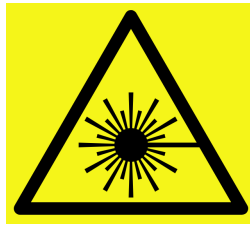


# **Laser Safety Program**



Environmental Health and Safety  
Office of Radiation Safety  
540-231-5364

**REVISION STATUS**

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# Section 1: Intro

## Purpose

The Laser Safety Program (LSP) at Virginia Tech is intended to ensure the safe use of laser systems by employees whose job responsibilities require the operation, maintenance, or servicing of Class 3R, Class 3B, or Class 4 lasers. The program is designed to minimize the risk of injury, death, or property damage associated with laser use by establishing clear safety practices, training requirements, and hazard control measures.

The LSP is structured in accordance with the ANSI (American National Standards Institute) Z136.1-2022, which provides nationally recognized guidance for the safe use of lasers in research, industrial, and educational environments. By aligning institutional practices with these standards, the program ensures that laser activities at Virginia Tech follow accepted best practices for hazard evaluation, control implementation, and personnel training. The program also supports compliance with regulations from the Occupational Safety and Health Administration (OSHA) governing workplace safety.

To meet these objectives, the Laser Safety Program:

- Classifies laser systems and evaluates associated hazards according to ANSI guidelines;
- Provides consultation on appropriate engineering and administrative controls to mitigate identified risks;
- Educates personnel on the potential biological effects of laser exposure;
- Trains authorized users in the proper and safe operation of laser systems;

Through these measures, the program promotes a culture of safety and responsible laser use while maintaining alignment with nationally recognized safety standards.

## Scope & Application

The LSP applies to all Virginia Tech employees and student researchers, regardless of worksite location, whose duties require them to:

- Operate, maintain, or service class 3R, 3B, or class 4 laser systems,
- Service embedded class 3R, 3B, or class 4 laser systems, or
- Align class 2 or higher laser systems.

In the following sections, this document will address the eight key elements to laser hazard management listed below:

- Roles & Responsibilities
- Laser Classification
- Laser Registration
- Laser Safety Training
- Beam Hazard Evaluation
- Non-Beam Hazard Evaluation
- Control Measures
- Laser Controlled Areas
- Emergency Response Procedures

## Section 2: Roles & Responsibilities

At Virginia Tech, principal investigators (PIs), employees, and Environmental Health & Safety are the three groups that have distinct responsibilities to comply with laser safety regulations. These three groups must each meet their obligations to effectively reduce laser safety hazards and prevent injury, death, or property damage.

### Environmental Health & Safety

The Virginia Tech Laser Safety Officer (LSO) is the Industrial Hygienist for Physical Agents from Environmental Health & Safety. The LSO shall:

- Administer the Laser Safety Program at Virginia Tech.
- Classify, or verify classifications of 3R, 3B, and class 4 laser systems at Virginia Tech.
- Review new laser requisitions requests with Procurement.
- Approve laser installation facilities and laser equipment prior to use.
- Periodically audit laser installation facilities, laser equipment, and protective equipment for laser work area hazards.
- Consult and advise on engineering and administrative controls to reduce laser work area hazards.
- Establish Nominal Hazard Zones in laser work areas.
- Approve alignment and standard operating procedures that are administrative controls.
- Approve the wording of area signs and equipment labels.
- Approve laser installation facilities and laser equipment prior to use.
- Provide safety education and training to authorized laser users.
- Determine medical surveillance requirements when applicable.
- Perform laser accident investigations.

### PI (Laser Owner of Laser System Supervisor) Responsibilities

PIs oversee specific laser facilities, laser equipment, and protective equipment and shall:

- Register all class 3R, 3B, and 4 lasers with Environmental Health & Safety using the Safety Management System before operating the laser system.
- Recognize the potential hazards of the laser system under their authority and control.
- Provide appropriate education and training to employees operating, maintaining, or servicing the laser system before they are allowed to perform these duties.
- Assure all users of the laser system(s) have attended Environmental Health & Safety laser safety training.
- Perform a hazard assessment to determine what PPE is required.
- Prohibit laser system use unless appropriate controls are utilized.
- Provide the Laser Safety Officer (LSO) with names of employees authorized to operate, maintain, or service the laser system using the Safety Management System.
- Provide the LSO with documentation of employee education and training using the Safety Management System.
- Provide the LSO with a Class 3R, 3B or 4 laser system's Standard Operating Procedures (SOPs) for operation, maintenance, and service and Class 2 laser system alignment SOPs using the Safety Management System.
- Notify the LSO of new equipment or facilities modifications prior to installation or activation.
- Notify the LSO immediately of any laser system accident (both beam and non-beam).

## Employees & Student Researchers

Employees and student researchers are those personnel the laser system supervisor authorizes to use the laser system and shall:

- Recognize the potential hazards of the laser system.
- Receive appropriate education and training to operate, maintain, or service the laser system.
- Utilize appropriate controls when using the laser system.
- Notify the laser system supervisor (or LSO if the supervisor is not available) immediately of any laser system accident (both beam and non-beam).

## Section 3: Laser Classification

### FDA Regulations

Laser safety standards are derived from government-mandated regulations and voluntary standards. Safety rules governing the manufacture of lasers are established by the Federal Government. Laser products manufactured after Aug. 2, 1976 must conform to performance standards established by the Food and Drug Administration (FDA), (21 CFR 1040.10). The standard requires that lasers be properly classified and labeled by the manufacturer. Thus, for most lasers, measurements or calculations to determine the hazard classification are not necessary. In addition, the standard establishes certain engineering requirements for each class and requires warning labels that state maximum output power. The performance standard regulates the manufacturer of lasers but does not address the safe use of lasers.

### OSHA Regulations

OSHA Regulations (29 CFR 1926.54 and 102) specify generalized rules for the safe use of lasers in the construction industry. These include user training, posting and labeling requirements, laser safety goggles, and maximum exposure intensities. Requirements for the use of laser goggles in the general industry are specified in sections 1910.132-133. The safe use of lasers in the general industry (including research laboratories) is covered under OSHA's General Duty Clause which states that employers must furnish employees a place of employment that is free from recognized hazards that are likely to cause death or serious injury. Extensive recommendations for the safe use of lasers have been developed by the American National Standards Institute (ANSI Z136 series).

Since August 1976 manufacturers have been required by Federal law to classify lasers. If the class is not known, one can be determined by measurements and/or calculations. Lasers are classified according to the ability of the primary or reflected beam to injure the eye or skin. The appropriate class is determined from the wavelength, power output, and duration of a pulse (if pulsed). Classification is based on the maximum accessible output power. There are four laser classes, with Class 1 representing the least hazardous. All lasers, except Class 1, must be labeled with the appropriate hazard classification.

### Class 4

Class 4 lasers are the most hazardous lasers. Exposure to the primary beam, specular reflections, and diffuse reflections are hazardous to the skin and eyes. In addition, class 4 lasers can ignite flammable targets, create hazardous airborne contaminants and usually contain a potentially lethal high voltage supply. The power output for CW lasers operating in all wavelength ranges is greater than 500 mW. All pulsed lasers operating in the ocular focus region (400 nm to 1,400 nm) should be considered Class 4.

### Class 3B

Class 3B lasers can produce accidental injuries to the eye from viewing the direct beam or a specularly reflected beam. Class 3B laser power outputs are between 5 - 500 mW for CW lasers. Except for higher power Class 3B lasers, this class will not produce a hazardous diffuse reflection unless viewed through an optical instrument.

## Class 3R

Class 3R (IIIA under the old classification) lasers cannot damage the eye within the duration of the blink, or aversion response (0.25 sec). However, injury is possible if the beam is viewed through binoculars or similar optical devices, or by staring at the direct beam. Power outputs for Continuous Wave (CW) lasers operating in the visible range are between 1 - 5 mW.

## Class 2

Class 2 lasers are incapable of causing eye injury the duration of the blink, or aversion response (0.25 sec). Although these lasers cannot cause eye injury under normal circumstances, they can produce injury if viewed directly for extended periods of time. Class 2 lasers only operate in the visible range (400 - 700 nm) and have power outputs between 0.4  $\mu$ W and 1 mW for CW lasers. The majority of Class 2 lasers are helium-neon devices.

## Class 1

Class 1 laser devices cannot produce damaging radiation levels to the eye even if viewed accidentally. Prolonged staring at the laser beam, however, should be avoided as a matter of good Industrial Hygiene practice. This class has a power output of less than 0.4  $\mu$ W for Continuous Wave (CW) lasers operating in the visible range. A completely enclosed laser is classified as a Class I laser if emissions from the enclosure cannot exceed limits for a Class 1 laser. If the enclosure is removed, e.g. during repair, control measures for the class of laser contained within are required.

## Unknown Class

Laser classification can be determined by measuring the output irradiance or radiant exposure using instruments traceable to the National Bureau of Standards. These measurements should only be performed by qualified personnel. The laser class can also be determined from calculations. For CW lasers, the wavelength and average power output must be known. Classification of pulsed lasers requires the following information: wavelength, the total energy per pulse (or peak power), pulse duration, pulse repetition frequency (PRF), and emergent beam radiant exposure. Also, laser source radiance and maximum viewing angle subtended by the laser must be known for extended-source lasers, such as injection laser diodes. Detailed information on classifying lasers may be found in the ANSI Z136.1-2022.

# Section 4: Laser Purchasing & Registration

## Laser Purchasing

**Step 1: Approval** - Prior to purchasing or receiving a Class 3R, 3B, or Class 4 laser/laser system, laser cutter/engraver, or confocal microscope, you must receive approval from the Laser Safety Officer (LSO).

1. Email the LSO (Donald Conner, [dcon@vt.edu](mailto:dcon@vt.edu)) with the following information:
  - a. Purpose and intended location of laser
  - b. Power and other physical characteristics (i.e. class, type, wavelength, etc.)
    - i. \*\*The best source of that information is the laser manufacturer's user manual.
  - c. Necessary control measures
  - d. [Standard Operating Procedure \(SOP\)](#) required for all class 3B & 4 lasers.
  - e. Names and PIDs of authorized laser users
2. The LSO will review this information and provide additional safety recommendations for control measures and personal protective equipment, as needed.
3. Once approved by the LSO, the laser or laser system can be acquired.

**Step 2: Purchase** - After receiving approval from the LSO, you should purchase your laser through HokieMart. Make sure to use the right codes to speed up procurement.

**\*\* Lasers are not procured until reviewed by the LSO.**

### **HokieMart codes:**

- 22412 for Class 3R, 3B, 4 lasers (greater than \$2,000)
- 22417 for Class 3R, 3B, 4 lasers (less than \$2,000)
- 22413 for Laser Engravers/Cutters with embedded Class 3R, 3B, 4 lasers (greater than \$2000)
- 22418 for Laser Engravers/Cutters with embedded Class 3R, 3B, 4 lasers (less than \$2,000)

### **\*\* Class definitions:**

- Class 3R limited to 5 mW,
- Class 3B ranges between 5 mW - 500 mW,
- Class 4 from 500 mW or greater.

**Get more information:** Contact [procurement.vt.edu](http://procurement.vt.edu).

## Laser Registration

**Step 3: Register** - Register all **Class 3B, 3R, & 4 laser systems**, all **laser cutters/engravers**, and all **confocal microscopes** with Environmental Health & Safety. Registration requires basic information about your laser system. The best source of that information is the laser manufacturer's user manual. Please use it along with your lab-specific information.

You can save and manage your registration in the [Safety Management System](#) and return to it as necessary.

For all Class 3B and Class 4 laser systems, you must also conduct a laser hazard analysis (LHA) on the proposed laser set up. This should be completed by the PI/Laser Owner. The LHA should be an overall examination of the laser system to evaluate risks based on laser class, wavelength, and power, examining both

beam and non-beam hazards. More information on this process is provided in the Laser Safety Program PDF, Section 6. Please fill in the EHS Laser SOP Template as you complete this process and upload it to the SMS with your laser registration. If your laser was purchased recently, you likely already completed this process in Step 1: Approval.

Once registration is complete, the Laser Safety Officer (LSO) will contact you to discuss any necessary modifications to meet compliance requirements. The LSO will also help you to determine appropriate eyewear for your laser or laser system, if you do not already have it.

***Lasers that are not currently in use must also be registered with EHS as “Inactive”. If the laser enters use again, make sure to update its status in the SMS.***

**When registering your laser in the [Safety Management System](#) make sure to have the following information prepared:**

- Location, PI (or custodian), number of users
- Laser type, power, and class
- Primary and secondary wavelength or range
- Manufacturer, Model #, and Serial #
- Beam distribution, shape, diameter, and divergence
- Laser operating mode and pulse details (if applicable)
- Cooling method? Dye? Target material? LGACs?
- Control measures (including SOP) and eyewear

**\*\* For all class 3B and 4 laser systems, make sure you have developed a [Standard Operating Procedure \(SOP\) using the 2026 template](#).**

## Section 5: Training Information

### Authorized Laser Users

Two tiers of training are required for all laser users. Laser users must complete basic laser safety training through EHS. Additionally, they should be trained on lab specific protocol by the laser owner (PI).

**EHS Training:** Before working with laser classes 3R, 3B, or 4, all personnel must register for and attend laser safety training. Environmental Health & Safety provides classes regularly and upon request. Please visit the [EHS training page](#) and select “Laser Safety”.

**Laser Specific Training:** All authorized laser users must also receive laser specific training from the PI. This second-tier training should include but not be limited to location of the laser, power output, wavelength, start and stop procedures, and specific personal protective equipment (PPE).

### Principal Investigator (PI) responsibilities

As the PI, you must train all Authorized Laser Users to follow the SOPs you developed for your laser system. You are responsible for keeping signed SOP training records. These records must be available to EHS during an inspection or upon request.

### For more information

Contact the Laser Safety Officer or call 540-231-5364.

# Section 6: Hazards

## Beam Hazards

### Biological Risks

When evaluating the potential harm from laser exposure, four primary factors must be considered: the body part exposed, the wavelength of the laser, the laser's power, and the duration of exposure. These factors are closely interrelated and must be assessed together during any hazard analysis. The parts of the body most vulnerable to laser radiation are the eyes and skin, each of which contains tissues that may be affected differently depending on the characteristics of the laser.

#### Eyes

The human eye is highly vulnerable to injury from exposure to laser radiation. The severity and type of injury depend on the laser's intensity, wavelength, and the duration of tissue exposure. Damage can occur through thermal effects or through photochemical reactions. Acute exposure may lead to burns of the cornea or retina, while repeated or chronic exposure can result in cataract formation or long-term retinal damage. Retinal injury is of particular concern for wavelengths in the visible and near-infrared regions.

Unlike most sources of incoherent light, which disperse energy broadly and deliver only a small fraction of their output to the eye, laser radiation is coherent and directional. A laser beam entering the eye can pass through the pupil and focus on a very small spot on the retina, depositing all its energy on this area. Visible and near-infrared wavelengths pose the greatest risk to the retina, causing partial or total vision loss if the optic nerve is damaged. These injuries may occur without immediate pain or noticeable symptoms but may be irreversible.

In addition to thermal damage, very high-powered, short-pulse lasers—such as Carbon Dioxide Lasers and Nd YAG Lasers operating in mode-locked configurations—can produce mechanical disruptions of retinal tissue. The rapid energy deposition from these lasers may cause retinal rupture or hemorrhage, further increasing the potential for severe eye injury.

#### Skin

Damage to the skin is also possible from exposure to laser beams. Acute exposure may cause injuries ranging from mild reddening to blistering and charring. Skin cancers may result from chronic exposure to ultraviolet light. The extent and type of damage depend on the amount of energy deposited and the wavelength of the light. Unlike injury to the eye, acute damage to the skin is usually repairable.

### Wavelength Specific Risks

**Ultraviolet Radiation (200 - 400 nanometers)** - Exposure to the eye from ultraviolet light in the 200 - 315 nm range is absorbed by the cornea and may cause photokeratitis (corneal inflammation). Unlike the skin, repeated exposure of the cornea to ultraviolet light does not result in a protective mechanism. Near ultraviolet light between 315 - 400 nm is absorbed largely in the lens and may cause cataracts. Wavelengths less than 400 nm do not pose a hazard to the retina.

Exposure to the skin from lasers that emit in the UV region may cause a photochemical reaction resulting in reddening, aging, and possibly skin cancer.

Examples of lasers operating in the ultraviolet region include the neodymium: YAG-Quadrupled (QSW & CW), and the Ruby (doubled) laser.

**Visible and Near-Infrared Radiation (400 - 1,400 nanometers)** - Exposure to laser beams in the visible (400 - 700 nm) and near-infrared (700 - 1,400 nm) regions of the spectrum may damage the retina. Laser beams in this region are readily transmitted by the eye and focused by the lens to produce an intense concentration of light energy on the retina. The incident exposure on the cornea can be concentrated by a factor of approximately 100,000 times at the retina due to this focusing effect. This energy is converted to heat and may cause a retinal burn resulting in visual loss or even blindness if the optic nerve is injured. Even low-energy laser beams, if concentrated by a factor of 100,000, can cause damage to the eye. For this reason, wavelengths in the 400 - 1,400 nm range are termed the ocular hazard region.

Exposure to the skin from laser beams in the visible and infrared regions may cause photosensitive reactions, skin burns, and excessively dry skin.

Lasers operating in the visible region of the spectrum include the ruby, neodymium: YAG (doubled), helium-cadmium, helium-neon, argon, and krypton. Lasers operating in the near-infrared region include the neodymium: YAG, gallium arsenide, and helium-neon.

**Middle and Far-Infrared Radiation (1,400 - 10,000 Nanometers)** - Laser beams in the middle and far-infrared regions produce injury primarily to the cornea and to a lesser extent the lens. Damage is usually from heating effects, although pulsed lasers such as the carbon dioxide laser may cause injury from thermomechanical effects. Virtually no light reaches the retina beyond 1,400 nm. Middle-infrared radiation between 1,400 nm and 3,000 nm may penetrate deep into the lens causing cataracts. Far-infrared radiation in the 3,000 - 10,000 nm range is absorbed by the cornea and may cause corneal burns and loss of vision.

The major danger to the skin from lasers operating in this region is burn damage.

Lasers operating in this region include hydrogen fluoride, carbon monoxide, carbon dioxide, and hydrogen cyanide.

## Beam Hazard Computations

### Maximum Permissible Exposure

Various agencies have developed Maximum Permissible Exposure (MPE) values to laser radiation for the eye and skin. These are recorded in Table 5 of ANSI Z136.1-2014. The MPE is the value at which personnel may be exposed without adverse biological change. The laser system manufacturer should provide the MPE value(s) associated with the laser system.

The LSO can assist the PI or Laser System Supervisors in determining the MPE value(s) for a specific laser system using:

- Wavelength
- Anticipated exposure duration
- Viewing conditions

After determining the MPE, the next step in Beam Hazard Evaluation is defining the Nominal Hazard Zone (NHZ). The NHZ is the space in which the direct, reflected, or scattered laser radiation exceeds the MPE. Again, the manufacturer should provide the Nominal Hazard Zone. If not, the LSO can assist the PI in defining this zone. For powerful lasers, the NHZ can extend for thousands of meters.

## Nominal Hazard Zone

The LHA should also identify two nominal hazard zones (NHZ), one for eyes and one for skin. The nominal hazard zones are measures of distance that denote the minimum distance an individual can be from a laser before it is no longer hazardous for direct exposure. Beyond the NHZ, the laser will have diverged enough to where the average energy impacting the person is incapable of harm. Knowing the NHZ for a laser determines whether curtains or other barriers are necessary.

## Non-Beam Hazards

In addition to the hazards of the laser beam, protection is also necessary from other hazards associated with the operation of the laser. These non-beam hazards include explosions, electrical shocks, cryogenic liquids, flammable liquids, noise, x-rays, UV radiation, and laser-generated air contaminants.

**Electrical Hazards** - Lethal electrical hazards may be present, especially around high-power laser systems. To date, the most common cause of death associated with laser system use is electrocution.

Continuous-wave lasers use direct current or radiofrequency power supplies and pulsed lasers employ large capacitor banks for electrical storage. Lasers and associated electrical equipment must be designed, constructed, installed, and maintained in accordance with the latest revision of the National Electrical Code® (NEC), the Occupational Health and Safety Administration (OSHA) standards, and other applicable industry standards including the American National Standards Institute (ANSI) and the Institute of Electrical and Electronics Engineers, Inc. (IEEE). Electrical work performed must be conducted in accordance with [Virginia Tech's Electrical Safety Program](#), and all personnel performing work on energized circuits or systems must be trained as electrical qualified persons. This training can be arranged by calling Environmental Health & Safety at 540-231-2341. Electrical circuits greater than 42.5 volts are considered hazardous unless limited to less than 0.5 mA.

To reduce electrical hazards, high voltage sources and terminals must be enclosed unless the work area is restricted to qualified persons only. Whenever feasible, power must be turned off and all high-voltage points grounded before working on power supplies. Capacitors must be equipped with bleeder resistors, discharge devices, or automatic shorting devices. Appropriate lockout/tagout procedures must be determined and the requirements of Virginia Tech's Lockout/Tagout Program must be followed at all times; personnel performing lockout/tagout must be trained and authorized. This training can be arranged by calling 540-231-3600. Operators are not to stand on metal floors, or in the

water while working with live electronic equipment. Accessible, non-current carrying metallic parts of laser equipment must be grounded. Electrical circuits should be evaluated with respect to fire hazards.

**Laser Generated Air Contaminants (LGACs)** - Vaporized target materials, toxic gases, vapors and fumes may be present in a laser area. Ozone is produced around flash lamps and concentrations of ozone can build up with high repetition rate lasers. Asbestos fibers may be released from the firebrick used as backstops for carbon dioxide lasers.

The increasing use of chemical lasers may introduce chemical hazards that are more dangerous than laser radiation. For example, fluorides used in a fluoride laser are highly toxic and demand immediate emergency measures upon contact. He-Cd lasers may contaminate the laboratory with toxic cadmium vapors if the exhaust gases are not vented to the outside. The dyes that are the active medium of tunable lasers are often very toxic and may cause acute or chronic skin problems. Some dyes may be carcinogenic. Gloves, laboratory coats, and proper eye protection must be worn when handling hazardous chemicals. An eyewash station and emergency shower shall be available in areas where there is a possibility that hazardous chemicals may be splashed in the eyes or on the skin. Food or drink should not be consumed in the laser lab if potential toxic air contaminants or chemicals are present. Adequate general ventilation or local exhaust must be maintained in laser installations to ensure that toxic air contaminants are below acceptable limits.

**Flammable Hazards** - Flammable solvents, gases, and combustible materials may be ignited by a Class 4 laser beam. Laser beams should be terminated by a non-combustible material such as a brick. Combustible solvents or materials must be stored in proper containers, and shielded from the laser beam or electrical sparks. Lasers and laser facilities must be constructed and operated to eliminate or reduce any fire hazard. Unnecessary combustible materials should be removed in order to minimize fire hazards. Laser laboratories should contain an appropriate fire extinguisher.

**Explosions** - Lasers and ancillary equipment may present explosion hazards. High-pressure arc lamps and filament lamps used to excite the lasing medium must be enclosed in housings that can withstand an explosion if the lamp disintegrates. In addition, the laser target and elements of the optical train may shatter during laser operation and should be enclosed in suitable protective housing. Capacitors may explode if subjected to voltages higher than their rating and must be adequately shielded; it is recommended that capacitors be equipped with current-limiting devices. High energy capacitors must be enclosed in one-eighth inch thick steel cabinets.

**Laser Dyes** - The organic dyes used in some laser systems are known to be carcinogens, mutagens, or teratogens. Proper laboratory safety protocols must be used when preparing, storing, handling, using, and disposing of laser dyes. Refer to the [Chemical Hygiene Plan](#) for more information on chemical safety.

**Cryogenics** - Cryogenic liquids (especially liquid nitrogen) may be used to cool the laser crystal and associated receiving and transmitting equipment. These liquified gases are capable of producing skin burns and may replace the oxygen in small unventilated rooms. The storage and handling of cryogenic liquids must be performed in a safe manner. Insulated handling gloves of quick removal type should be worn. Clothing should have no pockets or cuffs to catch spilled cryogenics. Suitable eye protection must be worn. If a spill occurs on the skin, flood the skin contact area with large quantities of water. Adequate ventilation must be present in areas where cryogenic liquids are used.

**Noise** - Noise levels in laser laboratories can exceed safe limits because of high voltage capacitor discharges. Hearing protection may be required. The Laser System Supervisor should contact 540-231-3600 if a potential noise hazard exists.

**X-Rays** - X-ray production is possible when voltages exceed 15 kV. Although most laser systems use voltages less than 8 kV, some research models may operate above 20 kV. Laser systems capable of producing ionizing radiation must be surveyed by the Radiation Safety team to ensure that X-ray levels are within legal limits.

**Ultraviolet Radiation** - Although laser radiation presents the chief hazard, it may not be the only optical hazard. Laser discharge tubes and pumping tubes may emit hazardous levels of ultraviolet radiation and should be suitably shielded. Particular care should be used with quartz tubes. Most lasers now use heat-resistant glass discharge tubes which are opaque in the UV-B (280 - 315 nm) and UV-C (100 - 280 nm) spectrum.

**Ergonomics** - There may be ergonomic hazards associated with the operation, maintenance, or service of the laser system. These ergonomic hazards such as awkward postures could contribute to improper actions if not addressed. The supervisor should refer to the Workplace Ergonomics Program.

## Hazard Analysis

Before a Class 3B/4 laser is operated, a laser hazard analysis (LHA) must be performed on the proposed setup. This should be done by the PI/Laser Owner. The LSO can provide assistance with this if requested. The LHA should be an overall examination of the laser system to evaluate risks based on class, wavelength, and power. It should examine both beam and non-beam hazards (as outlined above) and identify the maximum permissible exposure and nominal hazard zone for the laser system.

## Section 7: Control Measures

### Control Measures for Laser Radiation

The first step in safe laser use is to identify the class involved and then comply with the appropriate control measures. Control measures are designed to reduce the possibility of exposure to the eye and skin from hazardous laser radiation. Preventing ocular exposure from the primary beam and specular reflections is of primary concern because blindness or serious injury to the unprotected eye is possible.

Following the hierarchy of controls (Fig. 1), where elimination or substitution for a less hazardous process are not possible, priority should be given to the implementation of engineering controls to reduce laser hazards. Although commercial laser products manufactured since 1976 incorporate many engineering controls, the use of additional controls should be considered to reduce the risks. The most effective engineering control is to totally enclose the laser and all beam paths. The potential for exposure to hazardous laser radiation is probably greatest in the research laboratory where open and high-power laser beams are frequently encountered. Because researchers need the flexibility to change optical arrangements and make adjustments during experimental procedures, laser beams cannot always be totally enclosed.

Generally, in research laboratories where engineering controls cannot be relied upon, administrative controls, protective eyewear, and properly supervised laser-controlled areas must be rigorously enforced to reduce hazards. However, OSHA standards are performance-based which focuses efforts on reducing hazards. This regulation can provide some flexibility in how hazards are eliminated or controlled but they still must be controlled.

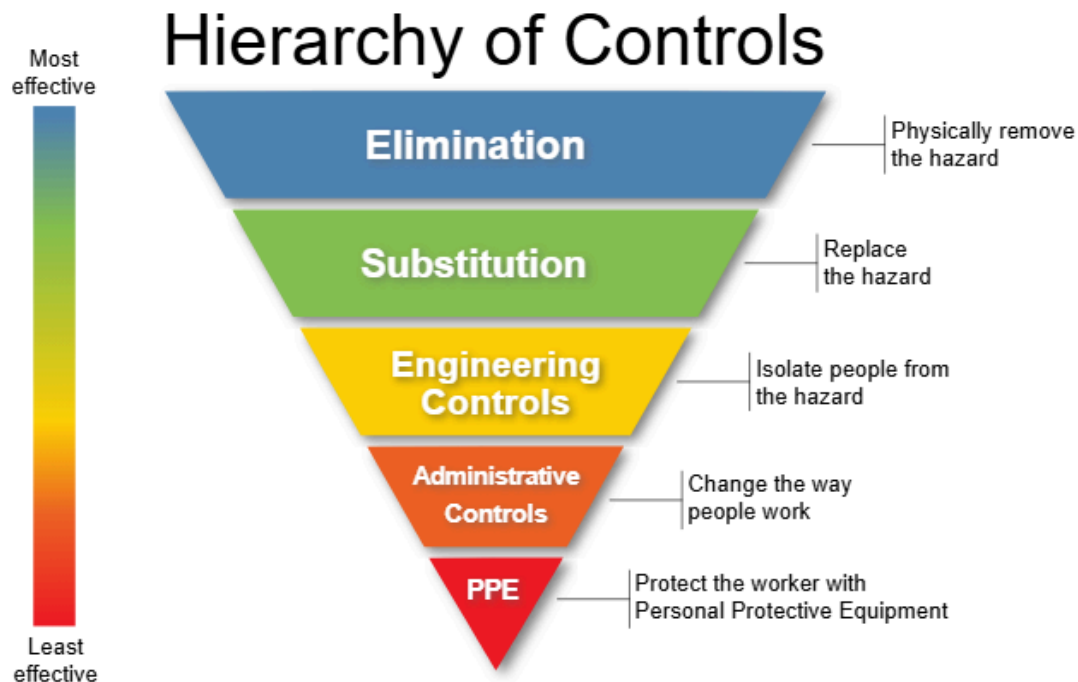


**Fig. 1. Hierarchy of Controls** - The hierarchy of controls is an OSHA-recognized five-level system used to minimize or eliminate workplace hazards.

# Engineering Controls

## Laser Access & Viewing

- **Protective Housing (All Classes)** - A protective housing shall be provided by the manufacturer to prevent access to laser radiation that exceeds the intended classification. If the protective housing is removed, as in research laboratories, control measures shall be based on the maximum accessible radiation.
- **Safety Interlock (All Classes)** - Any portion of the protective housing designed to be removed without tools shall be interlocked to prevent access to radiation in excess of the applicable class or to exposed energized circuitry.
- **Remote Interlock Connector (Class 3B, 4)** - A remote interlock connector shall be provided to allow electrical connections to an emergency disconnect interlock or a door interlock.
- **Optical Viewing Devices and Windows (All Classes)** - Viewing optics (including lenses, telescopes, microscopes, and viewing windows) shall not be used to view the direct beam or specular reflections unless an appropriate filter is used or adequate laser protective eyewear is worn to reduce laser radiation to safe levels.

## Laser & Optics Set Up

- **Firm Laser Mount (Class 2, 3R, 3B, 4)** - The laser must be mounted on firm support to ensure that the beam travels along its intended path.
- **Beam Stop or Attenuator (Class 3R, 3B, 4)** - Potentially hazardous beams should be terminated by a permanently attached beam stop or attenuator. The beam stop should be non-reflecting and fire-retardant.
- **Enclosed Beam Path (Class 3B, 4)** - The entire beam path, including the target area, should be enclosed if possible. Safety interlocks must be used with the enclosure. If the beam is enclosed the laser system could revert to a less hazardous laser classification.
- **Beam shutters (Class 3B, 4)** - Lasers should be equipped with a beam shutter that covers the aperture. The shutter should completely stop the laser beam. Black, non-reflective material is desirable.

## Laser Initiation & Warning Systems

- **Key-Switch (Class 3B, 4)** - Class 3B and 4 lasers shall be provided with a keyed switching device. The key shall be removable and the laser shall be inoperable once the key has been removed.
- **Emission Indicator (Class 3B, 4)** - Laser systems shall incorporate an emission indicator that provides a visible or audible signal during radiation emission.

- **Warning System (Class 3B, 4)** - A visible or audible warning device that activates prior to laser emission should be provided. The delay time should be sufficient to allow personnel to avoid exposure to the beam.

## Administrative & Procedural Controls

**Registration (Class 3R, 3B, 4)** - Lasers shall be registered with the Laser Safety Officer (LSO).

**Standard Operating Procedures (Class 3b, 4)** - Written standard operating procedures (SOP) are required for Class 3b and 4 lasers. The PI or laser system supervisor will provide the LSO with a draft SOP using the Laser SOP Template (2026), linked [here](#) or located on the [EHS Laser Safety Page](#). The SOP describes the application of the laser, startup and shutdown procedures, as well as procedures for alignment, and a full assessment of hazards and control measures.

**Reduction of Intensities (Class 3R, 3B, 4)** - If the full output power is not needed, the laser beam intensity should be reduced to a less hazardous level by using absorbing filters or beam shutters.

**Alignment (All Classes)** - Alignment of laser optical components (mirrors, lenses, beam deflectors, etc.) shall be done in a manner that ensures the eyes are not exposed to hazardous levels of radiation.

**Unattended Operation (All Classes)** - Operating lasers should not be left unattended for appreciable lengths of time. Lasers should be turned off and the key removed, or beam shutters or caps should be used when laser transmission is not required.

**Beam Direction (All Classes)** - The laser beam shall not be directed at people or into potentially occupied areas. Experiments should be designed so that the laser beam is not at eye level while sitting or standing.

**Workers and spectators shall not be exposed to light intensities above:**

- Direct staring: 1 microwatt per cm<sup>2</sup>
- Incidental observing: 1 milliwatt per cm<sup>2</sup>
- Diffused reflected light: 2.5 watts per cm<sup>2</sup>
- Directing beam at people (All Classes)

**Spectators (Class 3B, 4)** - Spectators must not be allowed in a laser-controlled area containing an unenclosed Class 3B or 4 laser unless permission has been obtained from the supervisor, potential hazards have been explained, and appropriate protective measures are taken.

**Warning Signs and Labels** - Warning signs and labels shall be in accordance with the FDA Performance Standard and ANSI Standards. Signs and labels shall be conspicuously displayed on equipment and on access doors where applicable. Additional precautionary instructions, such as eye protection required, must be included on the sign or label.

- **Class 1** - Warning labels and signs are not required for Class 1 lasers. **Enclosed Class 1 lasers** containing more hazardous laser radiation within shall have a warning label located on the access panel.
- **Class 2** - The label must include the laser hazard symbol and the words "CAUTION- Laser Radiation- Do Not Stare into Beam", the class, and the type of laser. Warning signs on doors are not required.

- **Class 3R** - Signs and labels shall include the laser hazard symbol and bear the words "CAUTION- Laser Radiation- Do Not Stare into Beam or View Directly with Optical Instruments", the class, and type of laser. Entrances to laser areas must be posted with a warning sign.
- **Class 3B** - Signs and labels shall include the laser hazard symbol and bear the words "DANGER- Laser Radiation- Avoid Direct Exposure to Beam", the class, and type of laser. Doors leading to the laser area shall be posted with warning signs.
- **Class 4** - Appropriate warning signs must be posted on equipment and doors leading to the facility. Signs and labels shall include the laser hazard symbol and bear the words "Danger- Laser Radiation- Avoid Eye or Skin Exposure to Direct or Scattered Radiation", the class, and type of laser. Additional precautions or protective actions should be provided as needed.

## Personal Protective Equipment (PPE)

**Safety Eyewear (Class 3R, 3B,4)** - Laser eyewear designed to protect the specific wavelengths of the laser shall be worn when exposure to hazardous levels of laser radiation are possible. Laser safety eyewear shall be worn in areas where unenclosed Class 3B or 4 lasers are operated. The optical density of the eyewear shall reduce the laser radiation to the eye to safe levels. Safety eyewear shall be labeled with the optical density of the lens and the wavelength that it protects against. More information about selecting appropriate eyewear is included below in the "Laser Safety Eyewear" section.

## Laser Control Areas

When the entire beam path from a Class 3B or Class 4 laser is not sufficiently enclosed and/or baffled to ensure that radiation exposure will not exceed the MPE, a laser controlled area is required. Access to the controlled area should be restricted to authorized personnel during the operation of the laser.

### Requirements for Class 3B and Class 4 Controlled Areas:

- Laser controlled areas must be posted with appropriate laser warning signs. The ANSI WARNING sign format is required for all Class 3B and some Class 4 lasers. Class 4 multi-kW lasers are required to use the DANGER sign format. The sign should indicate that protective eyewear must be worn before entering the restricted area. See Appendix E for sign details.
- Lasers are to be operated only by qualified and authorized personnel. All authorized personnel must have completed the EHS laser safety training.
- The laser beam path must be located and secured above or below eye level for any standing or seated position.
- Laser beam shall not be transmitted from an indoor laser controlled area.
- Safety eyewear of appropriate specifications must be used within the LCA. Eyewear must be in sufficient condition to properly protect a wearer. It should be available at the entrance to the LCA.
- The LSO should have approved an SOP for the use of the laser.

## Requirements for Class 4 & Recommendations for Class 3B Controlled Areas:

*Unenclosed Class 4 lasers must be restricted to a well-controlled area suitably administered and designed to protect personnel from exposure to laser radiation. The following requirements are in addition to those required for a Class 3B control area. These controls are also highly recommended for Class 3B LCAs. Some may be required for 3B systems, considering the wavelength and power of the laser and hazards posed to laser users. Please consult the LSO if you are unsure what control measures are necessary for your laser.*

- Access to the controlled area must be restricted to authorized personnel during the operation of the laser.
- A warning light connected to the power supply or shutter must be installed to indicate when the laser is powered on.
- The laser should have a master switch or key that controls its activation. If a key exists, it should not be stored in place within the lock. A switch may be physical or computerized.
- There should be a well-indicated emergency stop or “Panic Button” that disables or weakens the laser to safe levels.
- Specular surfaces should be removed from the beam path, if possible. If removal is not possible the surfaces should be painted a flat black color or covered with a diffuse material. The intended target should be a diffuse, absorbing material to prevent reflections.
- To reduce the possibility of specular reflections, personnel should not wear watches or jewelry in controlled areas.
- Beam blockers should be in use to prevent the beam from leaving the planned area of operation into the wider LCA. The work area must be separated from the surrounding environment by walls, panels, or black flameproof heavy curtains.
- Walls in the laser laboratory should be dark, dull, and non-reflecting of the wavelengths used.
- The facility must be light-tight. Windows and other openings should be covered to prevent the transmission of hazardous laser radiation to potentially occupied areas.
- If possible, Class 4 lasers should be operated by remote control and monitored by television.
- If the laser is not in use, it should be stored away or otherwise disabled. Disabling may be done by removal of activation requirements like keys.
- Egress from the LCA must be unobstructed for approved personnel and emergency services.
- Any laser alignments should have an approved, by the LSO, SOP specific for the alignment process. It may be as short as a statement that alignment is handled by an outside company that specializes in this process.

## Entryway Control Measures for Class 4 Lasers

*Class 4 laser-controlled areas require some form of area and entryway controls. Doorway interlocking has been the customary method of entryway control in the past. The ANSI Z136 Standard now provides several entryway control options that include:*

### a) **Nondefeatable Entryway Controls**

- The preferred option is a nondefeatable control, such as a magnetic switch built into the entryway door that cuts the beam off when the door is opened.

### b) **Defeatable Entryway Controls**

- Defeatable controls allow for a temporary override of the entryway interlock only if there are no hazards present at the point of entry. Proper laser protective eyewear must be worn by anyone entering the controlled area.

### c) **Procedural Entryway Controls**

- A blocking barrier, screen, or curtain that can block or filter the laser beam at the entryway may be used inside the controlled area to prevent the laser light from exiting. This option requires a warning light or sound outside the entryway that operates when the laser is energized and operating.

## **Temporary Laser Controlled Areas**

If conditions require that panels or protective housings be removed and interlocks defeated in order to service the laser, then a temporary laser-controlled area must be devised. Such an area, by nature, will not have the built-in protective features as defined for a laser-controlled area, but shall provide all of the necessary safety requirements for personnel. The ANSI NOTICE sign format shall be posted outside of temporary laser-controlled areas (See Appendix E).

## **Invisible Radiation**

Because infrared and ultraviolet radiation are invisible, special precautions must be used when working with lasers that emit radiation in these regions. Labels and warning signs should specify that lasers produce invisible radiation. In addition to the above requirements, the following recommendations should be used when working with infrared or ultraviolet lasers:

**Infrared** - For Class 3 lasers the beam path should be terminated with a highly absorbent, nonreflecting backstop. Caution should be used because metal surfaces that appear dull can cause specular reflections of infrared radiation. In addition, for Class 4 lasers, the beam path should be terminated by a fire-resistant backstop such as firebrick. The backstop should be inspected periodically for degradation. The beam and target area should be shielded with infrared absorbing materials, such as lucite or plexiglass, to minimize reflections from Class 3B or Class 4 lasers.

**Ultraviolet** - Exposure to ultraviolet radiation should be minimized by using materials that attenuate the radiation to safe levels. Special attention should be given to the possibility of producing undesirable reactions in the presence of ultraviolet radiation, e.g. ozone.

## **Laser Safety Eyewear**

The energy emitted from lasers is highly concentrated and can cause permanent eye injury. Although engineering controls are preferred to reduce hazards from the laser beam, it may be necessary to use laser safety eyewear when engineering controls are inadequate. The eyewear must 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 wavelength protection is provided. The following factors should be considered when purchasing laser protective eyewear:

**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 OD is measured on a logarithmic scale, thus a filter that attenuates a

beam by a factor of 1,000 has an OD of 3 and a filter with an OD of 6 attenuates the beam by a factor of 1,000,000. The required OD is determined from the maximum intensity to which an individual could be exposed.

**Laser Beam Intensity** - The maximum irradiance in watts/cm<sup>2</sup> for CW lasers and the maximum radiant exposure in joules/cm<sup>2</sup> 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 must 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 un-attenuated 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. Reflective lenses can create potentially hazardous specular reflections. These lenses are also heavy and uncomfortable and can scratch easily, allowing potentially hazardous radiation to reach the eye. Absorptive filters are not affected by surface scratches nor do they create potentially hazardous reflections. Polymeric filters, such as polycarbonate, offer several advantages over glass absorptive filters. They are lighter, have better impact resistance, and can withstand higher energy densities. Lenses are mounted in goggle-type frames to ensure maximum protection. No lens material is useful for all wavelengths and for all radiant exposures.

## Section 8: Emergency Procedures & Accident Reporting

### In Case of and Emergency:

1. Shut off the laser immediately and remove the interlock key.
2. If possible, alert everyone to exit the lab.
3. In case of exposure or suspected exposure to laser radiation, seek medical attention at either the emergency room, immediate care, the Schiffert Health Center (students only), or your primary care physician.
4. In the event of fire or health/life threatening injuries, call 911.
5. Promptly following any incident, ensure the PI and/or laser supervisor is informed.
6. Contact the EHS Laser Safety Officer (540-231-5364) to report the incident.

***\*\* Any time an employee must go to an urgent care facility, the emergency room, or is transported by ambulance or helicopter, Environmental Health & Safety must be notified directly.***

- **Robin McCall-Miller:** 540-231-2341 (and please follow up with an email to [rmmiller@vt.edu](mailto:rmmiller@vt.edu))
- **Zachary Adams:** 540-231-5985
- **Off-hours:** 540-391-0311

### Accident/Incident Reporting

Once an employee reports a job-related injury (as indicated above), the supervisor or department personnel must immediately file the [Employer's Accident Report Form](#).

[Instructions](#) for completing the Employer's Accident Report Form are available. A username and password are not required, simply select "Continue without logging in."

Please also complete the [EHS Incident Report Form](#) and someone from EHS will follow up with you. This form should be completed in addition to the accident report form above, in order to keep EHS up to date about accidents near misses on campus.

# APPENDICES

## Appendix A: Laser Quick Look Guide

| Laser Class                                                                    | Power Output       | Safe Use Considerations                                                                                                                                                                               | VT Registration Required | Signage Required                | PPE Required?            |
|--------------------------------------------------------------------------------|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|---------------------------------|--------------------------|
| <b>Class 1 (or I), 1M</b>                                                      | 0.4 $\mu$ W        | Considered non-hazardous. Hazard increases if viewed with optical aids, including magnifiers, binoculars, eye loupes, fiber inspection instruments or telescopes.                                     | No                       | None                            | No                       |
| <b>Class 2 (or II), 2M</b>                                                     | 0.4 $\mu$ W - 1 mW | Hazard increases when viewed directly for long periods of time. Hazard increases if viewed with optical aids.                                                                                         | No                       | Caution                         | No                       |
| <b>Class 3R (or IIIA)</b>                                                      | 1 - 5 mW           | Depending on power and beam area, can be momentarily hazardous when directly viewed or when staring directly at the beam with an unaided eye. Risk of injury increases when viewed with optical aids. | Yes                      | Warning                         | Maybe (system dependent) |
| <b>Class 3B (or IIIB)</b>                                                      | 5 - 500 mW         | Immediate skin hazard from direct beam and immediate eye hazard when viewed directly.                                                                                                                 | Yes                      | Warning                         | Yes                      |
| <b>Class 4 (or IV)</b>                                                         | > 500 mW           | Immediate skin hazard and eye hazard from exposure to either the direct or reflected beam; may also present a fire hazard.                                                                            | Yes                      | Warning or Danger (if multi kW) | Yes                      |
| <b>** Class 4 Lasers in Class 1 housing must still be registered.</b>          |                    |                                                                                                                                                                                                       |                          |                                 |                          |
| <b>** Even if a laser is NOT CURRENTLY in use it still MUST BE REGISTERED!</b> |                    |                                                                                                                                                                                                       |                          |                                 |                          |

## Appendix B: Laser SOP Template

Each registered Class 3B or Class 4 laser must have a Standard Operating Procedure (SOP) on file to reflect current or future laser use, safety hazards, and control measures.

Please use the [EHS Laser Standard Operating Procedure \(SOP\) Template](#). This document will provide guidance to describe your procedures to avoid or mitigate laser safety hazards for both beam and non-beam hazards.

Once completed, this SOP should be uploaded to the “Documents” tab for your lab in the EHS Safety Management System (SMS).

**\*\*The PI is required** to train all users to your SOP. Training records should be signed and a copy stored in the lab space.

## Appendix C: Eyewear Storage Solutions

Main considerations of all laser eye wear:

- Eyewear should be cleaned following manufacturer's directions.
- It should be stored away from contaminants & UV exposure.
- Laser eyewear is expensive! It should be stored to protect physical integrity and prevent damage.

Many companies produce eyewear storage bins. The two eyewear storage solutions shown below are both from Kentek. Similar products can be found through many different science supply companies; however, most range in price from \$100-\$200.



A simple and inexpensive storage solution is shown below. This product is sold as an over the door shoe organizer. Similar products can be purchased for as little as \$5-\$10 dollars online. Each pocket can be labeled with the OD and wavelength of the eye wear, and personnel can be trained to put the eye wear back in the correct location after use.



## Appendix D: Emergency Contacts Template

**\*\* This is not to be used as a door sign. This should be placed in the lab near the laser operating area.**

### **In Case of Emergency Call 911 EMERGENCY CONTACTS**

|                                  | <b>Name</b> | <b>Office Address</b> | <b>Telephone</b> |             |
|----------------------------------|-------------|-----------------------|------------------|-------------|
|                                  |             |                       | <b>Office</b>    | <b>Home</b> |
| <b>Principal Investigator(s)</b> |             |                       |                  |             |
| <b>Secondary Contact</b>         |             |                       |                  |             |
| <b>Other Contact</b>             |             |                       |                  |             |

| <b><i>Emergency Telephone Numbers</i></b> | <b><i>8 am - 5 pm</i></b>                      | <b><i>After 5 pm, Weekends</i></b> |
|-------------------------------------------|------------------------------------------------|------------------------------------|
| <b><i>Radiation Safety</i></b>            | <b><i>(540) 231-5364</i></b>                   | <b><i>911*</i></b>                 |
| <b><i>Hazardous Material Safety</i></b>   | <b><i>(540) 231-3600</i></b>                   |                                    |
| <b><i>Biological Safety</i></b>           | <b><i>(540) 231-5864 or (540) 231-3361</i></b> |                                    |
| <b><i>VT Police/Rescue</i></b>            | <b><i>911*</i></b>                             |                                    |
| <b><i>Blacksburg Fire Department</i></b>  |                                                |                                    |

**\* If using a cell phone to dial 911, remember to identify your location for the operator**

**OFF-CAMPUS SITES SHOULD USE 911 FOR LOCAL EMERGENCY RESPONSE**

**Use the non--emergency number, (540) 382-4343, for information and to contact VT support personnel as needed**

**Facility-specific safety manual (e.g., Chemical Hygiene Plan, Biosafety Manual) is located: \_\_\_\_\_**

**Safety Data Sheets and Material Safety Data Sheets (SDS/MSDSs) are located: \_\_\_\_\_**

**Effective Date: \_\_\_\_\_**

**Download Template Here: [Emergency Contact Template](#)**

## Appendix E: Laser Control Sign Catalog

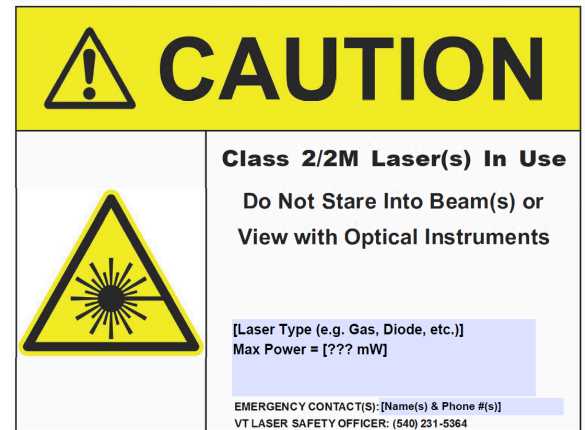
Displaying proper signage is one of the important aspects of a successful laser safety program. According to ANSI Z136.1 *Safe Use of Lasers*, laser warning signs should be posted around Class 2M and 3R laser areas, and are **required** to be posted around all Class 3B and 4 laser areas. Additionally, when Class 3B and Class 4 lasers are being serviced or receiving maintenance of any kind, NOTICE signs are required to be posted.

Signs can be purchased directly through HokieMart at this link: [HokieMart Laser Signs](#)

**Class 2 & 2M Signs:** ANSI Z136.1 indicates that laser area warning signs should be posted around Class 2 & 2M laser areas. Class 2/2M lasers can be hazardous to the eyes if someone deliberately stares into the beam or uses optical aids.

- **Requirements:**
  - Laser hazard symbol
  - "CAUTION- Laser Radiation- Do Not Stare into Beam or View Directly with Optical Instruments"
  - The class & type of laser
  - Warning signs on doors are not required.

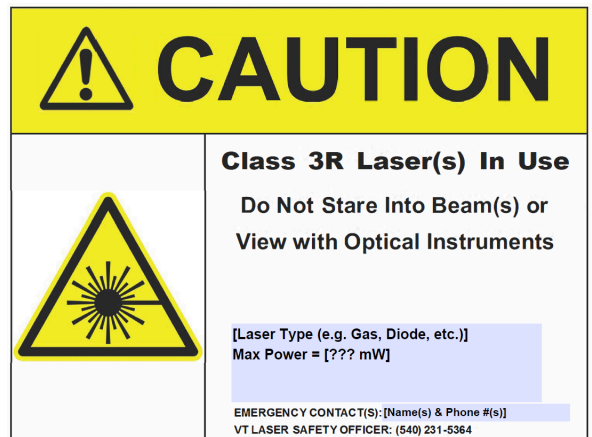
**\*\* Generate your own here:** [Class 2 Caution Sign Template](#)



**Class 3R Signs:** A Class 3R laser may produce up to five times the emission limit for Class 1 or Class 2 lasers. Visible continuous lasers in Class 3R are limited to 5 mW. Class 3R lasers have low-to-moderate risk and are hazardous for direct intrabeam viewing, especially with optical aids.

- **Requirements:**
  - Laser hazard symbol
  - "CAUTION- Laser Radiation- Do Not Stare into Beam or View Directly with Optical Instruments"
  - The class & type of laser
  - Entrances to laser areas must be posted with a warning sign.

**\*\* Generate your own here:** [Class 3R Caution Sign Template](#)

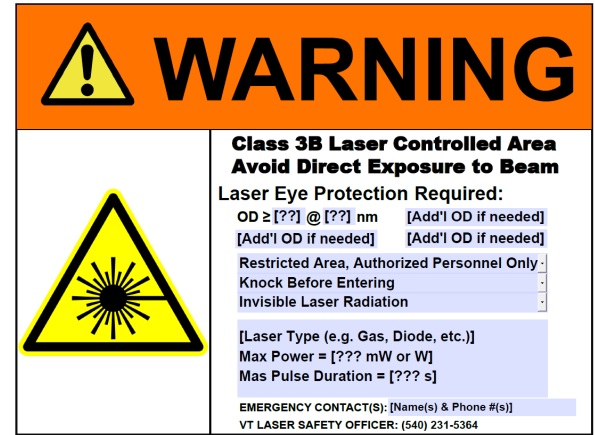


**Class 3B Signs:** A Class 3B laser is hazardous if the eye is exposed directly, but diffuse reflections such as from paper or other matte surfaces may be harmful. Continuous lasers in the wavelength range from 315 nm to far infrared are limited to 0.5 W. For pulsed lasers between 400 and 700 nm, the limit is 30 mJ.

**\*\* Signs are required for Class 3B and Class 4 lasers during maintenance, servicing, and similar situations.**

- **Requirements:**

- Laser hazard symbol
- "WARNING- Laser Radiation- Avoid Direct Exposure to Beam"
- The class and type of laser
- Doors leading to the laser area shall be posted with warning signs.



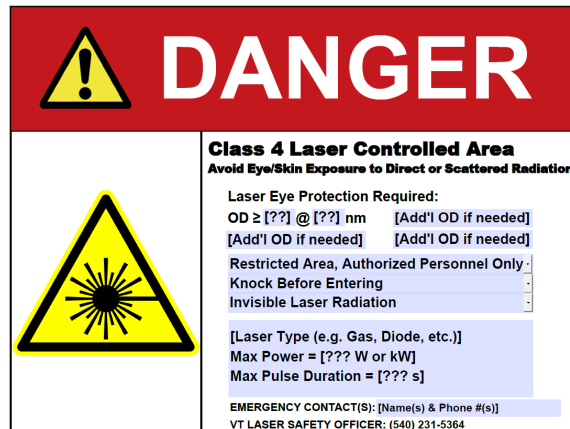
**\*\* Generate your own here: [Class 3B Warning Sign Template](#)**

**Class 4 Signs:** Class 4 lasers are high powered and are hazardous to view at all times and may cause devastating and permanent eye damage. Class 4 lasers may also have sufficient energy to ignite materials, and may cause significant skin damage. Exposure of the eye or skin to both the direct laser beam and to scattered beams, even those produced by reflection from diffusing surfaces, must be avoided at all times. In addition, they may pose a fire risk and may generate hazardous fumes.

- **Requirements:**

- Laser hazard symbol
- WARNING or DANGER
  - **Non multi kW lasers:** "WARNING- Laser Radiation- Avoid Eye or Skin Exposure to Direct or Scattered Radiation"
  - **For multi kW lasers:** "DANGER- Laser Radiation- Avoid Eye or Skin Exposure to Direct or Scattered Radiation"
- The class & type of laser
- Appropriate warning signs must be posted on equipment and ALL doors leading to the facility.
- Additional precautions or protective actions should be provided as needed.

**\*\* Generate your own here: [Class 4 Warning Sign Template](#)**  
**[Class 4 Danger Sign Template](#)**



**Notice Signs:** For temporary use when laser systems are under repair and the accessible laser radiation exceeds acceptable MPE.

**\*\* Generate your own here:** [Notice Sign Template](#)

| <b>NOTICE</b>                                                                       |                                                                                                                                                                                                        |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <p><b>LASER REPAIR IN PROGRESS</b></p> <p><b>DO NOT ENTER</b></p> <p><small>EMERGENCY CONTACT(S): [Name(s) &amp; Phone #(s)]</small></p> <p><small>VT LASER SAFETY OFFICER: (540) 231-5364</small></p> |

## Appendix F: Laser Acquisition, Installation, and Transfer SOP



Environmental Health and Safety  
Radiation Safety Office

### LASER ACQUISITION, INSTALLATION, AND INTERNAL TRANSFER

Principal Investigators (PI) must register all Class 3R, 3B, and 4 laser systems (including enclosed systems), all laser cutters/engravers, and all confocal microscopes with the Laser Safety Officer (LSO) prior to first use, when relocating to another space, or after significant changes of the laser system. Please review the guidelines and requirements below for each instance.

**\*\*Class definitions:**

- Class 3R limited to 5 mW,
- Class 3B ranges between 5 mW - 500 mW,
- Class 4 from 500 mW or greater.

*\*\* All equipment and materials must meet current standards set by National Electrical Manufacturers Association (NEMA), American National Standards Institute (ANSI), Underwriters Laboratories (UL), or other Nationally Recognized Testing Laboratories (NRTLs) recognized by the U.S. Department of Labor, and must bear appropriate approval labels for their intended use. See [EHS - Listing and Labelling of Equipment](#) for more detail.*

**Guide to New Laser Acquisition:** See the instructions below if you would like to purchase a laser/laser system, laser cutter/engraver, or confocal microscope

Prior to purchasing or receiving a Class 3R, 3B, or Class 4 laser/laser system, laser cutter/engraver, or confocal microscope, the LSO must be informed.

1. Email the LSO (Donald Conner, [dcon@vt.edu](mailto:dcon@vt.edu)) with the following information:
  - a. Purpose and intended location of laser
  - b. Power and other physical characteristics (i.e. class, type, wavelength, etc.)

**\*\*The best source of that information is the laser manufacturer's user manual.**
  - c. Necessary control measures
  - d. [Standard Operating Procedure \(SOP\)](#) required for all class 3B & 4 lasers.
  - e. Names and PIDs of authorized laser users
2. The LSO will review this information and provide additional safety recommendations for control measures and personal protective equipment, as needed.
3. Once approved by the LSO, the laser or laser system can be acquired.
  - Make sure to use the right purchase codes to speed up procurement. Lasers are not procured until reviewed. Use the following HokieMart codes:
    - 22412 for Class 3R, 3B, 4 lasers (greater than \$2,000)
    - 22417 for Class 3R, 3B, 4 lasers (less than \$2,000)
    - 22413 for Laser Engravers/Cutters with embedded Class 3R, 3B, 4 lasers (greater than \$2000)
    - 22418 for Laser Engravers/Cutters with embedded Class 3R, 3B, 4 lasers (less than \$2,000)
4. Upon receiving your laser, register it in the [Safety Management System](#) and notify the LSO.
5. Before initiation of your laser, the laser safety team will visit your lab to inspect the laser and follow-up on any necessary modifications or control measures.

**Guide to Using an Existing Laser at Virginia Tech:** See the instructions below if you have brought a laser/laser system, laser cutter/engraver, or confocal microscope with you from a previous institution.

1. Before installing your laser and initiating use, contact the LSO (Donald Conner, [dcon@vt.edu](mailto:dcon@vt.edu)) with the following information:
  - a. Purpose and intended location of laser
  - b. Power and other physical characteristics (i.e. class, type, wavelength, etc.)  
\*\*The best source of that information is the laser manufacturer's user manual.
  - c. Necessary control measures
  - d. **Standard Operating Procedure (SOP)** required for all class 3B & 4 lasers.
  - e. Names and PIDs of authorized laser users
2. The LSO will review this information and provide additional safety recommendations for control measures and personal protective equipment, as needed.
3. Before initiation of your laser, the laser safety team will visit your lab to inspect the laser and follow-up on any necessary modifications or control measures.
4. Once the approval process has been completed, register your laser in the **Safety Management System**.

**Laser Relocation or Transfer:** See the instructions below for internal transfers of lasers

**Internal Transfers ONLY** - Internal transfers or relocation of lasers on the VT campus require review and approval by the LSO before transfer. *Transfers can only be made if the laser is in **good working order** and complies with all applicable safety standards.*

1. To request a transfer, contact the LSO (Donald Conner, [dcon@vt.edu](mailto:dcon@vt.edu)) with the following:
  - a. Name and contact information of PI transferring the laser/laser system
  - b. The current location of the laser
  - c. Laser specifications (to include by not limited to: laser type, class, power, wavelength, control measures, SOP, etc.)
  - d. Name and contact information of PI receiving laser
  - e. New location of the laser
2. The LSO will review this information and provide safety recommendations for the transfer and installation process, as well as necessary control measures and personal protective equipment, as needed.
3. Before initiation of the laser, the laser safety team will visit the new lab to inspect the laser and follow-up on any necessary modifications or control measures.
4. Update the **Safety Management System** with the new information once the transfer is approved by the LSO.

**\*\*Under NO circumstances should university equipment be sold, loaned, given away (outside the university), scrapped/cannibalized or disposed of by any department without prior written approval of the University Surplus Officer in coordination with the Manager of FAEIS. Disposals of equipment must follow surplus property procedures. Please contact your department head or the designated individual within your department for questions with these policies.**

**\*\*** When registering your laser in the **Safety Management System** make sure to have the following information prepared:

- |                                                |                                                          |
|------------------------------------------------|----------------------------------------------------------|
| • Location, PI (or custodian), number of users | • Beam distribution, shape, diameter, and divergence     |
| • Laser type, power, and class                 | • Laser operating mode and pulse details (if applicable) |
| • Primary and secondary wavelength or range    | • Cooling method? Dye? Target material? LGACs?           |
| • Manufacturer, Model #, and Serial #          | • Control measures (including SOP) and eyewear           |

**\*\*Laser Acquisition, Installation, and Internal Transfer SOP PDF for printing**

# Appendix G: Laser Surplus & External Transfer SOP



Environmental Health and Safety  
Radiation Safety Office

## LASER SURPLUSING & EXTERNAL TRANSFER SOP

Before a Class 3R, 3B, or Class 4 laser/laser system, laser cutter/engraver, or confocal microscope is transferred or disposed of, approval from the University Surplus Property Manager and Laser Safety Officer (LSO) is required. Please review the guidelines and requirements below for each instance.

**\*\*Class definitions:**

- Class 3R limited to 5 mW,
- Class 3B ranges between 5 mW - 500 mW,
- Class 4 from 500 mW or greater.

**Laser Surplus, & External Transfers:** All university property that exceeds a department's needs—such as duplicated, damaged, or obsolete furniture and equipment—is classified as surplus and must go through the official surplus property disposal process managed by the [Procurement Department](#).

Departments may not sell, loan, give away, scrap, or otherwise dispose of surplus items without prior written approval from the Surplus Property Manager. Department Heads may act to transfer property to another department, but cannot sell or donate property to an individual or commercial firm.

Once transferred to surplus, if equipment is not able to be reallocated within the university, it will be sold at public auction or through sealed bid. Departments may request reimbursement, minus auction fees, for items that sell for \$1,000 or more. [University Policy 3955](#) provides specific guidance. Please contact your Department Head for help with this process.

### Laser Surplus

1. To begin the surplus process, contact your department head. Departments must submit an online Surplus Property report, coordinate any necessary movement or delivery of items, and ensure proper storage and security until transfer or disposal occurs.
  - Contact the LSO (Donald Conner, [dcon@vt.edu](mailto:dcon@vt.edu)) for guidance in decommissioning, proper storage, and delivery to surplus.
2. Once the laser has been transferred to surplus, the LSO must be notified and the laser status should be updated in the [Safety Management System \(SMS\)](#).

### External Transfers

1. When planning to transport or ship a laser to a location outside of Virginia Tech first obtain the appropriate permissions as indicated above by contacting the University Surplus Property Manager.
2. Once permissions are received, the LSO must be informed so they can assist with the determination of proper shipping conditions.
  - The LSO will provide guidance and approval, but the laboratory is responsible for all costs associated with shipping the laser or laser system.
3. Prior to shipping the laser, the LSO must be provided with the following:
  - i. Laser to be shipped
  - ii. Anticipated transfer date
  - iii. Names of person(s) shipping and receiving the laser
  - iv. The sending and receiving locations
  - v. Contact information of those responsible
4. If significant modifications have been made to the laser, approval from the FDA may be required.
5. Once the laser has been transferred, update the laser's status in the [Safety Management System \(SMS\)](#).

**\*\*Under NO circumstances should university equipment be sold, loaned, given away (outside the university), scrapped/cannibalized or disposed of by any department without prior written approval of the University Surplus Officer in coordination with the Manager of FAEIS. Disposals of equipment must follow surplus property procedures. Please contact your department head or the designated individual within your department for questions with these policies.**

**\*\*[Laser Surplusing & External Transfer SOP](#) PDF for printing**

## Appendix H: Preparing for a Laser Inspection & Laser Self Audit

Preparing for a laser inspection (for Class 3B/4 lasers) requires ensuring regulatory compliance, safety protocols, and proper documentation are in place. Use the following checklist as your own preparation measures. You may also be asked by the LSO to complete a [Laser Self Audit](#) in preparation for your inspection.

### **1. Documentation and Administrative Prep**

- **Review Standard Operating Procedures (SOPs):** Have written, up-to-date SOPs for all Class 3B and 4 lasers accessible in the lab.
- **Training Records:** Ensure all users have completed required laser safety training, including laser-specific training, with signed documentation available in the lab.
- **Registration:** Confirm all high-power lasers are registered with the Environmental Health and Safety (EHS) through the SMS.

### **2. Physical Setup and Safety Controls**

- **Warning Signs and Signals:** Ensure that appropriate DANGER, WARNING, or CAUTION signs are posted at entrances, and illuminated warning signs or lights are functional.
- **Interlocks:** Verify that entry door interlocks and laser housing interlocks are functional.
- **Beam Control:** Ensure the beam path is enclosed where possible, and beam blocks are used to terminate the beam at the end of its useful path.
- **Reflective Items:** Remove unnecessary reflective materials (jewelry, tools) from the nominal hazard zone.
- **Emergency Controls:** Identify and test the Emergency Power Off (EPO) button for Class 4 systems.

### **3. Personal Protective Equipment (PPE)**

- **Eyewear:** Ensure proper protective eyewear for the specific wavelength and optical density (OD) is available, clean, and free of cracks or scratches.
- **Protective Barriers:** Confirm that curtains or screens are properly rated and in good condition.

### **4. Housekeeping and Operational Safety**

- **Lab Area:** Maintain a tidy workspace, ensuring eye wash stations and emergency exits are free of clutter.
- **Electrical Hazards:** Ensure high-voltage power supplies are properly enclosed and that electrical panels are accessible.
- **Laser Generated Contaminants:** If using lasers for cutting or marking, ensure proper local exhaust ventilation is in place to manage laser-generated air contaminants.

### **Summary Checklist for Day of Inspection**

- ☐ SOPs available.
- ☐ Training records signed.
- ☐ Laser eyewear available and in good condition.
- ☐ Warning signs posted.
- ☐ Beam enclosed or blocked.
- ☐ Interlocks are functional.
- ☐ No unauthorized personnel present.

## Appendix I: Frequently Asked Questions

### Q1: What should I do about equipment decontamination for service/moving?

Equipment that may be contaminated with hazardous materials must be cleaned by the user/owner before asking anyone outside the group to service, move, or pick-up for surplus sale. The [Lab Equipment Decontamination Form](#) is used to prepare items for handling by workers including service personnel, Division of Campus Planning, Infrastructure, and Facilities, and Surplus Property staff.

### Q2: How do I get help in my workplace when using lasers?

The Laser Safety Program provides worksite consultations for laser hazards and offers solutions to reduce occupational exposures to both beam and non-beam hazards for classes 3R, 3B, and 4. If you have any laser concerns or questions, please contact Laser Safety Officer Donald Conner, at 540-231-5364, or email at [dcon@vt.edu](mailto:dcon@vt.edu).

### Q3: Laser Safety Training?

**Is training mandatory? If so, when?** Yes, for Class 3R, 3B, and 4 laser users.

**Class length:** 1 hour

**When is refresher training required?** Every 3 years.

**EHS provides laser safety training regularly:** You may register for or request a class at <https://www.ehss.vt.edu/train.php>. Scroll down to the Laser Safety classes then click the register button adjacent to a date and time that work with your schedule.

### Q4: What about laser pointers?

The Laser Safety program addresses high-powered lasers (class 3R, 3B, and 4) that pose a significant risk of eye or skin injury. Laser pointers are of lower power and outside the scope of the laser safety program. However, they can pose other risks especially if misused.

To learn more about laser pointers, their safe use, and risks of misuse, please visit the [Laser Institute of America](#).

### Q5: What is the Laser Safety Program?

The three-fold purpose of the Laser Safety Program is:

1. To provide a Laser Safety Program to serve those Virginia Tech employees whose job duties require them to operate, maintain, or service a laser system.
2. To effectively comply with all Occupational Safety and Health Administration (OSHA) regulations and ANSI standards concerning laser use.
3. To prevent injury and death or property damage from using laser systems.

The primary tools of the Laser Safety Program (LSP) include:

- Register all class 3R, 3B, and 4 lasers with EHS using the EHS SMS online system,
- Consulting on engineering and administrative controls for identified hazards,
- Educating about the potential biological effects of laser use,
- Training in the proper use of laser systems.

The scope of the LSP includes all Virginia Tech employees whose job duties require them to:

- Operate, maintain, or service class 3B or class 4 laser systems,
- Service enclosed class 3B or class 4 laser systems, or
- Align class 2 or higher laser systems.

## Appendix J: Laser Safety Definitions

**ACGIH:** American Conference of Governmental Industrial Hygienists.

**ACTIVE MEDIUM:** A substance that can be raised to a higher energy level by the introduction of energy from a pumping device.

**ANSI:** American National Standards Institute.

**APERTURE:** An opening in the protective housing that radiation can pass through.

**ATTENUATION:** The decrease in the power of a laser beam as it passes through an absorbing or scattering substance.

**AVERSION RESPONSE:** Blink reflex, time, or movement of the head to avoid bright light. Occurs in approximately 0.25 seconds.

**BEAM DIVERGENCE:** The increase in beam diameter over distance, measured in radians or milliradians.

**CHEMICAL LASER:** A laser that excites electrons to higher energy levels by a chemical reaction.

**COHERENT LIGHT:** Light which is in phase. The amplitudes are exactly equivalent and the waves rise and fall together.

**COLLIMATED BEAM:** Beam of light where the rays are parallel. Characterized by very small beam divergence.

**COLLIMATOR:** Device that changes a diverging or converging beam of light into a parallel beam.

**CONTROLLED AREA:** An area that is controlled and supervised to protect individuals from laser radiation.

**CORNEA:** The transparent outer tissue of the eye that covers the iris and pupil.

**CRYOGENICS:** Field of science dealing with very low temperatures.

**CRYSTAL LASER:** Laser whose active medium is an atomic substance added as an impurity to a crystal such as a ruby. Also known as a solid-state laser.

**CW LASER:** Continuous-wave laser; emitting for a period greater than 0.25 seconds.

**DIFFUSE REFLECTOR:** A reflection over a wide range of angles.

**DYE LASER:** Type of laser that uses an organic dye as the lasing material.

**ELECTROMAGNETIC RADIATION:** Energy flow formed from oscillating electric and magnetic fields traveling through space at the speed of light. Examples include x-rays, ultraviolet light, visible light, infrared radiation, and radio waves.

**ENCLOSED LASER:** Any laser located within an enclosure that does not allow the emission of hazardous laser radiation or access to the radiation.

**ENERGY (Q):** The ability to do work. Commonly used to characterize the output from pulsed lasers. Measured in joules(J).

**ENERGY DENSITY:** Energy per unit area, expressed in joules per square centimeter. Also known as radiant exposure.

**EXPOSURE:** The product of irradiance and time.

**GAS LASER:** Lasers that use a gas such as He-Ne for the lasing medium. Usually found in CW lasers.

**HERTZ:** Unit of frequency, measured in cycles per second.

**INFRARED RADIATION:** Electromagnetic radiation with wavelengths in the range of 700 - 10,000 nm.

**INTRABEAM VIEWING:** Viewing the laser beam from within the direct

**IRRADIANCE (E):** Radiant power divided by the area irradiated. Measured in watts per square centimeter.

**JOULE (J):** Unit of energy normally used to describe a single pulsed output. Equal to one watt-second.

**LASER CAVITY:** The enclosed resonator enables the amplification of the beam. Produced by reflecting the beam back and forth between mirrors. Also called a resonant or optical cavity.

**LASER CLASSIFICATION:** A ranking of comparative hazards for lasers with class 1 being the least hazardous, and class 4 the most hazardous.

**LASER CONTROLLED AREA:** An area that is controlled for the purpose of protecting individuals from exposure to laser radiation.

**LASER:** Acronym for light amplification by stimulated emission of radiation. Source of highly intense, coherent, monochromatic, and directional light.

**LIGHT:** Visible portion of the electromagnetic spectrum with wavelengths between 400 - 700 nm.

**LIQUID LASER:** A laser that uses an organic dye or inorganic liquid as the lasing medium.

**LUMINOUS TRANSMITTANCE:** Term that describes the ability to see through an optical filter, expressed in percent.

**MAXIMUM OUTPUT:** The maximum radiant power and the maximum radiant energy per pulse of accessible radiation emitted by a laser device.

**ND-GLASS LASER:** Solid-state laser in which neodymium is added to the glass. The neodymium serves as the active medium.

**ND-YAG LASER:** Solid-state laser in which neodymium is added to yttrium aluminum garnet.

**OPTICAL DENSITY (D):** A logarithmic expression is commonly used to express the attenuation of an eye protection filter.

**OPTICAL RADIATION:** Electromagnetic radiation in the range from 200 - 10,000 nm covering ultraviolet, visible, and infrared radiation.

**OPTICALLY-PUMPED LASERS:** A type of laser that uses energy from or specularly reflected beam.

**OSHA:** Occupational Safety and Health Administration.

**OUTPUT ENERGY:** Term used to describe energy output per pulse in pulsed lasers. Usually expressed in joules per pulse.

**OUTPUT POWER:** Term used to evaluate CW laser. Laser output is defined by energy per unit time. The power output level is usually expressed in milliwatts.

**POPULATION INVERSION:** Situation in a laser medium created by pumping in which there are more atoms in an excited state than in the ground state.

**POWER DENSITY:** Power per unit area. Also called irradiance.

**POWER:** The rate at which energy is transferred. Expressed in watts (joules per second). Also termed radiant flux.

**PROTECTIVE HOUSING:** Device used to prevent access to radiant power or energy that is higher than the intended classification.

**PRF:** Pulse repetition frequency; measured in hertz.

**PULSE DURATION:** The time between the half-peak-power points on the front and trailing edges of a pulse. Usually measured in microseconds, milliseconds, or nanoseconds.

**PULSED LASER:** Laser that delivers its energy in short pulses (less than 0.25 seconds) rather than continuously.

**PUMPING:** The activation of the laser medium to a higher energy state by the absorption of energy; usually from flash lamps or an electric current.

**Q-SWITCH LASER:** A laser that can produce extremely high peak powers in a pulse length of very short duration (nanoseconds).

**RADIANT ENERGY (Q):** Electromagnetic energy expressed in units of joules (watt-second).

**RADIANT INTENSITY (I):** Radiant -power of a source transmitted in a particular direction. Expressed in watts per steradian.

**RADIANT EXPOSURE (H):** Radiant energy divided by the area. Expressed in joules per square centimeter. Usually used to express pulsed laser radiation.

**RADIANT POWER:** The time rate of transfer of radiant energy. Measured in watts. Also called radiant flux.

**SEMICONDUCTOR LASER:** A laser in which the lasing action occurs in a semiconductor, such as gallium arsenide. Usually pumped by an electron beam.

**SHALL:** The word "shall" is always mandatory.

**SHOULD:** The word "should" denotes a recommendation.

**SOLID STATE LASER:** A laser in which the active medium is an atomic substance added as an impurity to a crystal or glass.

**SPECULAR REFLECTION:** A mirror-like reflection.

**STERADIAN (SR):** Unit of measurement for a solid angle. A sphere contains  $4(\pi)$  steradians.

**STIMULATED EMISSION:** Radiation emitted during a transition from a higher energy state to a lower state that contains the same frequency, wavelength, and phase as the initiating photon.

**ULTRAVIOLET LIGHT:** Electromagnetic radiation wavelengths in the range from 200- 400 nm.

**VISIBLE RADIATION:** Electromagnetic radiation that describes wavelengths in the range between 400 - 700 nm.

**WATT:** Unit of power. Equals one joule per second.

**WAVELENGTH:** Distance between the same points on subsequent waves.