OSU Laser Safetv Manual

Table of Contents

I. Introduction to the OSU Laser Safety Program

The Oregon State University laser safety program provides guidance to the OSU community on the safe user of lasers. Persons administering a laser program should be familiar with the following topics covered in the manual:

- Registration of Class 3B and Class 4 lasers.
- Training and documentation for all users of Class 3B and Class 4 lasers.
- Evaluation of each laser for proper control measures, including required postings and personal protective equipment (PPE).
- Completion of laser hazard evaluations (see the Laser Safety Checklist).

The regulation of lasers falls under the rules of the Oregon Occupational Safety and Health Administration (OR-OSHA). In enforcing the provisions of the Oregon Safe Employment Act, OR-OSHA Program Directive A-285 “Laser Inspection Guidelines” recognizes ANSI Z136.1 “American National Standard for Safe Use of Lasers” as the industry standard. This directive and ANSI Z136.1 are used as the basis for the OSU Laser Safety Program.

See Appendix A for a glossary of terms and abbreviations used in this document.

II. Responsibilities and Program Administration

Radiation Safety Committee (RSC) serves as the advisory group on OSU policies relating to laser safety. Bylaws of the RSC are found in the OSU Radiation Safety manual (RSM).

The **Laser Safety Officer (LSO)** is appointed by the Assistant Director of Environmental Health and Safety (EH&S). The LSO has the following responsibilities:

1. Establish a Laser Safety Program.
2. Classify or verify the classification of all lasers under the LSO’s jurisdiction.
3. Conduct hazard evaluations.
4. Assure all control measures are implemented and followed.
5. Approve operating procedures related to the use of lasers.
6. Recommend and/or approve laser PPE.
7. Ensure all employees who use or are exposed to laser hazards are provided with information and training on the safe use of the equipment.
8. Recommend medical evaluation after laser exposure incidents.
9. Establish procedures to investigate all incidents with potential or actual employee exposure to laser radiation.

Principle Investigator (PI)

Principal Investigators are directly responsible for laboratory laser safety, and implementing a safety program as prescribed in this manual and in consultation with the LSO. This includes the implementation of hazard controls, oversight and management of non-laser hazards, and informing the LSO of any changes that affect the laser users. It is also the responsibility of the PI to assure that all laser users have met the training requirements.

Authorized Laser Operators

Laser users are responsible for their own safety and the safety of other personal working in the laser facility. Individuals planning to work with lasers must complete the training requirements prior to beginning work.

III. Training and Qualifications

The PI is responsible for verifying training status of all operators. Before operating a Class 3B or Class 4 laser, all personnel shall:

A. Review the Laser Safety Manual and complete the EH&S Online Laser Safety Training (http://oregonstate.edu/ehs/laser).

B. Receive training from the PI or laboratory supervisor, including safe operation of the laser to be used and administrative, alignment and other applicable procedures.

C. Review the operating and safety instructions furnished by the manufacturer.

IV. Laser Acquisition, Transfer and Disposal

A. Registration of new laser machines

All Class 3B and Class 4 lasers must be registered with EH&S. Registration can be completed using the online Laser Registration Form (http://oregonstate.edu/ehs/laser). The LSO must be notified when significant modifications are made to the original laser or work area. The LSO will conduct a hazard evaluation of the laser work area and make necessary recommendations.

B. Transfer and Surplus

The LSO must be notified when a Class 3B or Class 4 laser is transferred from one PI to another PI on-campus, or if the laser is sold or transferred through Surplus Property.

C. Disposal

1. Several considerations should be given when disposing of a laser – making the laser inoperative, removing it from inventory, and proper disposal of any hazardous waste that may be involved.
2. Under no circumstances shall Class 3B or Class 4 lasers be abandoned. Contact the LSO to initiate proper disposal of a laser system.

V. Control Measures – General

Safety Facts

The most common causes of laser accidents in research labs are the following:
(1) Not wearing appropriate safety goggles
(2) Not reducing power for alignment procedures, or unintended power increase
(3) Stray beams left uncontained by beam stops or other barriers

A. Control measures shall be devised to reduce the possibility of exposure of the eye and skin to hazardous levels of laser radiation and other hazards associated with lasers during operation, service and maintenance. The LSO will evaluate and monitor laser hazards and appropriate control measures.

B. Laser control methods minimize worker's exposure or potential for exposure. Control methods can be divided into three areas, in order of preference:

1. **Engineering controls**, such as barriers, beam blocks, interlocks, etc.
2. **Administrative controls**, such as training, signs, labels, procedures, etc.
3. **Personal protective equipment (PPE),** such as laser protective eyewear and skin coverings.

C. In most cases the requirements for control measures are based on the hazard classification of the laser radiation that is accessible during operation, maintenance, or service. After review and approval of the LSO, the control measures specified in this section may be replaced by other controls that provide equivalent protection.

Summary of Required Control Measures *(see Appendix C for more information on control measures for specific applications)*	
Class 1	Exempt from any control measures for laser radiation
Class 1 Embedded Laser Systems	Exempt from any control measures, except for the case when operating with any factory interlocks or other safety features defeated requires hazard evaluation and approval by the LSO
Class 1M	Exempt from any control measures except when using optically aided ("magnified") viewing, and/or the beam is operated unattended into a location where it can be directly viewed by personnel uninformed about the hazards
Class 2	Exempt from any control measures except during intentional direct viewing of the beam.
Class 2M	Exempt from any control measures except during intentional direct viewing of the beam, and/or potential for directly viewing the optically aided ("magnified") beam.
Class 3R **Class 3A**	Exempt from any control measures or other forms of surveillance except for conditions when directly viewing the beam or its specular reflection,

	and/or unattended operation with the beam directed into a location where it can be directly viewed by personnel uninformed about the hazards. Follow the manufacturer's safety instructions.
Class 3B and Class 4	Requires approval of appropriate control measures by the LSO to reduce the risk of hazardous exposure to the eye or skin from the direct and reflected beam. Class 4 lasers may require additional protection from diffusely reflected beams, potential skin hazards, fire hazards and non-beam hazards such as LGAC and plasma radiation.

VI. Control Measures – for Class 1, 1M, 2, 3M and 3A Lasers

For control measures for other than Class 3B or 4 lasers, see

- Appendix C "Control Measures for Specific Laser Applications'
- Appendix D "Laser Classifications"

VII. Control Measures – for Class 3B and Class 4 Lasers

A. Minimum requirements for Class 3B and Class 4 indoor laser controlled areas:

1. Be controlled such that lasers and laser systems are operated only by personnel who have been trained in laser safety and in the operation of the laser or laser system.
2. Be posted with the appropriate area warning sign(s), posted in conspicuous locations to warn onlookers.
3. Be operated in a manner such that the beam path is well defined.
4. Require the appropriate eye protection for personnel within the laser-controlled area.
5. Use the lowest laser power possible for beam alignment procedures.

B. Additional requirements for Class 4 lasers, and recommended for Class 3B lasers:

1. Be under the direct supervision of an individual knowledgeable in laser safety.
2. Be located so that access to the area by spectators is limited and requires approval. This may require interlocks on access doors.
3. Have any potentially hazardous beam terminated in a beam stop of an appropriate material.
4. Where feasible, have only diffusely reflecting material in or near the beam path. There shall be no unnecessary specular reflecting surfaces or tools near the beam path.
5. Have the laser secured such that the exposed beam path is above or below eye level of a person in any standing or seated position, if possible.
6. Have all windows, doorways, open portals, etc., from an indoor facility 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. Require storage or disabling (e.g., removal of the key or lock-out/tag-out) of the laser or laser system when not in use to prevent unauthorized use.

C. Control measures for Class 3B and Class 4 lasers used outdoors:

1. The LSO shall affect a laser hazard analysis to establish the nominal hazard zone (NHZ) and a laser-controlled area (LCA). The requirements for indoor LCA shall apply to the outdoor LCA, as applicable.

2. Under no circumstances will visible laser beams be directed toward automobiles, aircraft, or other manned structures or vehicles, or otherwise disrupt critical tasks.

VIII. Control Measures – Signs and Labels

A. Required laser hazard signs shall be conspicuously displayed in locations where they will best serve to warn onlookers. All access doors to rooms that contain Class 3B or 4 lasers are to be posted with a laser hazard sign. Laser hazard signs may be posted for Class 2 and Class 3A/3R lasers, but are not required

B. Signal words “Caution”, “Warning” and “Danger” for hazard signs are assigned as follows:

1. **“CAUTION”** indicates a hazardous situation that, if not avoided, could result in minor or moderate injury. The signal word “CAUTION” shall be used with all signs and labels associated with Class 2 and Class 2M lasers. “CAUTION” should be printed in black letters on a yellow background.

2. **“WARNING”** indicates an imminently hazardous situation that, if not avoided, could result in death or serious injury. The signal word “WARNING” shall be used on laser area warning signs associated with lasers and laser systems whose output exceed the MPE for irradiance, including all Class 3B and Class 4 lasers and laser systems. “WARNING” should be printed in black letters on an orange background.

3. Note: the **"DANGER"** signal word is restricted to Class 4 lasers with high (multi-kW) output power or pulse energies with exposed beams, and indicates an imminently hazardous situation that, if not avoided, will result in death or serious injury.

4. The signal word ***“NOTICE”*** is not appropriate or allowed on signs warning of a laser hazard or hazardous situation, instead use “CAUTION” or “WARNING” in these situations.

C. Required warning signs shall include the following information, as applicable:

1. The hazard class of the laser controlled area

2. “Laser Eye Protection Required”, including OD and wavelength of protective eyewear

3. “Invisible Laser Radiation” (“Laser Light” may be used for visible lasers)

4. “Knock Before Entering”
5. “Do Not Enter When Light is Illuminated”
6. “Restricted Area, Authorized Personnel Only”
7. Name and contact information for PI and LSO

D. Laser hazard signs that meet previous ANSI sign standards are allowed because they have been “grandfathered” in to the current 2014 standards. (Contact EH&S with questions or to produce signs for your facility.)

E. Examples of signs that meet the ANSI standard:

F. Labels on Laser Housing – Lasers should be labeled by the manufacturer with the following:

1. Class of laser
2. Wavelength, pulse duration, and maximum output power.
3. Precautionary statements for users, such as
   a) For Class 2 lasers, “Laser Radiation-Do Not Stare into Beam”
   b) For Class 2M lasers, “Laser Radiation-Do Not Stare Into Beam or View Directly with Optical Instruments”
   c) For Class 3R and Class 3B lasers, “Laser Radiation-Avoid Direct Eye Exposure to Beam”
   d) For Class 4 lasers, “Laser Radiation-Avoid Eye Exposure to Direct or Scattered Radiation; Avoid Skin Exposure to Direct Radiation”

IX. Control Measures – Standard Operating Procedures (SOP)

An SOP is required for Class 3B and Class 4 lasers. The SOP should document procedures for alignments, maintenance and normal operations, and any LSO approved variations from control measure, such as procedures, PPE, administrative or engineering controls used in place of requirements in the ANSI standards. The SOP should be used as a training document for new users.

See the OSU laser website for guidance on developing an SOP (http://oregonstate.edu/ehs/laser)

X. Control Measures – Protective Equipment

A. Engineering controls shall be given primary consideration in instituting a control measure program for limiting access to laser radiation. Enclosure of the laser equipment and the beam path, or remote viewing and operation are the preferred methods of control to isolate or minimize the hazard. When engineering controls are impractical or inadequate, administrative and procedural controls and PPE shall be used, and requirements documented in the laser SOP.

B. The Principal Investigator is responsible for ensuring that the appropriate PPE is available and worn. Laser operators are responsible for properly using all required protective equipment.

C. Availability and Use of Laser Safety Eyewear

1. Laser safety eyewear shall be available and worn by laser operators, attendants and visitors in laboratories where a Class 3B or Class 4 laser is present and there is a potential exposure to the beam or reflected beams at levels above the MPE.
2. Laser safety eyewear is not required for Class 2, Class 2M or Class 3R/3A lasers unless intentional long-term (>0.25 seconds) direct viewing is required.

D. Laser safety eyewear shall be chosen based on the level of protection needed to protect the eyes from a worst case scenario. The following information is needed when selecting appropriate laser safety eyewear:

1. Wavelength(s)
2. Mode of operation (continuous wave or pulsed)
3. Maximum exposure duration (assume worst case scenario)
4. Maximum irradiance (W/cm2 for CW) or radiant exposure (J/cm2 for pulsed)
5. Maximum permissible exposure (MPE)
6. Optical density (OD)
7. One pair of laser safety eyewear may not be sufficient when working with tunable or multiple wavelength lasers. Always check the OD and wavelength prior to use. Eyewear with multiband filters and flip-up eyewear are available for some applications.
8. For ultra-fast (femtosecond) lasers, temporary bleaching may occur from high peak irradiances from ultra-fast laser pulses. Contact the manufacturer of the laser safety eyewear for test data to determine if the eyewear will provide adequate protection before using them.

E. Other considerations for laser safety eyewear:

1. Visible light transmission (VLT)
2. Effect on color vision
3. Field of view provided by the design of the eyewear
4. Reversible bleaching of absorbing media
5. Need for prescription lenses
6. Fit and comfort
7. Impact resistance
8. Glass laser eyewear is heavier and more costly than plastic, but it provides better visible light transmittance. There are two types of glass lenses, those with absorptive glass filters and those with reflective coatings. Reflective coatings can create specular reflections and the coating can scratch, minimizing the protection level of the eyewear.
9. Polycarbonate: Polycarbonate laser eyewear is lighter, less expensive and offers higher impact resistance than glass, but allows less visible light transmittance.
10. Diffuse Viewing Only (DVO): As the name implies, DVO eyewear is to be used when there is a potential for exposure to diffuse reflections only. DVO eyewear may not provide protection from the direct beam or specular reflections.

F. Alignment Eyewear: Alignment eyewear may be used when aligning low power visible laser beams. Alignment eyewear transmits enough of the specified wavelength to be seen for alignment purposes, but not enough to cause damage to the eyes. Alignment eyewear cannot be used during operation of high power or invisible beams and cannot be used with pulsed lasers.

G. Labeling of Laser Safety Eyewear

Laser safety eyewear shall be labeled with the optical density and the wavelength(s) the eyewear provides protection for. Additional labeling may be added for quick identification of eyewear in multiple laser laboratories.

H. Inspecting laser safety eyewear, check for:

1. Pitting, crazing, cracking and discoloration of the attenuation material.
2. Mechanical integrity of the frame.
3. Light leaks.
4. Damage to the lens coating.
5. Use care when cleaning eyewear and follow manufacturers’ instructions to avoid damage to absorbing filters or reflecting surface.

XI. Ultraviolet (UV) Laser Protection

A. Particular care shall be taken when using UV lasers due to the potential for significant photochemical bioeffects and the high level of scattering of UV radiation by air molecules. UV radiation may produce undesirable reactions, for example formation of skin sensitizing agents, ozone and other Laser Generated Airborne Contaminates (LGAC). Chronic eye and skin exposure to UV radiation may have long term adverse health effects which are not fully understood.

B. Exposure to UV radiation shall be minimized by using beam shields and clothing that attenuate the radiation to levels below the MPE for the specific UV wavelengths. For example, for an excimer laser operating in the UV, the use of a skin cover shall be employed if chronic (repeated) exposures are anticipated at exposure levels at or near the applicable MPE's for skin.

XII. Non-Beam Hazards

Non-beam hazards often exist in laser-related operations and can pose significant health and safety risks. All non-beam hazards must be addressed in SOPs. Examples of non-beam hazards may include:

A. Electrical hazards from power supplies

B. Laser generated air contaminants (LGAC), which may be generated when a Class 4 or some Class 3B lasers interact with matter. Materials such as plastics, composites, metals and biological tissues may release toxic, noxious or carcinogenic air contaminants. Ozone is produced around flash lamps and can build up with high repetition rate lasers.

C. Fire hazards from Class 4 lasers

D. Compressed gases

E. Laser dyes and solvents may contain complex fluorescent organic compounds. Hazards should be addressed in the laboratory chemical hygiene plan (CHP).

XIII. Laser Hazard Evaluation

A. Each laser installation will have hazards unique to that installation. Hazard considerations include optical hazards, skin hazards such as UV radiation, high voltages, ozone generation, toxic chemicals and gases (LGAC), etc.

B. 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 PI should contact the LSO for assistance in performing the hazard evaluation. The following hazards should be evaluated for each laser installation:

1. The laser and laser system's capability of injuring personnel.
2. The environment in which the laser is used.
3. The personnel who may use or be exposed to laser radiation.

XIV. Exposure Incidents

Seek medical attention in the event of an exposure or suspected exposure to laser radiation capable of an eye or skin injury. Notify the PI and LSO when exposure incidents occur. In the case of suspected eye injury from a laser, the LSO may require an eye examination by a qualified medical expert to evaluate laser induced eye injury.

ANSI Z136.1 "ANSI Standard for Safety User of Lasers", Appendix F, provides guidance for medical referral following suspected or known laser injury. This Standard does not recommend a medical surveillance program for laser users e.g. pre-screening for laser workers (ANSI Z136.1 Appendix F3).

Appendix A: Glossary

Administrative Control Measures
Procedures, training and warning signs designed to inform personnel to safety work near laser radiation.

ANSI Z136.1
"American National Standard for Safe Use of Lasers." This document is the regulatory laser protection standard in the US. The OSU Laser Safety Program is based on this standard.

Authorized Personnel
Individuals approved by management to operate, maintain, service, or install laser equipment.

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

Class 3B, Class 4 Laser (see Laser Classification)

Collecting Optics
Lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars, microscopes, or loupes. Collecting optics are a hazard in laser labs, and require particular attention when used around Class 1M or 2M lasers.

Continuous Wave (CW)
A laser operating with a continuous output for a period > 0.25 s is regarded as a CW laser.

Control Measure
A means to mitigate potential hazards associated with the use of lasers. Control measures can be divided into three groups: engineering, administrative (procedural), or personal protective equipment (PPE).

Cornea
The transparent outer layer of the human eye which covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

Critical Frequency
The pulse repetition frequency above which the laser output is considered continuous wave (CW). For example, for a short unintentional exposure (0.25 s to 10 s) to nanosecond (or longer) pulses, the critical frequency is 55 kHz for wavelengths between 0.40 and 1.05 μm, and 20 kHz for wavelengths between 1.05 and 1.40 μm.

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. A diffuse reflector will cause the reflected laser radiation to be spread over a wider area, and have a significantly reduced hazard level compared to the direct laser beam (see "Specular Reflection")

Divergence
The divergence is the increase in the diameter of the laser beam with distance from the exit aperture, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/e times the maximum value. Symbol: φ

Embedded Laser
An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission. Many laser cutters are Class 4 lasers in a Class 1 laser enclosure, and require no special laser safety precautions as long as the factory installed safety features remain intact.

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

Engineering Control Measure
Key controls, interlocks, beam housings, shutters, etc. designed to prevent exposure to hazardous levels of laser radiation. Engineering controls are considered the most effective laser safety control measures.

Erythema
Redness of the skin due to exposure from laser radiation.

Eye-safe Laser
A Class 1 laser product. Because of the frequent misuse of the term "eye-safe wavelength" to mean "retina-safe," (e.g., at 1.5-1.6 μm) and eye-safe laser to refer to a laser emitting at wavelengths outside the retinal-hazard region, the term "eye-safe" can be a misnomer. Hence, the use of eye-safe laser is discouraged.

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.

Intrabeam Viewing
The viewing condition whereby the eye is exposed to all or part of a laser beam.

Iris
The circular pigmented structure which lies behind the cornea of the human eye. The iris is perforated by the pupil.

Irradiance
Radiant power incident per unit area upon a surface, expressed in watts-per- centimeter-squared (W·cm-2). Symbol: E

Laser
An acronym for Light Amplification by Stimulated Emission of Radiation. A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both.

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 controlled laser area.

Laser Classification
An indication of the beam hazard level of a laser or laser system during normal operation. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4. In general, the potential beam hazard level increases in the same order. (see Appendix D)

Laser Controlled Area (LCA)
An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards. The Nominal Hazard Zone (NHZ) is within the LCA.

Laser-Generated Air Contaminants (LGAC)
Air contaminants generated when Class 4 and some Class 3b laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend on the target material, cover gas and beam irradiance. Materials such as plastics, composites, metals and tissues may release carcinogenic, toxic and noxious air contaminants. Ozone is produced around flash lamps and can build up with high repetition rate lasers. Special optical materials used for far infrared windows and lenses may also release hazardous air contaminants.

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

Laser Pointer
A laser product that is usually hand held that emits a low-divergence visible beam and is intended for designating specific objects or images during discussions, lectures or presentations as well as for the aiming of firearms or other visual targeting practice. These products are normally Class 1, Class 2 or Class 3R.

Laser Safety Officer (LSO)
One who has authority and responsibility 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.

M**acula**
The small uniquely pigmented specialized area of the retina of the eye, which, in normal individuals, is predominantly employed for acute central vision (i.e., area of best visual acuity).

Magnified Viewing
Viewing a small object through an optical system that increases the apparent object size. This type of optical system can make a diverging laser beam more hazardous (e.g., using a magnifying optic to view an optical fiber with a laser beam emitted). (see Collecting Optics)

Maximum Permissible Exposure (MPE)
The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin. The MPE is useful in laser safety calculations, such as determining the nominal hazard zone (NHZ).

Nominal Hazard Zone (NHZ)
Exposure within the boundary of the NHZ to direct, reflected, or scattered laser radiation has the potential to exceed the MPE and thus cause injury. Exposures beyond the boundary of the NHZ are below the MPE, and unprotected exposure will not cause damage to the eye or skin.

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

Non-beam Hazard
A class of hazards that result from factors other than direct human exposure to a laser beam. Examples include electrical hazards, compressed gases, chemical hazards from dyes or solvents, sharp objects and fire hazards.

Ocular Fundus
The interior posterior surface of the eye (the retina), as seen upon ophthalmoscopic examination.

Optically Aided Viewing
Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam (see Collecting Optics).

Optical Density (OD)
The OD is the measure of the laser radiation permitted to pass through a filter. Laser protective eyewear will always specify an OD for specific wavelengths of laser light. OD is a logarithmic scale: $OD = \log10\ (1/\tau\lambda)$ where $\tau\ \lambda$ is the transmittance at the wavelength of interest ($\tau\ \lambda$=flux received by filter/flux transmitted by filter). Symbol: $D(\lambda)$, $D\lambda$ or OD

Personal Protective Equipment (PPE)
Equipment worn to minimize exposure to laser radiation. The most common PPE is laser protective eyewear. Skin covering may be required for certain applications, e.g. long sleeved shirts for work around UV laser radiation.

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

Pulse Duration
The duration of a laser pulse, usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse. Symbol: t

Pulse-repetition Frequency (PRF)
The number of pulses occurring per second, expressed in hertz. Symbol: F.

Pulsed Laser
A laser which delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse is less than 0.25 s. (see Continuous Wave)

Pupil
The variable aperture in the iris through which light travels to the interior of the eye.

Q-switched Laser
A laser that emits short (~10-250 ns), high-power pulses by means of a Q-switch.

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.

Safety Latch
A mechanical device designed to require a conscious decision to override the latch to gain entry into a controlled area.

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.

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. The specular reflection of the laser can be as hazardous as the primary laser beam (see “Diffuse Reflection”)

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

Threshold Limit (TL)
The TL is an expression of the “resistance factor” for beam penetration of a laser protective device (such as eyewear filters, protective windows, and barriers). The Threshold Limit (TL) of the protective device is generally expressed in W·cm-2 or J·cm-2. It is the maximum average irradiance or radiant exposure at a given beam diameter for which a laser protective device provides adequate beam resistance. Thus, laser exposures delivered on the protective device at or below the TL will limit beam penetration to levels at or below the applicable MPE.

Ultraviolet Radiation
Electromagnetic radiation with wavelengths between 0.18 and 0.40 μm (shorter than those of visible radiation).

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.

Viewing Window
A visually transparent part of an enclosure that contains a laser process. It may be possible to observe the laser processes through the viewing windows.

Visible Light Transmission (VLT)
The percent of visible light transmitted through laser protective eyewear. The VLT of laser protective eyewear should be as high as possible to aid in viewing the work environment.

Visible Radiation (light)
The term is used to describe electromagnetic radiation which can be detected by the human eye. This term is used to describe wavelengths which lie in the range 0.4 to 0.7 μm. Derivative standards may legitimately use 0.38 – 0.78 μm for the visible radiation range.

Appendix B: OSU Laser Safety Training

Training is required for operators of Class 3B and Class 4 lasers. Training is available online at www.oregonstate.edu/ehs/laser.

The laser training covers the following topics:

- Fundamentals of laser operation
- Bioeffects of laser radiation on the eye and skin
- Significance of specular and diffuse reflections
- Non-beam hazards of lasers
- Laser and laser system classifications
- Control measures
- Management and employee responsibilities in the laser safety program
- Medical examination practices for laser injuries

OSU does not have formal training for Class 1, 2, 2M, 3A and 3R laser use. These lasers can be safely operated by following the manufacturer's instructions. More information is found in Appendix C "Control Measure for Specific Laser Applications" and Appendix D "Laser Classifications."

Appendix C: Control Measures for Specific Laser Applications

Control Measures for Laser Pointers

Laser Pointers shall not exceed Class 3R, and are exempted from area posting requirements. Users must be aware of the potential hazards and follow safety procedures provided by the manufacturer.

When used responsibly for the intended purpose such as an aid in visual presentations, laser pointers are valuable tools that present little potential hazard. However, laser pointers have received a lot of attention in the media and have raised public concern. The safety concerns regarding the use of lasers are the potential optical hazards. These optical hazards may be exposures from momentary direct viewing with the potential side effects being glare, flash-blindness, after images and possible startle effects. Typically these side effects last on the order of several minutes up to a few hours.

Under no circumstances will visible laser beams be directed toward automobiles, aircraft, or other manned structures or vehicles, or otherwise disrupt critical tasks.

Control Measures for Laser Levels

Laser levels and other laser devices used in construction are typically Class 3A or 3R. These can produce spot blindness and other eye injuries, but are safe to use if you follow the laser safety precautions from the manufacturer, and observe basic laser safety practices:

- Never stare into a laser beam.
- Don’t try to repair or disassemble a laser level.
- Read the instruction manual before you use a laser level.
- Never point a laser level at vehicles, drivers, people, or pets.
- Don’t let children play with laser levels.
- Always turn the laser level off when you’re not using it. Leaving it on increases the risk of someone unintentionally staring into the laser beam.
- Don’t remove or deface any laser level labels.
- The laser light is very bright compared to ordinary light, enough to cause an automatic aversion response against the intense light (blinking to close the eyelid, turning the head to avoid the light, automatic constriction of the pupil). Prevent injury to the eye by avoiding intentionally overcoming this aversion response.
- Don’t operate a laser level near flammable liquids, gasses, or dust.
- Don’t aim the laser beam at shiny or reflective surfaces; they’re not suitable for laser use.

Control Measures for Confocal Microscopes

Laser scanning confocal microscopes are Class 1 laser systems that contain embedded Class 3 or Class 4 lasers. When the confocal microscope is used as intended, no control measures are necessary.
If the protective housing is removed for alignment, maintenance or service activities, a temporary laser-controlled area shall be established and control measures appropriate to the class of the embedded laser shall be implemented.

Appendix D: Laser Classifications

Lasers classes are based on the capability of injuring personnel. The manufacturer is responsible for properly classifying lasers using US FDA regulations.

Human Aversion Response: Laser light is very bright compared to ordinary light, bright enough to cause an automatic aversion response against the intense light (blinking to close the eyelid, turning the head to avoid the light, automatic constriction of the pupil). The human aversion response of 0.25 seconds can be used to evaluate the potential for injury from visible laser light, such as Class 1, 2 and 3A lasers. Prevent injury to the eye by avoiding intentionally overcoming this aversion response. Note that Class 3B and Class 4 lasers are capable of causing injury before the aversion response has time to protect the eye; Class 3A and 3R have the potential in certain cases to cause injury before the aversion response can protect the eye.

Summary of Laser Classes and Hazards

Class 1
These are low-power lasers and laser systems that cannot emit radiation levels greater than the maximum permissible exposure (MPE). Class 1 lasers and laser systems are incapable of causing eye injury under normal operating conditions. This class may include lasers of a higher class whose beam are confined within a suitable enclosure so that access to laser radiation is physically prevented.

Class 1M
Class 1M lasers produce large-diameter beams, or beams that are divergent. The MPE for a Class 1M laser cannot normally be exceeded unless focusing or imaging optics are used to narrow down the beam. If the beam is refocused, the hazard of Class 1M laser may be increased and the product class may be changed.

Class 2
A Class 2 laser emits in the visible region. It is presumed that the human blink reflex (<0.25 seconds) will be sufficient to prevent damaging exposure, although prolonged viewing may be dangerous. Class 2 lasers are limited to 1 mW when operating in the continuous wave mode, or more if the emission time is less than 0.25 seconds.

Class 2M
A Class 2M laser emits in the visible portion of the spectrum in the form of a large diameter or divergent beam. It is presumed that the human blink reflex will be sufficient to prevent damaging exposure, but if the beam is focused down, damaging levels of radiation may be reached and may lead to a reclassification of the laser.

Class 3R
A Class 3R laser is potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffused-reflection hazard. Class 3R visible lasers (0.4 to 0.7 um) are limited to 5 mW when operating in continuous wave mode. For other wavelengths and pulse lasers, other limits apply.

Class 3B
Class 3B lasers are capable of causing eye damage from short-duration (< 0.25s) viewing of the direct or specularly-reflected beam. Diffuse reflections from these lasers are generally not hazardous, except for intentional staring at distances close to the diffuser.

Class 4
Lasers in this class are high powered and capable of causing severe eye damage with short-duration exposure to the direct, specularly-reflected, or diffusely-reflected beam. They are also capable of producing severe skin damage. Flammable or combustible materials may ignite if exposed to the direct beam. Accidental exposure to high powered Class 4 lasers may result in serious injury or death.

Appendix E: Alignment Procedures Guidelines

More laser accidents occur during beam alignment than any other laser manipulation. Use the following techniques to prevent accidents.

- Exclude unnecessary personnel from the laser controlled area during alignment.
- Perform alignment at the lowest possible power level.
- Use low-power visible lasers for path simulation of high-power visible or invisible lasers, when possible.
- Use a temporary beam attenuator over the beam aperture to reduce the level of laser radiation below the MPE, when possible.
- Wear laser safety eyewear during alignment. Laser alignment eyewear provides less protection than laser protective eyewear designed for full power operation, but alignment eyewear balances protection with ability to view the laser beam. Alignment eyewear may be used when operating the primary laser at low power, or when using a low power visible laser specifically for alignment. See Section 10 “Control Measures – Protective Equipment”.
- Use beam display devices (image converter viewers or phosphor cards) to locate beams when aligning invisible lasers.
- Use shutters or beam blocks to block high-power beams at their source except when needed during the alignment procedure.
- Use beam blocks to block high-power beams downstream of the optics being aligned
- Use beam blocks or protective barriers when alignment beams could stray into areas with uninvolved personnel.
- Place beam blocks behind optics such as turning mirrors to terminate beams that may miss the mirrors during alignment.
- Locate and block all stray reflections before proceeding to the next optical component or section.
- Ensure that all beams and reflections are terminated before resuming high-power operation.

Appendix G: Laser Inspection Checklist

Use the Laser Safety Checklist to evaluate your program. The checklist is derived from the current ANSI laser safety standard. The most recent version of the checklist is available on the EH&S Laser website:

http://oregonstate.edu/ehs/laser