Western Carolina University Laser Safety Manual

The privilege to use lasers (non-ionizing radiation) at Western Carolina University requires each individual user to follow and adhere to the guidelines recommended in the American National Standard Institute for the Safe Use of Lasers (ANSI Z136.1). All individuals who work with lasers are responsible for knowing and adhering to applicable requirements. Failure of any individual to comply with requirements can jeopardize the investigation, the laboratory, and the institution. This manual provides an orientation on lasers and describes the laser safety policies and procedures we have implemented to ensure a safe research environment for students, faculty, and staff. The Office of Safety and Risk Management is responsible for managing the laser safety program.

Office of Safety and Risk Management *Revision Date: June 2017*

Laser Safety Program Table of Contents

Section 1.0 Introduction

Western Carolina University makes all reasonable efforts to protect the health and safety of WCU faculty, staff, and students by providing information about health and safety standards. To help fulfill this University policy the Laser Safety Program has been developed to provide guidance for the safe use of lasers and laser systems. This program and recommendations are based upon the American National Standards Institute (ANSI) Z136.1-2000 Standard for Safe Use of Lasers.

Section 2.0 Responsibilities

2.1 Office of Safety and Risk Management

- Laser safety program development and oversight
- Approve Standard Operating Procedures (SOPs), alignment procedures and other procedures that may be subject to administrative and procedural controls
- Conduct Hazard Evaluations for each Class 3b and Class 4 laser
- Classify constructed or modified lasers and laser systems
- Provide laser safety training
- Provide ANSI approved warning signs and labels
- Periodically audit laser use facilities
- Investigate laser accidents
- Maintain inventory of Class 3b and Class 4 lasers and laser systems

2.2 Supervisors/ Principal Investigators (PI):

- Submit a Laser Registration Form to the Safety Office for each Class 3b and Class 4 laser or laser system. Forms are available from the Safety Office website.
- Identify laser hazards present in the work area, implement appropriate hazard controls (including ANSI approved signs and labels) and correct any identified unsafe conditions
- Develop current Standard Operating Procedures (SOPs) for each Class 3b and Class 4 laser or laser system.
- Identify all authorized personnel who are eligible to operate or maintain a Class 3b or Class 4 laser or laser system
- Provide ANSI approved warning signs and labels
- Conduct annual self-inspection of lasers and laser use area using checklist available from the Safety Office
- Designate a Laser Safety Contact (LSC) for each laser or laser system
- Ensure that laser users follow established safety procedures
- Keep copies of all current SOPs, trainings, and inspections/investigations
- Maintain a copy of this written program in the workplace

2.3 Laser User:

- Know the hazards and the precautionary procedures for laser use in their work area
- Complete required training(s)
- Plan and conduct operations in accordance with established procedures and good safety practices
- Use personal protective equipment in accordance with prescribed training

Section 3.0 Laser Classification

Lasers are divided into a number of classes depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or potential for causing fires from direct exposure to the beam or from reflections from diffuse reflective surfaces. A qualitative description of laser classes can be found below (ANSI Z136.1-2000).

- A **Class 1** laser system is:
  - Considered to be capable of producing exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or telescope (collimated beam), and
  - Exempt from any control measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

- A **Class 2** laser system:
  - Emits radiation in the visible portion of the spectrum (0.4 to 0.7 µm), and
  - Eye protection is normally afforded by the aversion response

- A **Class 2M** laser system:
  - Emits in the visible portion of the spectrum (0.4-0.7 µm) and
  - Eye protection is normally afforded by the aversion response for unaided viewing
  - However, Class 2M is potentially hazardous if viewed with certain optical aids

- A **Class 3** laser system (medium power):
  - May be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard. There are two subclasses:
    - A **Class 3R** laser system (formerly Class 3A): potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but that probability of an actual injury is small. The laser will not pose either fire hazard or diffuse-reflection hazard.
    - A **Class 3B** laser system: may be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard.

- A **Class 4** laser system (high power):
  - Is a hazard to the eye or skin from the direct beam, and
  - May pose a diffuse reflection or fire hazard
  - May also produce laser generated air contaminants (LGAC) and hazardous plasma radiation.

Commercially produced lasers are classified according to the CDRH Federal Standard (FLPPS, 21 CFR 1040) and are identified by labels affixed to the laser. Removal of protective housing or system modification can increase a laser's classification. Contact the Safety Office for review prior to servicing or system modification.

Section 4.0 Laser Acquisition, Transfer, and Disposal

4.1 Acquisition

The PI must notify the Safety Office of all Class 3b or Class 4 lasers/laser systems by submitting a Laser Registration Form for each laser/laser system to the Safety Office. A form must be re-submitted when significant modifications are made to the original laser/laser system. The Safety Office will conduct a hazard evaluation of the laser work area and make necessary recommendations.

4.2 Transfer

The Safety Office must be notified when a Class 3b or 4 laser is transferred from the jurisdiction of one PI to another PI on-campus. The new PI/LSC must complete a Laser Registration form. The Safety Office must also be notified if the laser is transferred off-campus.

4.3 Disposal

The Safety Office must be notified when a Class 3b or 4 laser is sold or disposed of and will coordinate with the Hazardous Waste Program, as appropriate.

Section 5.0 Control Measures

5.1 Class 1, 2, & 3R Laser Systems

1. When used as intended Class 1, 2, and 3R laser systems are generally low hazard devices; however some requirements still apply.
2. As with any piece of equipment PIs/LSC are responsible for ensuring training on proper use of that equipment.
3. Exposure to laser radiation must be kept below the Maximum Permissible Exposure (MPE) under all conditions of operation or maintenance.
4. Laser systems must have the appropriate warning labels with the laser sunburst logotype symbol and the appropriate cautionary statement. See Section 7.0.
5. Removal of protective housing or system modification can increase a laser's classification. Contact the Safety Office for review prior to servicing or system modification.
6. Use of class 3R laser with telescopes, microscopes, or alignment devices should be reviewed by the Safety Office prior to operation.

5.2 Control Area Requirements

A laser hazard analysis, including determination of the MPE and Nominal Hazard Zone (NHZ), must be made by the Safety Office. If it is determined that the classification associated with the maximum level of accessible radiation is Class 3b or 4, a laser-controlled area is established and control measures instituted. Control measures are only required within the NHZ.

Class 3b Control Areas

1) Must be controlled to permit lasers and laser systems to be operated only by authorized personnel.
2) Must be posted with the appropriate warning sign(s). See Section 7.0.
3) All area or entryway safety controls must be designed to allow rapid egress by laser personnel and admittance to the laser controlled area under emergency conditions.
4) Must be operated in a manner such that the laser beam path is well defined and projects into a controlled airspace when the laser beam must extend beyond an indoor controlled area, particularly to the outdoors under adverse atmospheric conditions, i.e. rain, fog, snow, etc.
5) Must be under the direct supervision of an individual knowledgeable in laser safety.
6) Must have all windows, doorways, or open portals either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the applicable ocular MPE.
7) Must have only diffusely reflecting materials in or near the beam path where possible.
8) Must have appropriate personal protective equipment readily available (i.e., eye protection).

Class 4 Control Areas

Class 4 laser control areas must incorporate all Class 3b control measures, plus the following:

1) Control area interlocks or alternate controls to preclude the entry of unprotected personnel while Class 4 laser radiation is present in the control area. The interlock system may be designed to preclude entry while the laser is operating or to terminate laser operation when the door is opened without deliberate overriding of the interlock by a trained laser user

Or

1) Blocking barrier, screen, curtains, etc. must be used to block, screen, or attenuate the laser radiation levels so that the MPE is not exceeded at the entry point.
2) At the entryway there must be a visible or audible signal indicating that the laser is energized and operating at Class 4 levels. A lighted laser warning sign or flashing light (visible through protective eyewear) is acceptable as entryway warning light alternatives.
3) Personnel trained on entryway procedures and adequate personal protective equipment provided upon entry.

5.3 Engineering Controls

The engineering control measures required for Class 3b and 4 lasers are listed below. Where specific engineering controls are infeasible they may be replaced with specific administrative and procedural controls and personal protective equipment (PPE) with prior review by the Safety Office.

Engineering Controls ✓ Required * Recommended	Laser Class 3b	 4
Protective Housing – for active laser work with housing off, contact Safety Office for hazard analysis and appropriate controls.	✓	✓
Interlocks on protective housing	✓	✓
Service Access Panels Interlocked or tool required and appropriate warning label on the panel	✓	✓
Viewing windows, diffuse display screens, or collecting optics (microscopes, lenses, etc.) are controlled with interlocks, filters, or attenuators to maintain laser radiation at the viewing position at or below the applicable MPE.	✓	✓
Key Control	*	✓
Remote Interlock Connector	*	✓
Beam stop or Attenuator	*	✓
Laser Activation Warning System	*	✓
Emission Delay		✓
Panic Button		✓
Enclosed Beam Path	*	*
Remote Firing and Monitoring		*

5.4 Administrative and Procedural Controls

Administrative and procedural controls are methods or instructions that specify rules, or work practices, or both, which implement or supplement engineering controls. Necessary administrative and procedural controls for 3b and 4 laser and laser systems include, but are not limited to:

1) Authorized Personnel – PI must identify authorized personnel and ensure that those personnel are the only ones that operate, maintain, or service a Class 3b or 4 laser or laser system. Laser Safety Training must be completed and PPE must be provided before access to Class 3b and 4 laboratories is granted.
2) Alignment Procedures –
   i. Exclude unnecessary personnel from the laser area during alignment.
   ii. Use low-power visible lasers for path simulation of higher power visible or invisible lasers whenever possible.
   iii. Wear laser protective eyewear during alignment. Use special alignment eyewear when circumstances (e.g. wavelength, power, etc.) permit their use.
   iv. When aligning invisible (e.g. UV, IR) beams, use beam display devices such as image converter viewers or phosphor cards to locate beams.
   v. Perform alignment tasks using high-power lasers at the lowest possible power level.
   vi. Use a shutter or beam block to block high-power beams at their source except when actually needed during the alignment process.
   vii. Use a laser rated beam block to terminate high-power beams downstream of the optics being aligned.
   viii. Use beam blocks and/or laser protective barriers in conditions where alignment beams could stray in to areas with uninvolved personnel.

ix. Place beam blocks behind optics (e.g. turning mirrors) to terminate beams that might miss mirrors during alignment.
x. Locate and block all stray reflections before proceeding to the next optical component or section.
xi. Be sure all beams and reflections are properly terminated before high-power operation.
xii. Post appropriate area warning signs during alignment procedures where lasers are normally Class 1 (enclosed).
xiii. Alignments should be done only by those who have received laser safety training.

3) Use minimum laser radiation required for the application. If necessary, the Safety Office may require the reduction of levels of accessible power or radiant energy during the operation or maintenance of a Class 3b or Class 4 laser system.
4) Lasers or laser systems must have the appropriate warning labels. See Section 7.0 for warning label requirements.
5) Maintain beam height at a level other than the normal position of the eye of a person in the standing or seated position.

Section 6.0 Protective Equipment

Personal protective equipment may have serious limitations and must be used only in conjunction with engineering and administrative controls, when working with Class 3b and Class 4 lasers and laser systems.

6.1 Personal Protective Equipment

Eye Protection

Appropriate eye protection devices must be worn when working with Class 3b and Class 4 lasers or laser systems. Laser protective eyewear is usually not required for Class 2 of Class 3a lasers or laser systems, except in conditions where intentional long-term (> 0.25 seconds) direct viewing is required. Eyewear must be specifically selected to withstand either direct or diffusely scattered beams and shall meet all provisions of ANSI Z87.1-1989. (4.6.2.3)

Eyewear must be inspected before each use, and replaced if necessary, to maintain the eyewear in good condition. Contact the Safety Office for assistance in selecting protective eyewear.

Factors in selecting appropriate eyewear:

- Laser power and /or pulse energy
- Wavelength(s) of laser output
- Potential for multi-wavelength operation
- Radiant exposure or irradiance levels for which protection (worst case) is required
- Exposure time criteria
- Maximum permissible exposure
- Optical density requirement of eyewear filters at laser output wavelength
- Angular dependence of protection afforded

- Visible light transmission requirement and assessment of the effect of the eyewear on the ability to perform tasks while wearing the eyewear
- Need for side-shield protection and maximum peripheral vision requirement
- Radiant exposure or irradiance and the corresponding time factors at which laser safety filter characteristics change occurs, including transient bleaching especially for ultra-short pulse lengths
- Need for prescription glasses
- Comfort and fit
- Degradation of filter media, such as photo bleaching
- Strength of materials (resistance to mechanical trauma and shock)
- Capability of the front surface to produce a hazardous specular reflection
- Requirement for anti-fogging design or coating

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 recommended. Minimize exposure to UV radiation by using beam shields and clothing (opaque gloves, tightly woven fabrics, laboratory jacket or 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.).

6.2 Facility Window Protection

Exterior or interior windows that are located within the NHZ of a Class 3b or Class 4 laser of laser system must be provided with appropriate absorbing filter, scattering filter, blocking barrier or screen to reduce any transmitted laser radiation to levels below the applicable MPE level. Important factors for selection include: ability to withstand direct and diffusely scattered beams, flammability and decomposition products of the window material.

6.3 Laser Protective Barriers and Curtains

A blocking barrier, screen or curtain which can block or filter the laser beam at the entryway should be used inside the controlled area to prevent Class 3b or Class 4 laser light from exiting the area at levels above the applicable MPE level. Important factors for selection include: ability to withstand direct and diffusely scattered beams, flammability and decomposition products of the protective barrier or curtain.

Section 7.0 Warning Signs and Equipment Labels

ANSI approved signs and labels are provided by the PI and must be conspicuously displayed in locations where they best serve to warn onlookers. Personnel who do not read/understand the English language and who may need to enter areas where lasers are used must be provided appropriate instructions as to the meaning of warning signs and labels. The PI/LSC is responsible for identifying and training such personnel.

7.1 Warning Signs

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

- Danger: Must be used with all signs and labels associated with all Class 3a lasers and laser systems that exceed the appropriate MPE for irradiance, and all Class 3b and Class 4 lasers and laser systems.
- Caution: Must be used with all signs and labels associated with Class 2 lasers and laser systems, and all Class 3a lasers and laser systems that do not exceed the appropriate MPE for irradiance.
- Notice: Must be used on signs posted outside a temporary laser controlled area. The area within the temporary controlled area must also have appropriate signs posted (danger warning for Class 3b or Class 4).

7.2 Equipment Label

All lasers or laser systems (except Class 1) must have appropriate warning labels affixed to a conspicuous place on both the housing and the control panel (if separated by more than 2 meters).

- Class 2 lasers and laser systems: "Laser Radiation – Do Not Stare into Beam"
- Class 3a lasers and laser systems (accessible irradiance does not exceed MPE based upon 0.25 second exposure for wavelengths between 0.4 and 0.7 µm):"Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments"
- All other Class 3a lasers or laser systems: "Laser Radiation – Avoid Direct Eye Exposure"
- Class 3b lasers or laser systems: "Laser Radiation – Avoid Direct Exposure to Beam"
- Class 4 lasers or laser systems: "Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation"

7.3 Labeling of Protective Equipment

- Labeling of Protective Eyewear
  - All eyewear must be clearly labeled with the optical density and wavelength. Color-coding or other distinctive identification is recommended in multi-laser environments.
- Labeling of Laser Protective Windows and Collecting Optic Filters
  - All laser protective windows must be labeled with the optical density and wavelength(s) for which protection is afforded, and should be labeled with the threshold limit and exposure time for which the limit applies, and the conditions under which protection if afforded.
- Labeling of Laser Protective Barriers
  - All laser protective barriers must be labeled with the barrier threshold limit and exposure time for which the limit applies, and beam exposure conditions under which protection is afforded. Contact the Safety Office for any assistance.

Section 8.0 Training

PIs are responsible for ensuring that staff and students receive appropriate training on the hazards in their work area and that documentation of that training is maintained. Before operating a Class 3b or Class 4 laser or laser system, all users must:

1. Read the Laser Safety Program,
2. Receive laser safety training (available by contacting the Safety Office),
3. Receive laboratory-specific safety training (including a thorough review of the laser equipment, administrative and engineering controls, and alignment and standard operating procedures) from the LSC or PI, and
4. Read and sign a copy of the applicable Laser SOPs.

Laser users must be re-trained whenever a new hazard is introduced into the work area.

Section 9.0 Non-Beam Hazards

Non-beam hazards often exist in laser-related operations and can pose significant health and safety risks. Non-beam hazards should be evaluated during risk assessments. For guidance contact the Safety Office. Below are examples of typical non beam hazards:

- Electrical Hazards: An electrical shock hazard can occur from contact with exposed utility power utilization, device control, and power supply conductors operating at potentials of 50 volts and above. Individuals involved in such uses must be trained in electrical safety and in proper lockout-tagout procedures. Class 3b and 4 lasers should have a separate circuit and local cut-off switch (breaker) for the circuit. Label and post electrical high voltage hazards and switches. Clearly identify the main switches to cut-off power. Before working on a laser, de-energize the machine. Positively disconnect it, if there is more than one source of power, disconnect them all. Lock out and tag the disconnect switches so that power is not reconnected while you are working on the laser. Have at least two persons in an area while working on high-energy power systems. Keep cooling water connections away from main power and high voltage outlets and contacts. Use double hose clamps on cooling water hoses. Inspect cooling water hoses and connections and power cables and connectors periodically as part of a regular equipment inspection. Check with Facilities Management on the proper installation of cooling water lines.
- Laser-Generated Air Contaminants (LGAC): LGAC's may be generated when certain Class 3b and Class 4 lasers beams interact with matter. Characteristics of the contaminants depend upon the target material, cover gas, and beam irradiance. Coordinate with the Safety Office to ensure proper evaluation and recommendation of appropriate controls, if necessary.
- Radiation: Refers to radiation produced by system components other than the primary laser beam. The Safety Office will coordinate with various departments to ensure proper evaluation and recommendation of appropriate controls, if necessary
    - X Radiation (Ionizing Radiation): May be produced from electrical components of laser systems greater than 15 kV and from laser-metal induced plasmas.
    - Ultraviolet (UV) and Visible Radiation: May be generated from laser discharge tubes and pump lamps. Can cause skin and eye damage.
    - Radiofrequencies (RF): Some lasers contain RF excited components.
    - Plasma Radiation: Created during certain processes, and may contain hazardous UV and blue light emissions.

- Fire Hazards: Class 4 laser beams represent a fire hazard and under some situations it is possible that Class 3 lasers can initiate fires. Use flame retardant materials wherever applicable with all laser applications. Users should be aware that opaque laser barriers, e.g. curtains, can be designed to offer a range of protection, however, they normally cannot withstand high irradiance levels for more than a few seconds without some damage, e.g., production of smoke, open fire, or penetration. Operators of Class 4 lasers should also be aware of the ability of unprotected wire insulation and plastic tubing to catch on fire from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths.
- Explosion Hazards: High-pressure arc lamps, filament lamps, and capacitor banks in laser equipment must be enclosed in housings which can withstand the maximum explosive pressure resulting from component disintegration.
- Compressed Gases: Individuals who work with compressed gasses must be familiar with their hazards. Reference the University Chemical Hygiene Plan, Compressed Gas Manual, and Compressed Gas SOP.
- Laser Dyes and Solvents: Laser dyes are complex fluorescent organic compounds which, when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. PIs/supervisors must ensure that all individuals who work with laser dyes and solvents receive appropriate training on hazardous material handling, storage, and disposal.
    - Note: The use of dimethylsulfoxide (DMSO) as a solvent for cyanine dyes in dye lasers should be discontinued if possible. DMSO aids in the transport of dyes through the skin and into the blood stream.
- Noise: A good "rule of thumb" for determining if your work area or activity requires hearing protection is as follows. If you have difficulty hearing or understanding a "normal" tone of voice at a distance of about three feet, noise levels are probably exceeding safe levels and you should be using hearing protection. Please contact the Safety Office for an evaluation.
- Waste Disposal: Dispose of all wastes in accordance with the relevant guidelines. Contact the Safety Office for additional help.
- Limited Work Space: Limited workspace can be a problem especially while working near or around mechanical or high voltage equipment. WCU requires a minimum isle width of 24” with 36” clearance around electrical panels. In all cases there must be sufficient room for personnel to turn around and maneuver freely.
- Ergonomics: Consider ergonomic principles in laser system designs, such as positioning of the laser system and area illumination.

Section 10.0 Special Considerations

- Service of Embedded Class 3b or Class 4 Lasers
    - Access to Class 3b or Class 4 lasers or laser systems enclosed within a protective housing or protected area enclosure is limited to properly trained individuals and by specific engineering and administrative controls. Contact the Safety Office for more information.
- Outdoor Control Measures
    - Projection of Class 3a, 3b, or 4 lasers beams in the outside environment requires prior review by the Safety Office.
- Additional Laser Uses
    - Lasers may also be used in optical fiber transmission systems and robotic installations. Contact the Safety Office for more information regarding applicable control measures.

Section 11.0 Laser Accidents

Response/ Reporting Procedures:

All accidents/exposures are to be reported to the supervisor as soon as possible.

Serious Injury/ Illness:

For health-threatening injuries/ illnesses, call 911.

Supervisors should contact the Safety Office at 828-227-7443 to report any serious injury, illness, or death as soon as possible and no later than 24 hours. An injury or illness is defined as "serious" if:

- It requires inpatient hospitalization for a period in excess of 24 hours for other than medical observation
- It requires medical treatment beyond first aid
- An employee suffers a loss of any member of the body
- An employee suffers any serious degree of permanent disfigurement

All Other Injuries:

For treatment of all other injuries, proceed to University Health Services.

11.1 Accident Investigation

All accidents, illnesses and fires will be investigated by the Safety Officer for the purpose of analyzing the circumstances surrounding the event, the possible need for corrective action to prevent future occurrence, and the compensability of a reported injury or illness under the terms of the North Carolina Workers' Compensation Act. A safety follow-up report will be completed for all accidents.

Section 12.0 Record-Keeping

The PI is responsible for maintaining all laser safety-related records (i.e., laser safety training, SOPs, inspections/ audits) for each employee for a minimum of one year. For general purposes, it is recommended that records be maintained for as long as the employee works with that laser or laser system.

Section 13.0: Definitions

Continuous wave (CW): The output of a laser which is operated in a continuous rather than a pulsed mode. In this standard, a laser operating with a continuous output for a period 0.25 seconds is regarded as a CW laser.

Controlled area: An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards.

Embedded laser: An enclosed laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

Emission Delay: Time between warning system activation and activation of the laser or laser system. The delay must be sufficient to allow appropriate action to be taken to avoid exposure to laser radiation. Required for Class 4 laser or laser systems.

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).

Infrared radiation. Electromagnetic radiation with wavelengths which lie within the range 0.7 µm to 1 mm.

Interlocks: Engineering control designed to prevent access to laser radiation above the applicable maximum permissible exposure. The interlock may, for example, be electrically or mechanically interfaced to a shutter that interrupts the beam when the protective housing is opened or removed. Interlocks on protective housings that enclose Class 3b or 4 lasers or laser systems are required. Remote interlocks for rooms, entryways, or areas are recommended for Class 3b lasers or laser systems and required for Class 4 lasers or laser systems.

Ionizing radiation: Electromagnetic radiation having sufficiently large photon energy to directly ionize atomic or molecular systems with a single quantum event.

Key Control: Single master switch operated by a key, or by a coded access required for beam and/or system activation. Required for Class 4 lasers or laser systems and recommended for Class 3B lasers or laser systems.

Laser. A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both. An acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

Laser barrier. A device used to block or attenuate incident direct or diffuse laser radiation. Laser barriers are frequently used during times of service to the laser system when it is desirable to establish a boundary for a temporary (or permanent) laser controlled area.

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.

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 section.

Maximum permissible exposure (MPE). Maximum allowable level of laser irradiance.

Must. The word "must" is to be understood as mandatory.

Nominal hazard zone (NHZ). 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.

Non-beam hazard. A class of hazards that result from factors other than direct human exposure to a laser beam.

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 *service* as defined in this section.

Protective housing. An enclosure surrounding the laser or laser system that prevents access to laser radiation above the applicable MPE level. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated optics and a workstation, and limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals.

Pulsed laser. A laser which delivers its energy in the form of a single pulse or a train of pulses.

Reflection. Deviation of radiation following incidence on a surface.

Refraction. The bending of a beam of light in transmission through an interface between two dissimilar media or in a medium whose refractive index is a continuous function of position (graded index medium).

Repetitive pulse laser. A laser with multiple pulses of radiant energy occurring in a sequence.

Retinal hazard region. Optical radiation with wavelengths between 0.4 and 1.4 µm, where the principal hazard is usually to the retina.

Secured enclosure. An enclosure to which casual access is impeded by an appropriate means, e.g., a door secured by a magnetically or electrically operated lock or latch, or by fasteners that need a tool to remove.

Service. The performance of those procedures or adjustments described in the manufacturer's service instructions which may affect any aspect of the performance of the laser or laser system. It does not include *maintenance* or *operation* as defined in this section.

Should. The word "should" is to be understood as advisory.

Spectator. An individual who wishes to observe or watch a laser or laser system in operation, and who may lack the appropriate laser safety training.

Specular reflection. A mirror-like reflection.

Standard operating procedure (SOP). Formal written description of the safety and administrative procedures to be followed in performing a specific task.

Ultraviolet radiation. Electromagnetic radiation with wavelengths shorter than those of visible radiation; for the purpose of this program, 0.18-0.4 µm.

Uncontrolled area. An area where the occupancy and activity of those within is not subject to control and supervision for the purpose of protection from radiation hazards.

Visible radiation (light). In this program, the term is used to describe electromagnetic radiation which can be detected by the human eye. This term is commonly used to describe wavelengths which lie in the range 0.4 to 0.7 µm.