or other invisible light may also be a reduced level of the actual laser used for surgery or for other applications.

AMPLIFICATION - The growth of the radiation field in the laser resonator cavity. As the light wave bounces back and forth between the cavity mirrors, it is amplified by stimulated emission on each pass through the active medium.

AMPLITUDE - The maximum value of the electro-magnetic wave, measured from the mean to the extreme; simply stated: the height of the wave.

ANGLE OF INCIDENCE - See Incident Ray

ANGSTROM UNIT - A unit of measure of wavelength dual to 10^{-10} meter, 0.1 nanometer, or 10^{-4} micrometer, no longer widely used nor recognized in the SI system of units.

ANODE - An electrical element in laser excitation which attracts electrons from a cathode.

APERTURE - An opening through which radiation can pass.

APPARENT VISUAL ANGLE - The angular subtense of the source as calculated from the source size and distance from the eye. It is not the beam divergence of the source.

AR COATINGS - Antireflection coatings used on optical components to suppress unwanted reflections.

ARGON - A gas used as a laser medium. It emits blue/green light primarily at 448 and 515 nm.

ARTICULATED ARM CO₂ - laser beam delivery device consisting of a series of hollow tubes and mirrors interconnected in such a manner as to maintain alignment of the laser beam along the path of the arm.

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

AUTOCOLLIMATOR - A single instrument combining the functions of a telescope and a collimator to detect small angular displacements of a mirror by means of its own collimated light.

AVERAGE POWER - The total energy imparted during exposure divided by the exposure duration.

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. In this standard, 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 s or less.

AXIAL-FLOW LASER - A laser in which an axial flow of gas is maintained through the tube to replace those gas molecules depleted by the electrical discharge used to excite the gas molecules to the lasing. See gas discharge laser.

AXICON LENS - A conical lens which, when followed by a conventional lens, can focus laser light to a ring shape.

AXIS, OPTICAL AXIS - The optical centerline for a lens system; the line passing through the centers of curvature of the optical surfaces of a lens.

BEAM - A collection of light/photonic rays, characterized by direction, diameter (or dimensions), and divergence (or convergence).

BEAM BENDER - A hardware assembly containing an optical device, such as a mirror, capable of changing the direction of a laser beam; used to repoint the beam, and in "folded," compact laser systems.

BEAM DIAMETER - The distance between diametrically opposed points in the cross section of a circular beam where the intensity is $1/e$ (0.368) times that of the peak power or energy.

BEAM DIVERGENCE - The increase in the diameter of the laser beam with distance from the beam waist, based on the full angle at the point where the irradiance (or radiant exposure for pulsed laser) is $1/e$ times the maximum value.

BEAM EXPANDER - An optical device that increases beam diameter while decreasing beam divergence (spread). In its simplest form consists of two lenses, the first to diverge the beam and the second to re-collimate it. Also called an upcollimator.

BEAM SPLITTER - An optical device using controlled reflection to produce two beams from a single incident beam.

BEAM WAIST - The minimum diameter, in centimeters, of a focused, axis-symmetric beam. For non-symmetric beams, there may be a beam waist along each major axis, each located at a different distance from the source.

BLINK REFLEX - See aversion response.

BREWSTER WINDOWS - The transmissive end (or both ends) of the laser tube, made of transparent optical material and set at Brewster's angle in gas lasers to achieve zero reflective loss for one axis of plane-polarized light. They are non-standard on industrial lasers, but a must if polarization is desired.

BRIGHTNESS - The visual sensation of the luminous intensity of a light source. The brightness of a laser beam is most closely associated with the radio-metric concept of radiance.

CALORIMETER - An instrument that measures the energy, usually as heat generated by absorption of the laser beam.

CARBON DIOXIDE - Molecule used as a laser medium. Emits far energy at 10,600 nm (10.6 μm).

CATHODE - A negatively charged electrical element providing electrons for an electrical discharge.

CLOSED INSTALLATION - Any location where lasers are used which will be closed to unprotected personnel during laser operation.

CO₂ LASER - A widely used laser in which the primary lasing medium is carbon dioxide gas. The output wavelength is 10.6 μm (10600 nm) in the far infrared spectrum. It can be operated in either CW or pulsed.

COAXIAL GAS - A shield of inert gas flowing over the target material to prevent plasma oxidation and absorption, blow away debris, and control heat reaction. The gas jet has the same axis as the beam, so the two can be aimed together.

COHERENCE - A term describing light as waves which are in phase in both time and space. Monochromaticity and low divergence are two properties of coherent light.

COLLIMATED LIGHT - Light rays that are parallel. Collimated light is emitted by many lasers. Diverging light may be collimated by a lens or other device.

COLLIMATION - Ability of the laser beam to not spread significantly (low divergence) with distance.

COMBINER MIRROR - The mirror in a laser which combines two or more wavelengths into a coaxial beam.

CONTINUOUS MODE - The duration of laser exposure is controlled by the user (by foot or hand switch).

CONTINUOUS WAVE (CW) - Constant, steady-state delivery of laser power.

CONTROLLED AREA - A locale where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

CONVERGENCE - The bending of light rays toward each other, as by a positive (convex) lens.

CORRECTED LENS - A compound lens that is made measurably free of aberrations through the careful selection of its dimensions and materials.

CRYSTAL - A solid with a regular array of atoms. Sapphire (Ruby Laser) and YAG (Nd:YAG laser) are two crystalline materials used as laser sources.

CURRENT REGULATION - Laser system regulation in which discharge current is kept constant.

CURRENT SATURATION - The maximum flow of electric current in a conductor; in a laser, the point at which further electrical input will not increase laser output.

CW - Abbreviation for continuous wave; the continuous-emission mode of a laser as opposed to pulsed operation.

DAMAGE THRESHOLD – The ability limit of material to withstand intense laser irradiation without observable changes in its optical properties.

DEPTH OF FIELD - The working range of the beam in or near the focal plane of a lens; a function of wavelength, diameter of the unfocused beam, and focal length of the lens.

DEPTH OF FOCUS - The distance over which the focused laser spot has a constant diameter and thus constant irradiance.

DICHROIC FILTER - Filter that allows selective transmission of colors desired wavelengths.

DIFFRACTION - Deviation of part of a beam, determined by the wave nature of radiation and occurring when the radiation passes the edge of an opaque obstacle.

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.

DIFFUSER - An optical device or material that homogenizes the output of light causing a very smooth, scattered, even distribution over the area affected. The intensity will obey Lambert's law (see Diffuse Reflection).

DIVERGENCE - The increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser radiant exposure or irradiance is e^{-1} or e^{-2} of the maximum value, depending upon which criteria is used.

DOSIMETRY - Measurement of the power, energy, irradiance or radiant exposure of light delivered are two crystalline materials used as laser to tissue.

DRIFT - All undesirable variations in output either amplitude or frequency).

ANGULAR DRIFT - Any unintended change in direction of the beam before, during, and after warmup; measured in mrad.

DUTY CYCLE - Ratio of total "on" duration to total exposure duration for a repetitively pulsed laser.

ELECTRIC VECTOR - The electric field associated with a light wave which has both direction and amplitude.

ELECTROMAGNETIC RADIATION - The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. Gamma rays, X-rays, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, and photon energy.

ELECTROMAGNETIC SPECTRUM - The range of frequencies and wavelengths emitted by atomic systems. The total spectrum includes radio waves as well as short cosmic rays. Wavelengths cover a range from 1 hz to perhaps as high as 1020 hz.

ELECTROMAGNETIC WAVE - A disturbance which propagates outward from an electric charge that oscillates or is accelerated. Includes radio waves; X-rays; gamma rays; and infrared, ultraviolet, and visible light.

ELECTRON - Negatively charged particle of an atom.

EMBEDDED LASER - A laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the systems lower classification is appropriate to the engineering features limiting accessible emission.

EMERGENT BEAM DIAMETER - Diameter of the laser beam at the exit aperture of the system in centimeters (cm) defined at e^{-1} or e^{-2} irradiance points.

EMISSION - Act of giving off radiant energy by an atom or molecule.

EMISSIVITY - The ratio of the radiant energy emitted by any source to that emitted by a blackbody at the same temperature.

EMITTANCE - The rate at which emission occurs.

ENCLOSED LASER DEVICE - Any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure. The laser inside is termed an "embedded laser."

ENERGY (Q) - The capacity for doing work. Energy is commonly used to express the output from pulsed lasers and it is generally measured in Joules (J). The product of power (watts) and duration (seconds). One watt second = one Joule.

ENERGY SOURCE - High voltage electricity, radio waves, flashes of light, or another laser used to excite the laser medium.

ENHANCED PULSING - Electronic modulation of a laser beam to produce high peak power at the initial stage of the pulse. This allows rapid vaporization of the material without heating the surrounding area. Such pulses are many times the peak power of the CW mode (also called "Superpulse").

ETALON - A Fabry-Perot interferometer with a fixed air gap separation. Such a device also serves as a basic laser resonant cavity.

EXCIMER "EXCITED DIMER" - A gas mixture used as the active medium in a family of lasers emitting ultraviolet light.

EXCITATION - Energizing a material into a state of population inversion.

EXCITED STATE - Atom with an electron in a higher energy level than it normally occupies.

EXEMPTED LASER PRODUCT - In the U.S., a laser device exempted by the U.S. Food and Drug Administration from all or some of the requirements of 21 CFR 1040.

EXTENDED SOURCE - An extended source of radiation can be resolved into a geometrical image in contrast with a point source of radiation, which cannot be resolved into a geometrical image. A light source whose diameter subtends a relatively large angle from an observer.

F-NUMBER - The focal length of lens divided by its usable diameter. In the case of a laser the usable diameter is the diameter of the laser beam or a smaller aperture which restricts a laser beam.

FABRY-PEROT INTERFEROMETER - Two plane, parallel partially reflective optically flat mirrors placed with a small air gap separation (1-20 mm) so as to produce interference between the light waves (interference fringes) transmitted with multiple reflections through the plate.

FAIL-SAFE INTERLOCK - An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

FEMTOSECONDS - 10^{-15} seconds.

FIBEROPTICS - A system of flexible quartz or glass fibers with internal reflective surfaces that pass light through thousands of glancing (total internal) reflections.

FLASHLAMP - A tube typically filled with Krypton or Xenon. Produces a high intensity white light in short duration pulses.

FLUORESCENCE - The emission of light of a particular wavelength resulting from absorption of energy typically from light of shorter wavelengths.

FLUX - The radiant, or luminous, power of a light beam; the time rate of the flow of radiant energy across a given surface.

FOCAL LENGTH - Distance between the center of a lens and the point on the optical axis to which parallel rays of light are converged by the lens.

FOCAL POINT - The point toward which radiation converges or from which radiation diverges or appears to diverge.

FOCUS - As a noun, the point where rays of light meet which have been reflected by a mirror or refracted by a lens, giving rise to an image of the source. As a verb, to adjust focal length for the clearest image and smallest spot size.

FOLDED RESONATOR - Construction in which the interior optical path is bent by mirrors; permit compact packaging of a long laser cavity.

FREQUENCY - The number of light waves passing a fixed point in a given unit of time, or the number of complete vibrations in that period.

GAIN - Another term for amplification.

GAS DISCHARGE LASER - A laser containing a gaseous lasing medium in a glass tube in which a constant flow of gas replenishes the molecules depleted by the electricity or chemicals used for excitation.

GAS LASER - A type of laser in which the laser action takes place in a gas medium.

GATED PULSE - A discontinuous burst of laser light, made by timing (gating) a continuous wave output - usually in fractions of a second.

GAUSSIAN CURVE NORMAL - Statistical curve showing a peak with even distribution on either side. May either be a sharp peak with steep sides, or a blunt peak with shallower sides. Used to show power distribution in a beam. The concept is important in controlling the geometry of the laser impact.

GROUND STATE - Lowest energy level of an atom.

HALF-POWER POINT - The value on either the leading or trailing edge of a laser pulse at which the power is one-half of its maximum value.

HEAT SINK - A substance or device used to dissipate or absorb unwanted heat energy.

HELIUM-NEON (HeNe) LASER - A laser in which the active medium is a mixture of helium and neon. Its wavelength is usually in the visible range. Used widely for alignment, recording, printing, and measuring.

HERTZ (Hz) - Unit of frequency in the International System of Units (SI), abbreviated Hz; replaces cps for cycles per second. The term also describes the number of repetitive pulses occurring per second.

HOLOGRAM - A photographic film or plate containing interference patterns created by the coherence of laser light. A three dimensional image may be reconstructed from a hologram. There are transmission, reflection or integral holograms.

IMAGE - The optical reproduction of an object, produced by a lens or mirror. A typical positive lens converges rays to form a "real" image which can be photographed. A negative lens spreads rays to form a "virtual" image which can't be projected.

INCIDENT LIGHT - A ray of light that falls on the surface of a lens or any other object. The "angle of incidence" is the angle made by the ray with a perpendicular to the surface.

INFRARED RADIATION (IR) - Invisible electromagnetic radiation with wavelengths that lie within the range of 0.70 to 1000 μm . These wavelengths are often broken up into regions: IR-A (0.7-1.4 μm), IR-B (1.4-3.0 μm) and IR-C (3.0-1000 μm).

INTEGRATED RADIANCE - Product of the exposure duration times the radiance. Also known as pulsed radiance.

INTENSITY - The magnitude of radiant energy.

INTRABEAM VIEWING - The viewing condition whereby the eye is exposed to all or part of a direct laser beam or a specular reflection.

ION LASER - A type of laser employing a very high discharge current, passing down a small bore to ionize a noble gas such as argon or krypton.

IONIZING RADIATION - Radiation commonly associated with X-Ray or other high energy electro-magnetic radiation which will cause DNA damage with no direct, immediate thermal effect. Contrasts with non-ionizing radiation of lasers.

IRRADIANCE (E) - Radiant flux (radiant power) per unit area incident upon a given surface. Units: Watts per square centimeter.

IRRADIATION - Exposure to radiant energy, such as heat, X-rays, or light.

JOULE (J) - A unit of energy (1 watt-second) used to describe the rate of energy delivery. It is equal to one watt-second or 0.239 calorie.

JOULE/cm² - A unit of radiant exposure used in measuring the amount of energy incident upon a unit area.

KTP - Potassium Titanyl Phosphate. A crystal used to change the wavelength of a Nd:YAG laser from 1060 nm (infrared) to nm (green).

LAMBERTIAN SURFACE - An ideal diffuse surface whose emitted or reflected radiance (brightness) is independent of the viewing angle.

LASER - An acronym for light amplification by stimulated emission of radiation. A laser is a cavity, with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. A device that produces an intense beam of light with the unique properties of coherency, collimation and monochromaticity.

LASER ACCESSORIES - The hardware and options available for lasers, such as secondary gases, Brewster windows, Q-switches and electronic shutters.

LASER CONTROLLED AREA - See CONTROLLED AREA.

LASER DEVICE - Either a laser or a laser system.

LASER MEDIUM - (Active Medium) material used to emit the laser light and for which the laser is named.

LASER OSCILLATION - The buildup of the coherent wave between laser cavity end mirrors producing standing waves.

LASER PRODUCT - A legal term in the U.S. See 21 CFR 1040.10, a laser or laser system or any other product that incorporates or is intended to incorporate a laser or a laser system.

LASER ROD - A solid-state, rod-shaped lasing medium in which ion excitation is caused by a source of intense light, such as a flashlamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal.

LASER SAFETY OFFICER (LSO) - One who has authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

LASER SYSTEM - An assembly of electrical, mechanical and optical components which includes a laser. Under the Federal Standard, a laser in combination with its power supply (energy source).

LEADING EDGE SPIKE - The initial pulse in a series of pulsed laser emissions, often useful in starting a reaction at the target surface. The trailing edge of the laser power is used to maintain the reaction after the initial burst of energy.

LENS - A curved piece of optically transparent material which depending on its shape is used to either converge or diverge light.

LIGHT - The range of electromagnetic radiation frequencies detected by the eye, or the wavelength range from about 400 to 760 nanometers. The term is sometimes used loosely to include radiation beyond visible limits.

LIGHT REGULATION - A form of power regulation in which output power is monitored and maintained at a constant level by controlling discharge current.

LIMITING ANGULAR SUBTENSE - The apparent visual angle which divides intrabeam viewing from extended-source viewing.

LIMITING APERTURE - The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation and classification.

LIMITING EXPOSURE DURATION - An exposure duration which is specifically limited by the design or intended use(s).

LONGITUDINAL OR AXIAL MODE - Determines the wavelength bandwidth produced by a given laser system controlled by the distance between the two mirrors of the laser cavity. Individual longitudinal mode standing waves within a laser cavity.

LOSSY MEDIUM - A medium which absorbs or scatters radiation passing through it.

LUMINOUS TRANSMITTANCE - The ratio of transmitted light to the incident light.

MAINTENANCE - Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this glossary.

MAXIMUM PERMISSIBLE EXPOSURE (MPE) - The level of laser radiation to which person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

MENISCUS LENS - A lens which has one side convex, the other concave.

METASTABLE STATE - The state of an atom, just below a higher excited state, which an electron occupies momentarily before destabilizing and emitting light. The upper of the two lasing levels.

MICROMETER - A unit of length in the International System of Units (SI) equal to one-millionth of a meter. Often referred to as a "micron".

MICRON - An abbreviated expression for micrometer which is the unit of length equal to 1 millionth of a meter. See MICROMETER.

MICROPROCESSOR - A digital chip (computer) that operates, controls and monitors some lasers.

MODE - A term used to describe how the power of a laser beam is geometrically distributed across the cross-section of the beam. Also used to describe the operating mode of a laser such as continuous or pulsed laser.

MODE LOCKED - A method of producing laser pulses in which short pulses (approximately 10-12 second) are produced and emitted in bursts or a continuous train.

MODULATION - The ability to superimpose an external signal on the output beam of the laser as a control.

MONOCHROMATIC LIGHT - Theoretically, light consisting of just one wavelength. No light is absolutely single frequency since it will have some bandwidth. Lasers provide the narrowest of bandwidths that can be achieved.

MULTIMODE - Laser emission at several closely-spaced frequencies.

NANOMETER (nm) - A unit of length in the International System of Units (SI) equal to one-billionth of a meter. Abbreviated nm - a measure of length. One nm equals 10^{-9} meter, and is the usual measure of light wavelengths. Visible light ranges from about 400 nm in the purple to about 760 nm in the deep red.

NANOSECOND - One billionth (10^{-9}) of a second. Longer than a picosecond or femtosecond, but shorter than a micro-second. Associated with Q-switched lasers.

Nd:GLASS LASER - A solid-state laser of neodymium: glass offering high power in short pulses. A Nd doped glass rod used as a laser medium to produce 1064 nm light.

Nd:YAG LASER - Neodymium:Yttrium Aluminum Garnet. A synthetic crystal used as a laser medium to produce 1064 nm light.

NEAR FIELD IMAGING - A solid-state laser imaging technique offering control of spot size and hole geometry, adjustable working distance, uniform energy distribution, and a wide range of spot sizes.

NEMA - Abbreviation for National Electrical Manufacturers' Association, a group which defines and recommends safety standards for electrical equipment.

NEODYMIUM (Nd) - The rare earth element that is the active element in Nd:YAG laser and Nd:Glass lasers.

NOISE - Unwanted minor currents or voltages in an electrical system.

NOMINAL HAZARD ZONE (NHZ) - The nominal hazard zone describes the space within which the level of the direct, reflected or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

NOMINAL OCULAR HAZARD DISTANCE (NOHD) - The distance along the axis of the unobstructed beam from a laser, fiber end, or a connector to the human eye beyond which the irradiance or radiant exposure does not exceed the applicable MPE.

OBJECT - The subject matter or figure imaged by, or seen through, an optical system.

OPACITY - The condition of being non-transparent.

OPEN INSTALLATION - Any location where lasers are used which will be open to operating personnel during laser operation and may or may not specifically restrict entry to observers.

OPERATION - The performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include maintenance or services as defined in this glossary.

OPTIC DISC - The portion of the optic nerve within the eye which is formed by the meeting of all the retinal nerve fibers at the level of the retina.

OPTICAL CAVITY (Resonator) - Space between the laser mirrors where lasing action occurs.

OPTICAL DENSITY - A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter.

OPTICAL FIBER - A filament of quartz or other optical material capable of transmitting light along its length by multiple internal reflection and emitting it at the end.

OPTICAL PUMPING - The excitation of the lasing medium by the application of light rather than electrical discharge.

OPTICAL RADIATION - Ultraviolet, visible and infrared radiation (100 nm to 1 mm) that falls in the region of transmittance of the human eye.

OPTICAL RESONATOR - See Resonator.

OPTICALLY PUMPED LASERS - A type of laser that derives energy from another light source such as a xenon or krypton flashlamp or other laser source.

OUTPUT COUPLER - Partially reflective mirror in laser cavity which allows emission of laser light.

OUTPUT POWER - The energy per second measured in watts emitted from the laser in the form of coherent light.

PHASE - Waves are in phase with each other when all the troughs and peaks coincide and are "locked" together. The result is a reinforced wave in increased amplitude (brightness).

PHOTOCOAGULATION - Use of the laser beam to heat tissue below vaporization temperatures with the principal objective being to stop bleeding and coagulate tissue.

PHOTOMETER - An instrument which measures luminous intensity.

PHOTON - In quantum theory, the elemental unit of light, having both wave and particle behavior. It has motion, but no mass or charge. The photon energy (E) is proportional to the EM wave frequency (ν) by the relationship: $E=h\nu$; where h is Planck's constant (6.63×10^{-34} Joule-sec).

PHOTOSENSITIZERS - Substances that increase the biological response of a person to exposure by optical radiation.

PICOSECOND - A period of time equal to 10^{-12} seconds.

PIGMENT EPITHELIUM - A layer of cells at the back of the retina containing pigment granules.

PLASMA SHIELD - The ability of plasma to stop transmission of laser light.

POCKEL'S CELL - An electro-optical crystal used as a Q-switch.

POINT SOURCE - Ideally, a source with infinitesimal dimensions. Practically, a source of radiation whose dimensions are small compared with the viewing distance.

POINTING ERRORS - Beam movement and divergence, due to instability within the laser or other optical distortion.

POLARIZATION - Restriction of the vibrations of the electromagnetic field to a single plane, rather than the innumerable planes rotating about the vector axis. Various forms of polarization include random, linear, vertical, horizontal, elliptical and circular.

POPULATION INVERSION - A state in which a substance has been energized, or excited, so that more atoms or molecules are in a higher excited state than in a lower resting state. This is necessary prerequisite for laser action.

POWER - The rate at which energy is emitted, transferred, or received expressed in watts (joules per second).

POWER METER - An accessory used to measure laser beam power.

Pulse Repetition Frequency PRF - The number of pulses produced per second by a laser, expressed in hertz.

PROTECTIVE HOUSING - A protective housing is a device designed to prevent access to radiant power or energy.

PULSE - A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output.

PULSE DURATION - The "on" time of a pulsed laser, it may be measured in terms of milliseconds, microsecond, or nanosecond as defined by half-peak-power points on the leading and trailing edges of the pulse.

PULSE MODE - Operation of a laser when the beam is intermittently on in fractions of a second.

PULSED LASER - Laser which delivers energy in the form of a single or train of pulses. The duration of a pulse is less than 0.25 seconds.

PUMP - To excite the lasing medium. See Optical Pumping or Pumping.

PUMPED MEDIUM - Energized laser medium.

PUMPING - Addition of energy (thermal, electrical, or optical) into the atomic population of the laser medium, necessary to produce a state of population inversion.

Q-SWITCH - A device for producing very short (~10-250 ns) intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Q-SWITCHED LASER - A laser which stores energy in the laser media to produce extremely short, extremely high intensity bursts of energy.

RADIAN - A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle.

RADIANCE - Brightness; the radiant power per unit solid angle and per unit area of a radiating surface.

RADIANT ENERGY (Q) - Energy in the form of electromagnetic waves usually expressed in units of Joules (watt-seconds).

RADIANT EXPOSURE (H) - The total energy per unit area incident upon a given surface. It is used to express exposure to pulsed laser radiation in units of J/cm^2 .

RADIANT FLUX - Power emitted, transferred, or received in the form of radiation (watts).

RADIANT POWER - Power emitted, transferred, or received in the form of radiation (watts).

RADIANT INTENSITY - The radiant power expressed per unit solid angle about the direction of the light.

RADIATION - In the context of optics, electromagnetic energy is released; the process of releasing electromagnetic energy.

RADIOMETRY - A branch of science which deals with the measurement of radiation.

RAYLEIGH SCATTERING - Scattering of radiation in the course of its passage through a medium containing particles, the sizes of which are small compared with the wavelength of the radiation.

REFLECTANCE OR REFLECTIVITY - The ratio of the reflected radiant power to the incident radiant power.

REFLECTION - The return of radiant energy (incident light) by a surface, with no change in wavelength.

REFRACTION - The change of direction of propagation of any wave, such as an electromagnetic wave, when it passes from one medium to another in which the wave velocity is different. The bending of incident rays as they pass from one medium to another (eg.: air to glass).

REPETITIVELY PULSED LASER - A laser with multiple pulses of radiant energy occurring in sequence with a PRF greater than or equal to 1 Hz.

RESONATOR - The mirrors (or reflectors) making up the laser cavity including the laser rod or tube. The mirrors reflect light back and forth to build up amplification.

ROTATING LENS - A beam delivery lens designed to move in a circle and thus rotate the laser beam around a circle.

RUBY - The first laser type; a crystal of sapphire (aluminum oxide) containing trace amounts of chromium oxide.

SCANNING LASER - A laser having a time-varying direction, origin or pattern of propagation with respect to a stationary frame of reference.

SCINTILLATION - This term is used to describe the rapid changes in irradiance levels in a cross section of a laser beam produced by atmospheric turbulence.

SECURED ENCLOSURE - An enclosure to which casual access is impeded by an appropriate means (e.g., door secured by lock, magnetically or electrically operated, latch, or by screws).

SEMICONDUCTOR LASER - A type of laser which produces its output from semiconductor materials such as GaAs.

SERVICE - Performance of adjustments, repair or procedures on a non-routine basis, required to return the equipment to its intended state.

SOLID ANGLE - The ratio of the area on the surface of a sphere to the square of the radius of that sphere. It is expressed in steradians (sr).

SOURCE - The term source means either laser or laser-illuminated reflecting surface, i.e., source of light.

SPECTRAL RESPONSE - The response of a device or material to monochromatic light as a function of wavelength.

SPECULAR REFLECTION - A mirror-like reflection.

SPONTANEOUS EMISSION - Decay of an excited atom to a ground or resting state by the random emission of one photon. The decay is determined by the lifetime of the excited state.

SPOT SIZE - The mathematical measurement of the diameter of the laser beam.

STABILITY - The ability of a laser system to resist changes in its operating characteristics. Temperature, electrical, dimensional and power stability are included.

STERADIAN (sr) - The unit of measure for a solid angle.

STIMULATED EMISSION - When an atom, ion or molecule capable of lasing is excited to a higher energy level by an electric charge or other means, it will spontaneously emit a photon as it decays to the normal ground state. If that photon passes near another atom of the same frequency, the second atom will be stimulated to emit a photon.

SUPERPULSE - Electronic pulsing of the laser driving circuit to produce a pulsed output (250-1000 times per second), with peak powers per pulse higher than the maximum attainable in the

continuous wave mode. Average powers of superpulse are always lower than the maximum in continuous wave. Process often used on CO₂ surgical lasers.

TEM - Abbreviation for: Transverse Electro-Magnetic modes. Used to designate the cross-sectional shape of the beam.

TEM₀₀ - The lowest order mode possible with a bell-shaped (Gaussian) distribution of light across the laser beam.

THERMAL RELAXATION TIME - The time to dissipate the heat absorbed during a laser pulse.

THRESHOLD - The input level at which lasing begins during excitation of the laser medium.

TRANSMISSION - Passage of electromagnetic radiation through a medium.

TRANSMITTANCE - The ratio of transmitted radiant energy to incident radiant energy, or the fraction of light that passes through a medium.

TRANSVERSE ELECTROMAGNETIC MODE - The radial distribution of intensity across a beam as it exits the optical cavity. See TEM.

TUNABLE LASER - A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.

TUNABLE DYE LASER - A laser whose active medium is a liquid dye, pumped by another laser or flashlamps, to produce various colors of light. The color of light may be tuned by adjusting optical tuning elements and-or changing the dye used.

ULTRAVIOLET (UV) RADIATION - Electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).

VAPORIZATION - Conversion of a solid or liquid into a vapor.

VIGNETTING - The loss of light through an optical element when the entire bundle of light rays does not pass through; an image or picture that shades off gradually into the background.

VISIBLE RADIATION (LIGHT) - Electromagnetic radiation that can be detected by the human eye. It is commonly used to describe wavelengths that lie in the range between 400 nm and 700-780 nm.

WATT - A unit of power (equivalent to one Joule per second) used to express laser power.

WATT/cm² - A unit of irradiance used in measuring the amount of power per area of absorbing surface, or per area of CW laser beam.

WAVE - A sinusoidal undulation or vibration; a form of movement by which all radiant electromagnetic energy travels.

WAVELENGTH - The length of the light wave, usually measured from crest to crest, which determines its color. Common units of measurement are the micrometer (micron), the nanometer, and (earlier) the Angstrom unit.

WINDOW - A piece of glass with plane parallel sides which admits light into or through an optical system and excludes dirt and moisture.

YAG - Yttrium Aluminum Garnet; a widely used solid-state crystal which is composed of yttrium and aluminum oxides which is doped with a small amount of the rare-earth neodymium.

APPENDIX B: Form for Developing SOPs

The Form for Developing SOPs can be found on the following web page:

[Laser Standard Operating Procedure](#)

APPENDIX C: Laser Registration Form

All Class 3B and Class 4 lasers must be registered with the Office of Laboratory and Field Safety (OLFS). Equipment with embedded Class 3B or Class 4 lasers with reasonable expectation of beam exposure due to maintenance or similar activities must be registered with OLFS. The registry shall be updated when lasers are taken out of service or new lasers are purchased. This form must be sent to OLFS and a copy retained with the laser.

The Laser Registration Form can be found on the following web page:

[Laser Registry](#)

APPENDIX D: OSHA Guidance - Laser Hazards

OSHA guidance on laser hazards can be found at the following web page:

<https://www.osha.gov/SLTC/laserhazards/index.html>