PREAMBLE

This program provides recommendations for the safe use of lasers when conducting research in basic science, development, or testing environments or when used in education. The privilege to use lasers at the University of Virginia requires each individual user to follow and adhere to this program, relevant ANSI (American National Standard Institute) standards Safe Use of Lasers (ANSI Z136.1-2014), Safe Use of Lasers in Research, Development or Testing (ANSI Z138.8-2012) and Safe Use of Lasers in Educational Institutions (ANSI Z138.5-2000), manufacturers' guidelines, and local departmental operating procedures. Failure of any individual to comply with requirements can jeopardize the safety of personnel, the investigation, the laboratory, and the overall institution.

This laser safety program provides an orientation on lasers[1] and summarizes the laser safety policies and procedures implemented by the University to ensure a safe environment for students, faculty, research personnel, and the public. The program goal is to afford research users as much flexibility as is safe and consistent with UVA policy and in alignment with the ANSI Z136.1, Z136.8, and Z138.5 standards.

The Environmental Health & Safety Department of the University of Virginia is responsible for designating a qualified Laser Safety Officer (LSO) with the authority and responsibility to evaluate and control laser hazards, facilitate the implementation of appropriate control measures, and to guide laser users in compliance with relevant ANSI and Occupational Safety and Health Administration (OSHA) standards. The LSO is responsible for managing this laser safety program subject to the approval of the Radiation Safety Committee in accordance with the relationships described in Section 2 *Responsibilities and Relationships* within this document. The LSO is authorized to take whatever steps necessary to control and mitigate hazards in emergency situations or conditions immediately dangerous to life and health.

This program was last revised January 27, 2025.

[1] Non-ionizing coherent radiation as Light Amplification by Stimulated Emission of Radiation

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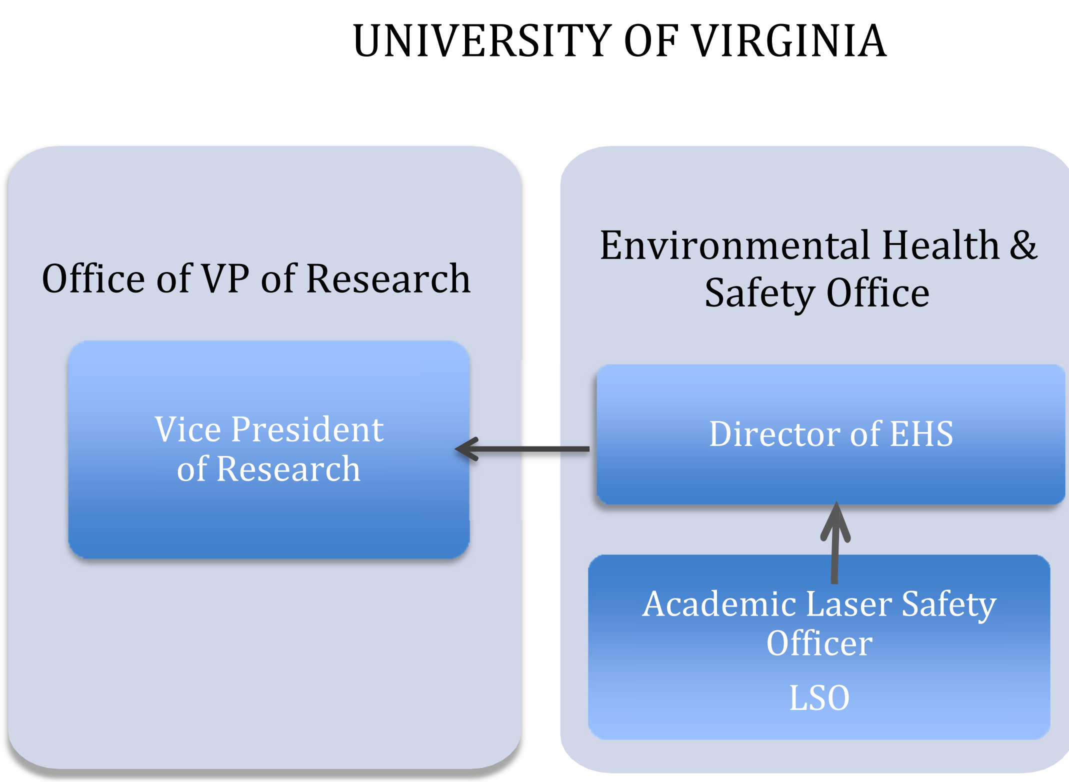
1. INTRODUCTION

Purpose - the University of Virginia laser safety program objective is to fulfill the University's laser safety policy (SEC-011) to provide programs and guidance to protect the safety and health of university students, faculty, researchers, and staff from the hazards associated with the operation of laser systems. The program's orientation is toward providing reasonable and adequate guidance for the safe use of lasers and laser systems in research, development, and testing environments, where safety controls common for commercial lasers may be either nonexistent or disabled. In testing environments, lasers may be operated in conditions or protocols different from normal operation, including access to levels of radiation higher than the accessible emission limits (AEL) for the assigned product class. This laser safety program is based on the guidelines found in ANSI Z136.1 and Z136.8 and applicable federal and state regulations covering academic research facilities.

2. RESPONSIBILITIES / RELATIONSHIPS



2.1 University Radiation Safety Committee

- Oversight and approval of academic & medical laser safety program.

2.2 Academic Laser Safety Officer (LSO)

- Laser safety program development, implementation, and updating
- Approve laser safety manuals (to include alignment procedures and other procedures that may be subject to administrative and procedural controls.)
- Conduct laser hazard analyses of Class 3B and 4 laser systems
- Design the laser safety training program
- Provide guidance on ANSI approved warning signs and labels
- Provide guidance in personnel protective equipment (laser eyewear and skin protection)
- Provide guidance in new laser laboratory design and laser lab upgrades
- Periodically audit laser facilities and laser users
- Investigate laser accidents
- Maintain inventory of Class 3B and 4 lasers and laser systems
- Classify constructed or modified lasers and laser systems
- Review and approve transfers and disposal of Class 3B and Class 4 lasers
- Member of Radiation Safety Committee, reporting on laser safety

2.3Principal Investigators (PI)/Lab Supervisors (LS)

- Register Class Class 3B and Class 4 lasers with the LSO via the EHS online laser registry. https://researchcompliance.web.virginia.edu/laser/user/home.cfm
  See Appendix C.
- Identify all authorized individuals within the research program under your leadership who are eligible to operate or maintain Class 3B or Class 4 lasers or laser systems.
- Ensure all laser users in your research program complete laser safety training; both Level 1 *basic laser physics and safety training* and Level 2 *laser and research program-specific* training. ANSI-compliant training is required. ANSI-compliant Level 1 laser safety online training is available via STAR at the EHS website.

- Develop and provide Level 2 *laser and research specific On-the-Job (OTJ) training* for each authorized laser user (including laser safety manual review, physical hazards, health hazards, emergency, and accident reporting procedures). Track laser safety training completion of each user. By establishing an account, all training can be tracked via the EHS STAR system. http://ehs.virginia.edu/ehs/
- Develop a laser safety manual for each Class 3B and Class 4 laser/laser system and submit to the LSO for authorization prior to operating the laser. Laser safety manual to include safe operating conditions, e.g. for laser alignment, as specified by ANSI Z136.1 and ANSI Z136.8. Include Core Laser Safety Practices http://ehs.virginia.edu/ehs/ehs.laser/laser.CLSP.html (see Appendix A). A laser safety manual template can be used or a basic laser safety manual can be generated as a pdf document at the completion of the online laser registration process. See Appendix B & C.

- Assure laser safety manuals are readily available to laser operators and reviewed by the same.
- Supervise the safe use of lasers in the laser environment to ensure that laser users follow established safety procedures including but not limited to:
  - ✓ Identify laser hazards present in the work area, implement appropriate hazard controls and correct any identified unsafe conditions
  - ✓ Completion of laser safety training,
  - ✓ maintaining control measures, e.g. laser area controlled access, beam enclosures & beam stops, window covering,
  - ✓ posting safety signs,
  - ✓ utilizing alignment eyewear and alignment procedures,
  - ✓ performing self-audits,
  - ✓ incident reporting,
  - ✓ following laser safety manual procedures

- Ensure all commercial lasers under the control of the PI or within the LS's area of responsibility are properly classified and labeled in accordance with Federal Laser Product Performance Standard (FLPPS) or IEC 60825-1.
- Contact the LSO for any laser system requiring classification or re-classification.
- Non-commercial laser systems developed and then sent off-grounds for evaluation/use and out of the control of the developer should meet as many FLPPS or IEC 60825-1 requirements as possible, with documentation.
- Resubmit laser safety manuals for authorization every 3 years or upon major changes to the laser laboratory (e.g. room relocation, different laser types, laser or system components that change laser classification or significantly modify safety & health risks).
- Conduct annual self-audit of lasers and laser use areas with the UVA laser safety program self-audit form. See Appendix E.
- Designate a laser safety trained Laser Safety Contact (LSC) knowledgeable in each laser or laser system in the lab. The LSC is lab liaison to the LSO. The LSC can be the PI, LS, or research staff designated by the PI or LS.
- Keep copies of current laser safety manuals, training programs, self-audits, and accident investigations.
- Accompany LSO during audits of the laboratory or designate the LSC or equally knowledgeable laboratory person(s).
- Immediately notify the LSO and/or Director of EHS in the event of a suspected overexposure to the beam or accident associated with the operation of any laser.
- In the event of a suspected overexposure to the beam, ensure that the individual receives a medical examination by a qualified ophthalmologist as soon as possible but no later than 24 hours after the incident.
- Notify the LSO prior to the transfer or disposal of a Class 3B or 4 laser or laser system.

2.4 Laser User

Prior to use of lasers:

- Know the hazards and precautionary procedures for laser use in their work area. Use Core Laser Safety Practices (see Appendix A). Read all laser safety manuals for lasers in their work area.

- Attend required Level 1 and Level 2 training(s).
- Plan and conduct operations in accordance with established procedures and good safety practices including but not limited to:
  - ✓ maintaining control measures, e.g. laser area controlled access, beam enclosures & beam stops, window covering,
  - ✓ posting safety signs,
  - ✓ utilizing alignment eyewear and alignment procedures,
  - ✓ performing self-audits,
  - ✓ incident reporting immediately to supervisor & LSO & HR,
  - ✓ adhere to procedures in the lab's laser safety manuals
- Use personal protective equipment (PPE) in accordance with prescribed training.

2.5Laser Safety Contact (LSC)

- The laboratory's contact person with the LSO.
- This role may be fulfilled by the PI, LS, or a PI designee who is a qualified Laser User.
- LSC may be designated and authorized by the PI to perform some of the PI's laser safety duties. The responsibility for the laser safety program, however, remains with the PI.

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3. LASER CLASSIFICATIONS

Commercial laser products are certified by the manufacturer, assigned into a number of classes by the CDRH Federal Laser Product Performance Standard (FLPPS – 21 CFR 1040) depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or the potential to cause a fire from direct exposure of the beam to a combustible material or from beam reflections to the same. A qualitative description of the laser classes can be found below (taken from ANSI Z136.1-2014).

Class 1 Laser System
Considered to be incapable of producing damaging radiation levels during operation and exempt from any control measures.

NOTE: A common example of a Class 1 laser system is one that includes an embedded higher-class laser, but during normal operation presents no laser radiation hazard to the user. Products that have been classified previously as Class IIa under FLPPS should be treated the same as those in Class 1. Confer with LSO for any reclassifications.

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

NOTE: The additional hazard from the use of eye loupes within 10 cm of the source will not increase the hazard classification to Class 1M per ANSI Z136.1-2014. Yet per the International Electrotechnical Commission (IEC) 60825-1 (2007) standard, the additional hazard resulting from the use of eye loupes within 10 cm of the source can result in an increase in the hazard class to Class 1M.

Class 2 Laser System
Emits in the visible portion of the spectrum (400-700nm) and eye protection is normally afforded by the aversion response.

Class 2M Laser System
Emits in the visible portion of the spectrum (400-700nm) and eye protection is normally afforded by the aversion response for unaided viewing. However, Class 2M is potentially hazardous if viewed with collection optics (e.g. telescope).

NOTE: The additional hazard from the use of eye loupes within 10 cm of the source will not increase the hazard classification to Class 2M per ANSI Z136.1-2014. Yet per the International Electrotechnical Commission (IEC) 60825-1 (2007) standard, the additional hazard resulting from the use of eye loupes within 10 cm of the source can result in an increase in the hazard class to Class 2M.

Class 3R Laser System
(formerly ANSI Class 3a, CDRH Class IIIa and IEC Class 3B emitting less than 5 mW)

Has reduced control requirements and is potentially hazardous under some direct and specular reflection viewing conditions 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 diffuse reflection hazard.

Class 3B Laser System
May be hazardous under direct and specular reflection viewing conditions, but is normally not a fire hazard, diffuse reflection hazard, nor a laser generated air contaminant (LGAC) production hazard.

Class 4 Laser System
Is a hazard to the eye or skin from the direct beam, may pose a fire hazard or diffuse reflection hazard, and may also produce LGAC and hazardous plasma radiation.

System Designation FLPPS, IEC, ANSI

Lasers or laser systems designated for a specific laser class by a manufacturer in accordance with the Federal Laser Product Performance Standard (FLPPS) CFR 21-1040-10 or International Electrotechnical Commission IEC 60825-1 may be considered as fulfilling all classification requirements of ANSI Z136.1-2014 and UVA's Laser Safety Program. Commercial laser products manufactured in accordance with the FLPPS will be certified by the manufacturer and will incorporate those engineering controls required by FLPPS or IEC. Homemade, original equipment manufacturer (OEM), non-certified and certified laser components and products and combinations are commonly in use in the research setting. Only certified lasers are required to meet FLPPS or IEC requirements. UVA Fabricated lasers for on-site use under the control of the PI are not required to be classified.

Lasers and Laser Systems Developed or Modified in a R&D Laboratory and non-certified

In research settings both manufacturer-certified and non-certified lasers and laser systems and components and systems developed prior to product registration are in common use. These non-certified devices can be used safely. An example would be a diode laser being aimed into an optical fiber on a breadboard.
PI's should employ routine laser safety principles with non-certified lasers also. Consideration should be given to the hazards, e.g. accessible laser energy, maximum permissible exposure limits, providing laser specific-training to users, consultation with LSO to review control measures and LSO authorization. Engineering controls listed in the sections below are recommended in home built or non-certified lasers, laser systems or components if laser energy equivalent to Class 3B and Class 4 is present. Exposure to laser radiation shall be maintained below maximum permissible exposure limits.

A master switch as a means of safe activation and deactivation should be designed in the laser (see Section 9 of this document and Z136.8 Section 4.2.4 for guidance) (Ref: ANSI Z136.8, 4.1.1)

Laser and laser system products being developed and then sent as technology transfers or offsite evaluation/use by others and out of the control of the developer should meet as many FLPPS or IEC safety code requirements as possible.

In cases where the laser or laser system classification is not provided, or where the class level may change because of the addition or deletion of optical elements and/or engineering control measures, the laser or laser system shall be classified by the LSO in consultation with the Radiation Safety Committee and in accordance with Section 3 and Section 9 of ANSI Z136.1-2014.

Class identification labels are affixed to each commercially produced laser. Removal of protective housing or system modification can increase a laser's classification. Contact the LSO for review prior to servicing or modification.

4. LASER ACQUISITION, TRANSFER AND DISPOSAL

4.1 Acquisition & Registration

The PI/LS/LSC must notify the LSO of all Class 3B or Class 4 lasers/laser system via the EHS online laser registry https://researchcompliance.web.virginia.edu/laser/user/home.cfm
The LSO, in consultation with the PI/LS/LSC, will conduct a hazard evaluation of the acquired laser and laser work area as part of the laser installation and prior to operation of the laser. Obtaining guidance from EHS, the LSO, and Facilities Management Project Services on architectural specifications for the hazard controlled area, fire safety, beam barriers, PPE and other exposure controls is strongly recommended.

If significant modifications are made to an original laser/laser system, the laser must be re-registered. All laser users working with the modified laser shall be trained on the modifications.

4.2 Transfer

The LSO must be notified when a Class 3B or Class 4 laser is transferred from the jurisdiction of one PI to another PI. The new PI/LS/LSC must register the laser via the online EHS laser registry.
https://researchcompliance.web.virginia.edu/laser/user/home.cfm
The LSO must be notified prior to the transferring of a Class 3B or Class 4 laser off-grounds.

4.3 Sale, Disposal, or Surplusing

The LSO must be notified prior to the sale, disposal, or surplusing of a Class 3B or Class 4 laser as well as embedded Class 3B or Class 4 lasers found in Class 1 or Class 2 equipment. Disposal requires permanent decommissioning of the laser. Sale or surplusing require confirmation of an LSO and laser safety program at the receiving institution.

5. CONTROL MEASURES

General Considerations

Control measures range from warning labels to undefeatable interlocks to laser eyewear to laser safe window coverings. These measures may be required or recommended as best practice based upon the particular research application. A laser controlled area (LCA) shall be established for all Class 3B and Class 4 laser operations and the research lab shall implement control measures described below based upon use patterns so to prevent exposure to laser radiation above the maximum permissible exposure limit (MPE). A hazard analysis of new and significantly modified laser installations shall be completed by the LSO. Aspects of a hazard analysis can be found in Appendix K.

Nominal Hazard Zone(NHZ), Maximum Permissible Exposure (MPE) and the LCA

The NHZ is the area within which contact with the laser beam, as an intra-beam exposure or exposure from scattered radiation exceeds the laser radiation MPE. The NHZ is identified and confined within the LCA. The NHZ may be the entire LCA however, as an extra safety measure; effort should be made to contain the NHZ to a smaller sub-area of the LCA using engineering controls such as perimeter guards, enclosures, beam blocks, barriers and curtains. Within the LCA, the NHZ should be clearly identified and have appropriate labels or signs as well as clear documentation in laser safety manual.

For all uses of lasers or laser systems in restricted or controlled areas, the minimum laser radiation required for the application should be used. Also, the beam height should be maintained at a level other than the normal position of the eye of a person in the standing or seated position unless additional controls have been put in place to protect individuals at such locations.

Laser safety training, Level 1 and Level 2, shall be completed and documented in the EHS STAR program. Engineering controls shall be given primary consideration in the lab's laser safety program design and are preferred over administrative controls. Enclosure of the laser equipment and the beam path, or remote viewing and operation are the preferred methods of control. Upon review and approval by the LSO, in consultation with the Radiation Safety Committee, engineering and administrative controls, specified in Sections 5.4 and 5.5, may be replaced by procedural, administrative and other alternate controls.

General considerations for engineered control measures are discussed below along with administrative, procedural and PPE controls. Further discussion specific to laser safety for different research scenarios can be found in ANSI Standard Z136.8, available from the University LSO in the UVA EHS Department.

Class 1, 1M, 2, 2M & 3R Laser Systems

These are low hazard devices when used as intended and with the following requirements:

- ✓ Ensure training on proper use of the laser
- ✓ Ensure laser radiation exposure is kept below the Maximum Permissible Exposure limit (MPE)
- ✓ All appropriate warning labels with laser sunburst symbol and cautionary statements must be present
- ✓ Removal of housing or system modification can increase a laser's classification. Contact the LSO for review prior to system modification.
- ✓ Use of Class 1M, 2M and 3R lasers with optical aides e.g. telescopes, microscopes or alignment devices should be reviewed with the LSO prior to operation.

Class 3B & 4 Laser Systems

Ensuring safe operation of a Class 3B or Class 4 laser requires consideration and application of several elements. These elements are exposure control measures that include but are not limited to; a laser hazard analysis, a laser controlled area (LCA), the use of engineering controls, barriers and PPE, and written procedures specifying safe work practices for beam hazards and non-beam hazards.

A laser hazard analysis, including determination of the MPE and Nominal Hazard Zone (NHZ) is to be made in consultation with the LSO. If the maximum level of accessible radiation is equivalent to Class 3B or 4, a laser-controlled area must be established and control measures instituted within the NHZ.

5.2 Class 3B Laser Control Area Requirements

The operation of Class 3B lasers requires the following procedures in the controlled area:

- ✓ Lasers and laser systems are permitted to only be operated by authorized personnel
- ✓ Appropriate warning signs posted
- ✓ An activation warning system, audible and visible (see ANSI Z136.8; 4.2.7.2 for guidance)
- ✓ Area and entryway controls in the laser controlled area designed to allow rapid egress by laser personnel and admittance by emergency responders under emergency conditions
- ✓ The laser beam path is well defined and projects into a controlled space. When the beam must extend outdoors beyond the indoor controlled area the beam path must be well defined and project into a controlled outdoor airspace. The latter is especially important under atmospheric conditions that would increase beam reflection, e.g. rain, fog, snow etc.
- ✓ Any potentially hazardous beam <u>should</u> be terminated (Class 3B) or <u>shall</u> be terminated (Class 4) in a beam stop of an appropriate material (Class 3B)
- ✓ The laser must be under the direct supervision of an individual knowledgeable in laser safety at all times. If <u>not</u> operated under direct supervision, laser radiation levels shall be limited by control measures documented in laser safety manual so that unprotected spectators in the area shall not be exposed to levels that exceed applicable MPEs. Control measures such as:
    - o beam traps, barriers, windows, enclosures, limited open beam access points
    - o interlock access control to the controlled area which will reduce laser exposure to at or below the MPE if an unauthorized person gains access
    - o laser safety training provided and documented to those who may enter unattended LCA
    - o the LSO has approved the operation
    - o warning signs containing the “DANGER” signal word and instructions regarding the hazards of entry into the space including “unattended laser in operation”
- ✓ Laser located so that access to the area by spectators is not permitted without supervisor approval. If permitted by the supervisor the degree of hazard and avoidance procedures must be explained to the spectator(s) and appropriate protective measures for the spectator(s) taken.
- ✓ All windows, doorways, open portals, etc. must be covered and/or restricted in such a way as to reduce the transmitted laser radiation to levels at or below the ocular MPE.
- ✓ Diffusively reflecting materials only present in or near the beam path where possible. Administrative safety controls applied if reflective surfaces present.
- ✓ Appropriate eye protection required for personnel within the laser-controlled area in accordance with laboratory specific procedures. Respiratory protection for LGAC made available as needed.
- ✓ Laser or laser system must be disabled (by removal of key or lock-out/tag-out) or securely stored when not in use to prevent unauthorized use.

5.3 Class 4 Laser Control Area Requirements

Incorporate all of the Class 3B requirements listed above plus the additional control methods below:

- ✓ The laser shall be secured such that the exposure beam path is above or below eye level of a person in any standing or seated position, if possible. If not possible, operating procedures and administrative controls shall be designed to prevent exposure to the beam at this orientation.
- ✓ Whenever appropriate and possible, Class 4 lasers and laser systems should be controlled and monitored at a position as distant as possible from the beam aperture or beam path.

- ✓ Preclude the entry of unprotected, unauthorized personnel while a Class 4 laser is operating by the use of control area interlocks or alternate controls. The interlock system may preclude entry while the laser is operating or be set to terminate laser operation or reduce energy to safe levels if the door is opened without deliberate overriding of the interlock by an authorized, trained laser user. Override is generally by password or keyed.

Or controlled by the following measures:

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

Very high energy Class 4 lasers (kW and multi-kW) shall require LSO evaluation for emergency conditions. The manner to obtain reduction in laser output power or a complete operational shutdown during an emergency will be determined in consultation with the PI and Facilities Management.

5.4 Engineering Controls

Per the hierarchy of controls, engineering controls are the first measure to be employed to ensure exposures below the MPE. Controls required for Class 3B and 4 lasers are listed in the following table. If specific engineering controls are not feasible, they may be replaced by specific administrative and procedural controls and PPE. See discussion of administrative and procedural controls in the next section. The alternate controls are to be noted in the laboratory's written laser safety manual and reviewed by the LSO prior to laser operation.

Engineered Control	**Laser Class 3B**	**Laser Class 4**
Protective Housing – for active laser work with housing off, contact LSO for hazard analysis and appropriate controls	√	√
Interlocks on protective housing	√	√
Service access panels interlocked or tool required and appropriate warning label on the panel	√	√
Key control	√	√
Remote interlock connector	+	√
Beam stop or attenuator	+	√

Laser Activation Warning System	+	√
Emission delay		√
Remote firing and monitoring		+
Emergency OFF button		√
Viewing windows, diffuse display screens, or collecting optics (lenses, microscopes, etc.) are controlled with interlocks, filters, or attenuators to maintain laser radiation at the viewing position at or below the applicable MPE	√	√
Enclosed beam path	+	+

√ = Required + = Recommended

5.5 Administrative and Procedural Controls

Administrative and procedural controls for Class 3B and Class 4 lasers include laser system program administration parameters and the written instructions, including methods and work practices, which define the safety procedures used during laser operation. Required administrative and procedural controls for Class 3B and 4 lasers include but are not limited to the following:

- ✓ Written laser safety manual for each Class 3B and Class 4 laser/laser system. Procedures for safe operation, maintenance, and ALIGNMENT procedures. See Appendix F for alignment procedures. Alternate means of viewing the beam such as CCD and web cameras should be considered before allowing the use of alignment eyewear. The lab's laser safety manual to be approved by LSO prior to operation of lasers or laser systems.

- ✓ Only personnel authorized by the PI or LS may operate, maintain, or service a Class 3B or 4 laser or laser system. The PI/Lab Supervisor must ensure that authorized personnel have 1) completed basic laser physics and safety Level 1 training as well as OTJ (on-the-job) Level 2 training, 2) are provided with PPE before access to the laboratory is granted, and 3) authorized personnel are the only personnel who operate the laser(s).

Note: Qualified laser users who are authorized to operate and maintain Class 3B and Class 4 lasers are NOT authorized for maintenance/service activities of a laser if the laser emission may exceed Class 3R or 5 mW while being serviced. Lasers that need service, such as repair or replacement of components, are to be performed by the manufacturer's service representative or under documented approval and guidance of the PI. Guidance to include additional training on the laser hazards during the service, (including CPR if working with high-voltage power supplies or system components), written operating procedures that address the service and assessment and control of laser hazards, maintenance of a laser controlled area, buddy system for service work, and proper restoration of equipment (e.g. interlocks) at completion.

- ✓ Always use the minimum laser radiation required for the application. The laser hazard analysis may find that reduction of levels of accessible power or radiant energy is required for the operation or maintenance of some Class 3B or 4 laser systems.

- ✓ Design the laser work so that the beam height is maintained at a level other than that of the eye when in a normal standing or sitting position.

- ✓ Lasers, laser systems, and the laboratory entryway(s) must have the appropriate warning labels and signs.

6. BARRIERS & PROTECTIVE EQUIPMENT

6.1 Laser Protective Barriers and Curtains

For Class 3B and Class 4 lasers, a barrier, curtain, or screen which can block or filter the laser beam at the entryway should be used inside the controlled area to prevent laser light from exiting the area at levels above the applicable MPE level. The material of construction should be 'laser safe', able to withstand direct and diffusely scattered beams. The barrier should exhibit a barrier threshold limit for beam penetration through the barrier for 100 seconds and be located at a distance from the laser source so that the threshold limit is not exceeded in the worst–case exposure scenario. It is also essential that the barrier material be non-flammable and not support combustion or be consumed by flames at the termination of the beam. It should also not present an airborne, respiratory hazard from decomposition products generated from the laser interaction with the barrier.

6.2 Facility Viewing Window Protection

All facility windows, exterior or interior, located within the NHZ of a Class 3B or Class 4 laser or laser system must be covered with appropriate absorbing filter, scattering filter, blocking barrier, or screen to reduce any transmitted laser radiation to levels below the applicable MPE level. Factors for selection are the same as those detailed above for laser protective barriers and curtains.

All viewing portals, optics, windows or display screens included as part of the laser or laser installation shall incorporate some means to attenuate the laser radiation transmitted through the windows to levels below the appropriate MPE. Lenses, telescopes, microscopes, endoscopes, and eye-loupes that integrate the use of a laser or laser system shall incorporate suitable means, such as interlocks, filters, and attenuators, to maintain the laser radiation transmitted through the collecting optics to levels at or below the applicable MPEs.

All permanently mounted collecting optics housings containing laser protective filters sold other than as an integral part of a product shall be labeled with the optical density and wavelength(s) for which protection is afforded. All collecting optics filter housings should also be labeled with the threshold limit and exposure time for which the limit applies and the condition under which protection is afforded.

6.3 Personal Protective Equipment

When other control measures are not practical to remove the potential for exposure to the laser beam, personal protective equipment (PPE) shall be used to provide protection against laser radiation. Laser eye protection, with optical density (OD) and wavelength matched to each laser, shall be used for Class 3B and Class 4 lasers and laser systems. Clothing and gloves specifically selected for suitable protection against laser radiation should be considered for Class 3B and 4 lasers and laser systems. NOTE: PPE has serious limitations when used with higher-powered Class 4 lasers and may be insufficient to reduce or eliminate the hazard and may be damaged by incident laser radiation. PPE should not be used as the only control measure with Class 4 lasers.

6.3a Eye Protection

Appropriate laser eyewear designed for protection against radiation from Class 3B and Class 4 lasers *should* be administratively required for Class 3B and *shall* be administratively required for Class 4 within the NHZ and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable maximum permissible exposure (MPE) to laser radiation. For example, if analysis demonstrates that the MPE will not be exceeded due to an extremely short NHZ, then laser safety eyewear may not be required, if confirmed in consultation with the LSO. This could occur due to laser beam emission characteristics (e.g. highly divergent beam), restrictions placed on the use of the laser or laser systems (e.g. limited open or enclosed beam path), or other factors.

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

Eyewear must be inspected before each use, cleaned periodically, and replaced if necessary, to maintain the eyewear in good condition. Contact the LSO for assistance in selecting protective eyewear. Refer to Appendix G for Eyewear Selection Chart including inspection and cleaning guidelines. Alternate means of viewing the beam such as CCD and web cameras should be considered before allowing the use of alignment eyewear.

Factors in selecting appropriate eyewear:
1) Laser power and/or pulse energy
2) Wavelength(s) of laser output
3) Potential for multi-wavelength operation
4) Radiant exposure or irradiance levels for which protection (worst case) is required
5) Exposure time criteria
6) Maximum permissible exposure (MPE)
7) Optical density requirement of eyewear filters at laser output wavelength
8) Angular dependence of protection afforded
9) Visible light transmission requirement and assessment of the effect of the eyewear on the ability to perform tasks while wearing the eyewear
10) Need for side-shield protection and maximum peripheral vision requirement
11) Radiant exposure or irradiance and the corresponding time factors at which laser safety filter characteristics change occurs, including transient bleaching especially for ultra-short pulse lengths
12) Need for prescription glasses
13) Comfort and fit
14) Degradation of filter media, such as photo bleaching
15) Strength of materials (resistance to mechanical trauma and shock)
16) Capability of the front surface to produce a hazardous specular reflection
17) Requirement for anti-fogging design or coatings

Filters used in the construction of laser safe eye protection all have physical damage thresholds that may be exceeded under certain conditions, e.g. ultrashort, high peak power and high pulse repetition laser systems. Consult with the LSO and laser eyewear manufacturers when selecting eyewear for these lasers.

Laser eyewear may also be inadequate to protect the user from serious ocular exposure from high power, multi-kilowatt laser beams.

6.3b Skin Protection and UV Lasers

Skin protection can best be achieved through engineering controls. Due to the potential for significant photochemical bio effects and the high level of scattering of UV radiation by air molecules, particular care shall be taken when using UV lasers or laser systems. Exposure to UV radiation shall be minimized using beam shields and clothing that attenuate the radiation below the applicable MPE. In some laser applications, e.g. excimer lasers operating in the UV, the use of skin cover shall be employed if chronic (repeated) exposures are anticipated at exposure levels at or near the applicable MPEs for skin. If potential skin damaging exposures exist, particularly for UV lasers 295nm to 400 nm and/or laser welding/cutting operations, then skin covers and or "sun screen" creams are recommended.

Tightly woven, flame- retardant fabrics provide the best protection for Class 4 lasers. Welders' gloves provide the best protection for Class 4 lasers. Studies have shown PPE used in hot industries and firefighting may provide some protection.

Special attention must be given to the possibility of producing undesirable reactions in the presence of UV radiation (formation of skin sensitizing agents, ozone, other laser generated airborne contaminants, etc.). Eye and skin PPE shall be used when working with open beam Class 3B or Class 4 UV lasers when the potential exists to exceed maximum permissible exposure limits.

NOTE: Relatively few studies have examined protective clothing and gloves for use with laser radiation so there is limited data on which to base recommendations. Caution should be taken in selecting PPE.

7. WARNING SIGNS, LABELS ON LASER EQUIPMENT & PROTECTIVE EQUIPMENT

ANSI/IEC approved signs and labels must be conspicuously displayed in locations where they best serve to warn onlookers. See Appendix H for details on sign formatting. Personnel who do not read/understand the English language and who may need to enter areas where lasers are used must be provided appropriate instructions as to the meaning of warning signs and labels. The PI/LSC is responsible for identifying and training such personnel under their area of responsibility. Facilities Management supervisors are responsible for instructing their personnel and contractors on the hazard warning system and coordinating laser safety for a project within the lab with the PI/LSC. ANSI-compliant door signs are available from the LSO and the laser manufacturer.

7.1 Warning Signs

Laser controlled areas must be posted with the appropriate warning signs at the entryway(s) and if necessary, within the laser controlled area. The highest hazard class of laser within the laser controlled area shall be on the warning sign. The signs shall be conspicuously displayed in locations where they best serve to warn onlookers.

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

- **Warning**: shall be used on laser area warning signs associated with lasers and laser systems whose output exceeds the MPE for irradiance, including all Class 3B and most Class 4 lasers and laser systems.
- **Caution**: shall be used with all signs and labels associated with Class 2 and Class 2M laser and laser systems that do not exceed the applicable MPE for irradiance.
- **Notice**: the signal word to address practices not related to personal injury but to mark the location of an exterior boundary and notify of a temporary laser controlled area, e.g. while laser servicing is occurring. The area outside the temporary area remains Class 1 while the area within is Class 3B or Class 4. Required to be used on signs posted outside the temporary laser controlled area. The area within the temporary controlled area must also have appropriate signs posted (danger warning for Class 3B or Class 4).

NOTE: The word "Radiation" on signs and labels may be replaced by the word "Light" for lasers operating in the visible range at wavelengths greater than 400 nm and equal to or less than 700 nm. For lasers operating outside of this visible range the word "Invisible" shall be placed prior to the words "Laser Radiation".

8. LABELING OF LASER EQUIPMENT AND PROTECTIVE EQUIPMENT

8.1 Equipment Labels

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

- Class 2 lasers and laser systems, "Laser Radiation – Do Not Stare into Beam"
- Class 2M lasers and laser systems, "Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments"
- Class 3R and 3B lasers or laser systems, "Laser Radiation – Avoid Direct Eye Exposure to Beam"
- Class 4 lasers or laser systems, "Laser Radiation – Avoid Eye Exposure to Direct or Scattered Radiation; Avoid Skin Exposure to Direct Radiation"

8.2 Labeling of Protective Eyewear

All eyewear shall be clearly labeled with the optical density (OD) and wavelength for which protection is afforded.
Color-coding or other distinctive identification is recommended in multi-laser environments. Individual users are responsible to confirm, by OD and wavelength, that the eyewear designated by a distinctive identification system in their area is the correct eyewear for their application.

8.3 Labeling of Laser Protective Windows and Collecting Optic Filters

All laser protective windows, sold other than as an integral part of a product, must be labeled with the optical density and wavelength(s) for which protection is afforded and should be labeled with the exposure time for which the limit applies and the conditions under which protection if afforded.

8.4 Labeling of Laser Protective Barriers

All laser protective barriers, sold other than as an integral part of a product, must be labeled with the barrier exposure time for which the limit applies and beam exposure conditions under which protection is afforded. Contact LSO for any assistance.

9. KEY CONTROL

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

All energy sources associated with Class 3B or Class 4 lasers shall be designed to permit lock-out/tag-out procedures required by the Occupational Safety and Health Administration (OSHA) 1910.147. http://ehs.virginia.edu/ehs/ehs.es/es.loto.html

10. NON-BEAM HAZARDS

The most notable non-beam hazards include electrical, laser generated air contaminants (LGAC), and trip hazards. These hazards can be significant and should be addressed in the laboratory-specific laser safety manual. See Appendix I for discussion of these and other non-beam hazards.

The electrical hazard discussion brought forward below due to the significant hazard it represents.

H.1 Electrical Hazards

An electrical shock hazard can occur from contact with exposed utility power utilization, device control, and power supply conductors operating at potentials of 50 volts and above. Individuals involved in such uses must be trained in electrical safety and in proper lockout-tagout procedures. See EHS Webpage on Electrical Safety http://ehs.virginia.edu/ehs/ehs.es/es.html http://ehs.virginia.edu/ehs/ehs.es/es.loto.html

- Class 3B and 4 lasers should have a separate circuit and local cut-off switch (breaker) for the circuit.
- Label and post electrical high voltage hazards and switches. Clearly identify the main switches to cut-off power. Before working on a laser, de-energize the machine. Positively disconnect it, if there is more than one source of power, disconnect them all. Lock out and tag the disconnect switches so that power is not reconnected while you are working on the laser.
- Have at least two persons in an area while working on high-energy power systems.

Keep cooling water connections away from main power and high voltage outlets and contacts. Use double hose clamps on cooling water hoses. Inspect cooling water hoses and connections and power cables and connectors periodically as part of a regular equipment inspection.

Ref: Electrical Safety in Laser Laboratories from "Electrical Safety Policy", LED 61-00-01-AIA published by the Lawrence Livermore National Laboratory

11. TRAINING

PIs are responsible for ensuring that staff and students receive appropriate training on the hazards in their work area and that documentation of that training is maintained. The UVA EHS STAR system is recommended for documenting and tracking training. See STAR at the EHS website http://ehs.virginia.edu/ehs/ and contact EHS for assistance as needed.

Before operating a Class 3B or Class 4 laser or laser system, all users must:

1) Read this Laser Safety Program,
2) Complete laser safety training Level 1 provided online through EHS STAR,
3) Receive laboratory-specific safety training Level 2 (including a thorough review of the laser equipment, administrative and engineering controls, and alignment and standard operating procedures) from the PI/LS, and
4) Read and sign a copy of the applicable laser safety manuals.

PI shall ensure laser users are re-trained whenever a new hazard is introduced into the work area.

PI/LSs are responsible for providing Laser Safety Awareness training to any visitors or spectators to the laboratory when lasers are in operation, to include the nature of the hazard and any measures to take to prevent exposure. A sign-in log which indicates awareness training has been completed is recommended as it would benefit PI/LS in the documentation of the safety measures taken in their laboratory.

12. LASER ACCIDENTS

Most laser accidents occur during beam alignment procedures. Be sure to that all personnel performing alignments perform their work in accordance with guidelines presented in Appendix F. Alternate means of viewing the beam such as CCD and web cameras should be considered before allowing the use of alignment eyewear.

12.1 Reporting Procedures

All accidents/exposures are to be reported to the PI and/or lab supervisor as soon as possible.

<u>Serious Injury/Illness</u>
For health-threatening injuries/illnesses, call 911 or proceed immediately to the UVA Hospital Emergency Department. Supervisors are to **<u>immediately</u>** report a work-related death.

All work-related employee inpatient hospitalizations, all amputations and all losses of an eye report shall be reported within 24 hour

Report to: UVA Human Resources Workers' Compensation Specialist 434-924-1426, dag9hu@virginia.edu.

The UVA Human Resources Workers' Compensation Specialist reports these events to the Occupational Safety & Health Administration (OSHA).

Accidents/exposures involving lasers are to be reported to the LSO by the PI or PI's designee within 24-48 hours.

<u>All Other Injury/Illness</u>
For treatment of all other injuries, proceed to:

For Students, Elson Student Health Center (400 Brandon Ave., x4-5352)
http://www.virginia.edu/studenthealth/
For Employees, contact UVA-WorkMed (1910 Arlington Blvd. x3-0075)
http://www.healthsystem.virginia.edu/pub/occupational-health

12.2 Medical Surveillance

Eye exams must be performed after an actual or suspected laser-induced eye injury. Evaluation by a medical professional should occur as soon as possible after the exposure, usually within 48 hours. Referrals for medical examinations shall be consistent with the medical symptoms and the anticipated biological effect based upon the laser system in use at the time of the incident. For laser-induced injury to the retina, the medical examination shall be performed by an ophthalmologist. Employees with skin injuries should be seen by a physician.

12.3 Standardized Forms for Accident/Exposures

Two forms are to be completed by the supervisor and employee and filed within 24 hours of the incident.

- Supervisors are to provide an *Employee's Claim for Workers' Compensation Benefits* form (http://www.hr.virginia.edu/forms/workers-compensation-forms/) to the injured employee immediately. Supervisors and employees are to complete within 24 hours.
- *Accident, Incident or Exposure Report* (for all non-auto related incidents/ injuries/exposures) has two sections: one for the supervisor and one for the employee to complete. To be completed within 24 hours and sent to Risk Management. (http://www.virginia.edu/riskmanagement/documents/ IncidentRptForm.pdf)

When an employee has one or more workdays lost, supervisors are to contact:

UVA Human Resources Workers' Compensation Specialist 434-924-1426, dag9hu@virginia.edu.

regarding forms for completing the Workers' Compensation Lost Workdays Report.

12.4 Accident Investigation

Upon notification of an accident involving a laser, LSO will conduct an investigation. Steps of the investigation include:
1) LSO, in cooperation with the PI/LS, interviews injured workers and witnesses
2) LSO, in cooperation with the PI/LS, examines workplace for factors associated with the accident/exposure
3) LSO, in cooperation with the PI/LS, determines the possible causes of the accident/exposure
4) PI/Lab supervisor takes corrective action to prevent the accident/exposure from recurring
5) PI/Lab supervisor records the findings and corrective actions taken. Findings and corrective actions are documented and maintained by the PI and made available to the LSO upon request.

13. EMBEDDED LASERS, OUTDOOR LASER USE & FIBER OPTICS for TRANSMISSION & ROBOTICS

For the following activities involving lasers, a consultation between the PI/LS/LSC and the LSO should be completed to discuss control measures.

- Embedded Class 3B & 4 lasers – for access into housing or protected enclosure area by individuals other than maintenance personnel from the laser manufacturer, contact LSO - EHS
- Class 3B & 4 outdoor use – contact the LSO 10 days prior to use for a required hazard review
- Lasers used in fiber optic transmission systems and robotic installations – contact EHS – LSO for applicable control measures.

14. RECORDKEEPING

The PI is responsible for maintaining all laser safety-related records (i.e., laser safety training, laser safety manual, inspections/ audits, incident/accident investigations) for each employee. Medical examinations related to occupational use of lasers or accidental laser exposure should be maintained for at least 30 years. For general purposes (non-medical), it is recommended that records be maintained as long as the employee works with that laser or laser system. The records related to an incident or accident which was required to be reported to OSHA as a recordable event shall be retained for a minimum of 5 years.

APPENDICES

APPENDIX A: CORE LASER SAFETY PRACTICES

Core Laser Safety Practices	
1	• Select proper eyewear in accordance with laboratory specific procedures; check eyewear condition before each use • Ensure all personnel are wearing appropriate eyewear as required
2	• Be knowledgeable of all safety controls and equipment safety features
3	• Remove or cover jewelry, watches, and other reflective objects
4	• **Communicate:** alert others prior to turning on laser, opening shutters, or creating new beam paths
5	• Exclude unnecessary personnel during alignment
6	• Have good diagnostics available for indirect viewing of the laser beam such as fluorescent cards, CCD cameras, or infrared (IR) viewers
7	• Keep primary and stray beams in horizontal plane below eye level when possible • Never bring eyes near plane in which the laser propagates
8	• Check for and block stray beams: when placing a new optical component in the beam, locate and block all stray reflections before proceeding to next step
9	• Use beam blocks: block the beam upstream until beam is needed; place a block downbeam of optic path being aligned
10	• Use special caution when using periscopes, beam-splitting polarizers, and other optics that may generate out-of-plane beams: secure appropriate beam blocks to contain possible stray beams
11	• Use *Class 1 enclosures* to eliminate laser hazards when possible • Use barriers, beam tubes, and table enclosures or side shields when possible
12	• Use irises to aid in alignment
13	• Use minimum intensity needed, and use low-power alignment lasers when possible
14	• Secure all optics to table • Practice good housekeeping
15	• Include *control of hazardous energy* practices in lab standard operating procedures i.e. Control of Hazardous Energy (CoHE) procedures e.g. lockout-tagout (LOTO) for electrical and zero energy verification for laser

Source: Michael Woods, Steve Edstrom, SLAC National Accelerator Laboratory SLAC PUB14345 & UVA EHS

APPENDIX B: LASER SAFETY MANUAL TEMPLATE

A link to the template can be found at the EHS Laser Safety Webpage

http://ehs.virginia.edu/ehs/ehs.laser/laser.html

APPENDIX C: INSTRUCTIONS & LINK TO ONLINE LASER REGISTRATION

Laser Registration UVA

OVERVIEW & INSTRUCTIONS

On the following pages of the registry you will be entering:

- technical specifications of the laser
- laser related operating procedures of your lab
- descriptions of laser safety design, e.g. safety systems integral to the laser, beam safety on the optical table, beam safety for the room, personal protective equipment, etc.
- a laser lab floor plan, click here for sample floor plan
- a standard operating procedure (SOP) for use of the laser
- an SOP for alignment of the laser, if performed by lab personnel

At the completion of the registration process, the UVA Academic Laser Safety Officer in the Office of Environmental Health & Safety will review your entries for approval of the laser safety program in your laboratory.

Two Steps: Online Registration & Laser Safety Manual

STEP 1: REGISTRATION

****All Class 3B and 4 UVA research lasers are required to be registered through this online registry ****

Previously registered & approved? (prior to July 1, 2016)

If your lasers have been registered with EHS in the past and a laser safety manual submitted and approved, those lasers are still to be entered in this registry, AND TO SAVE TIME, you may opt to refer to that laser safety manual in your responses to the latter portion of the registry where text responses are requested. Refer to your laser safety manual in text box responses by Principal Investigator, location, and laser type, e.g. Prof Benjamin Smith, Physics Bldg, Lab 216, Crystalaser Diode.

Multiple Laser Systems (more than 1 laser in the experimental design)

For laser systems comprised of multiple components, each laser in the system must be entered into the registry separately. There is a COPY option which allows a new registration to begin with registration details previously entered for another laser. Enter the specific data and information for the new laser by editing the copied registration form.

STEP 2: LASER SAFETY MANUAL

The Laser Safety Manual contains: 1) Laser specifications, 2) SOPs including alignment procedures[1]

Options:

- Use the pdf document generated from your laser registry entries as your laser safety manual and for training laboratory personnel.
  OR
- Your existing Laser Safety Manual submitted to LSO and approved prior to July 1, 2016
- Author a Laser Safety Manual based upon the Laser Safety Manual Template (future link to the updated manual) or your own format as long as all required topics are included as per the UVA Laser Safety Program (future link to the program)

LINK TO UVA LASER REGISTRATION:

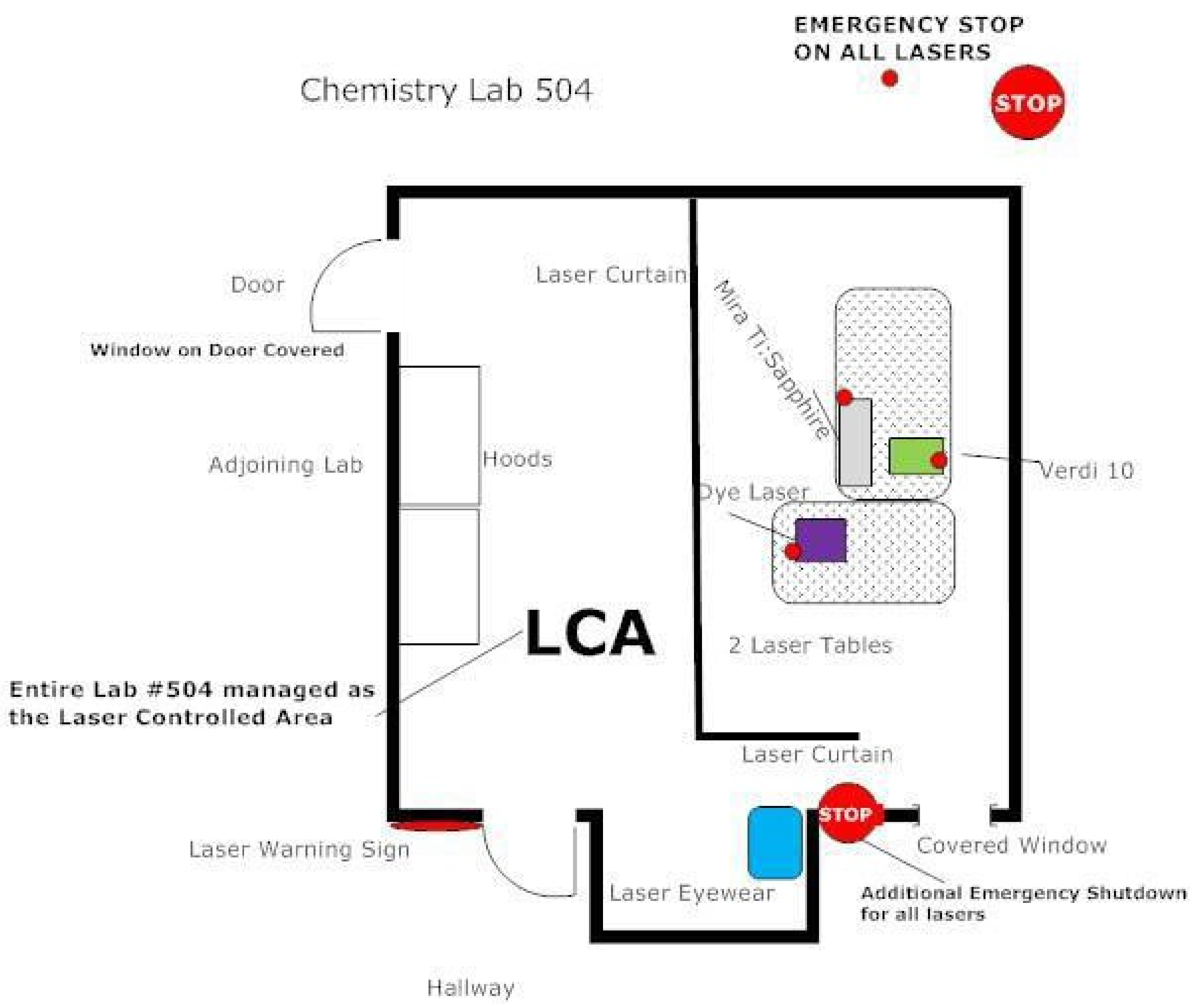
https://researchcompliance.web.virginia.edu/laser/user/home.cfm

APPENDIX D: SAMPLE LASER LABORATORY FLOOR PLAN

Requested elements:

Laser(s)	Laser table(s)	Laser controlled area
Doors	Windows	Laser warning light/signs
Laser curtain(s)	Emergency stop switch	Laser eyewear location

(hand drawn floor plan OK too)



APPENDIX E: SELF-AUDIT CHECKLIST

PI/Lab Supervisor_____________________Building & Room #__________________

This checklist can be used by a research group to evaluate the status of the laser safety program in the group's laboratories. Laboratories operating with DOE or DOD grants may be required to perform annual self-audits of their laser safety program. Audit results provide focus areas for improving laser safety through identifying deficiencies and taking corrective actions.

Date:	YES	NO
1. All authorized users and their completed laser safety training dates listed in your Laser Safety Manual, tracked on STAR or otherwise available?		
2. Any significant changes to laser system that impact laser exposure and safety documented in procedures and updated in laser safety training Level 2? Laser users have all completed updated training?		
3. Written standard operating, maintenance and alignment procedures kept with the laser equipment or readily available to users?		
4. Have all commercial product Class 3B and 4 lasers and all lasers modified on grounds been registered with the Academic Laser Safety Officer (LSO)?		
5. Are Class 3B and 4 laser labs posted to indicate that laser safe eyewear, by wavelength and optical density (O.D.) is available? Is laser eyewear stored properly and inspected in accordance with inspection and cleaning guidelines (See Appendix G)		
6. Are protective housings intact and interlocks tested or alternative controls reviewed with the LSO and written in your Laser Safety Manual?		
7. Is access to laser(s) controlled to prevent persons being accidently exposed to the laser beams by posting or controlling the entrance?		
8. Are laser controlled areas posted and equipment labeled with approved signs and labels?		
9. Are windows, ports, which could allow a laser beam to stray into uncontrolled areas covered or protected during laser operation?		
10. No exposed wiring or circuits?		
11. Beam stops present at end of all beam paths and non-combustible?		
12. Barriers/screens (if present) non-combustible and no burn holes present?		
13. Is an operational checklist covering the following items performed prior to each operation? 14. Protective eyewear is appropriate for laser operation and is clean/free of damage 15. All beams traced and dumped? 16. Mirror backs covered? 17. Beam path enclosed when possible? 18. Optical bench free of unnecessary reflective items? 19. If beam crosses walkway, are there posted barriers, is a rope or chain place across path during operation?		

Deficiencies Found	Corrective Action Identified	Date Corrective Action Taken

APPENDIX F: LASER ALIGNMENT GUIDELINES

Laser Alignment Guidelines [1]

In research settings, serious laser accidents are known to occur during laser alignment. Appropriate steps must be taken to minimize the risk to beam injuries occurring during alignment procedures. Class 3B lasers should and Class 4 lasers shall have corresponding alignment procedures written and maintained with the laser for reference.

Alignment Procedures for Class 3B and Class 4 Lasers

1. Alignments shall be done only by those who have received laser safety training. It is best to perform alignments with another trained person. Review all procedures before attempting the alignment. Make sure that all warning signs, lights, and locks are operating. In addition, the following actions should be taken:
2. Exclude unnecessary personnel from the laser area during alignment.
3. Housekeeping is paramount. The work area and optical table should be free of objects or surfaces that could reflect the light. Remove any jewelry, watches, rings (or cover rings with tape), remove objects in shirt pockets, and remove ID badges. Make sure any reflective surfaces in the area are blocked or covered. Remove any unnecessary equipment, tools, and combustible materials.
4. Whenever possible, use low-power visible lasers for path simulation of higher-power visible or invisible lasers.
5. Enclose the beam as much as possible.
6. Wear protective eyewear and clothing to the extent practicable. Use special alignment eyewear when circumstances (e.g. wavelength, power, etc.) permit their use. Alternate means of viewing the beam such as CCD and web cameras should be considered before allowing the use of alignment eyewear.
7. When aligning invisible (and in some cases visible) laser beams, use beam display devices such as image converter viewers or phosphor cards to locate beams.
8. Perform alignment tasks that use high-power lasers, at the lowest possible power level. Pulsed lasers are aligned with single pulses if possible. If the laser is Q-switched, turn off the Q-switch and use low power or CW.
9. Use a shutter or beam block to block high-power beams at their source except when actually needed during the alignment process.
10. Use a laser-rated beam block to terminate high-power beams down range of the optics being aligned.
11. Use beam blocks and/or laser protective barriers in conditions where alignment beams could stray into areas with uninvolved personnel.
12. Place beam blocks behind optics (e.g., turning mirrors) to terminate beams that might miss mirrors during alignment.

13. Locate and block all stray reflections before proceeding to the next optical component or section.
14. Be sure all beams and reflections are properly terminated before high-power operation.
15. Whoever moves or places an optical component on an optical table (or in a beam path) is responsible for identifying and terminating each and every stray beam coming from that component (meaning reflections, diffuse or specular).
16. There shall be no intentional intrabeam viewing with the eye.
17. Post appropriate area warning signs during alignment procedures where lasers are normally Class 1 (enclosed).
18. At alignment conclusion, normal laser hazard controls shall be restored. Controls set back in place include replacing all enclosures, covers, beam blocks, barriers and checking affected interlocks for proper operation

[1] ANSI Z136.1, EHS University of Washington, SLAC, Stanford University Laser Safety Program

APPENDIX G: EYEWEAR SELECTION CHART, INSPECTION & CLEANING GUIDELINES

Eyewear must be periodically cleaned, inspected before each use for pitting, crazing, cracking, discoloration, delamination or lifting of dielectric coatings, and replaced if necessary, to maintain the eyewear in good condition. Care should be observed when cleaning lenses to avoid damage of the absorbing and reflecting surfaces. Consult the manufacturers for instructions on proper cleaning methods
Include alignment eyewear guidelines.

Table 1. Simplified Method for Selecting Laser Eye Protection for a Point Source (Wavelengths Between 400 nm and 1400 nm)[a] from ANSI Z136.1-2014, Table 4

Q-Switched Laser (10^{-9} - 10^{-2} s)		Non-Q-Switched Lasers (0.4×10^{-3} - 10^{-2} s)		Continuous-Wave Lasers Momentary (0.25 - 10 s)		Continuous-Wave Lasers Long-Term Staring (< 1 hr)		Attenuation	
Maximum Output Energy (J)	Max Beam Radiant Exposure ($J \cdot cm^{-2}$)	Max Laser Output Energy (J)	Max Beam Radiant Exposure ($J \cdot cm^{-2}$)	Max Power Output (W)	Max Beam Irradiance ($W \cdot cm^{-2}$)	Max Power Output (W)	Max Beam Irradiance ($W \cdot cm^{-2}$)	Attenuation Factor	OD
10	20	100	200	10^{5} [b]	2×10^{5} [b]	100 [b]	200 [b]	10^{8}	8
1	2	10	20	10^{4} [b]	2×10^{4} [b]	10 [b]	20 [b]	10^{7}	7
10^{-1}	2×10^{-1}	1	2	10^{3} [b]	2×10^{3} [b]	1	2	10^{6}	6
10^{-2}	2×10^{-2}	10^{-1}	2×10^{-1}	100 [b]	200 [b]	10^{-1}	2×10^{-1}	10^{5}	5
10^{-3}	2×10^{-3}	10^{-2}	2×10^{-2}	10	20	10^{-2}	2×10^{-2}	10^{4}	4
10^{-4}	2×10^{-4}	10^{-3}	2×10^{-3}	1	2	10^{-3}	2×10^{-3}	10^{3}	3
10^{-5}	2×10^{-5}	10^{-4}	2×10^{-4}	10^{-1}	2×10^{-1}	10^{-4}	2×10^{-4}	10^{2}	2
10^{-6}	2×10^{-6}	10^{-5}	2×10^{-5}	10^{-2}	2×10^{-2}	10^{-5}	2×10^{-5}	10	1

[a] Use of this table may result in optical densities (OD) greater than necessary.

[b] Not recommended as a control procedure at these levels. These levels of power could damage or destroy the attenuating material used in the eye protection. Skin protection is also required at these levels.

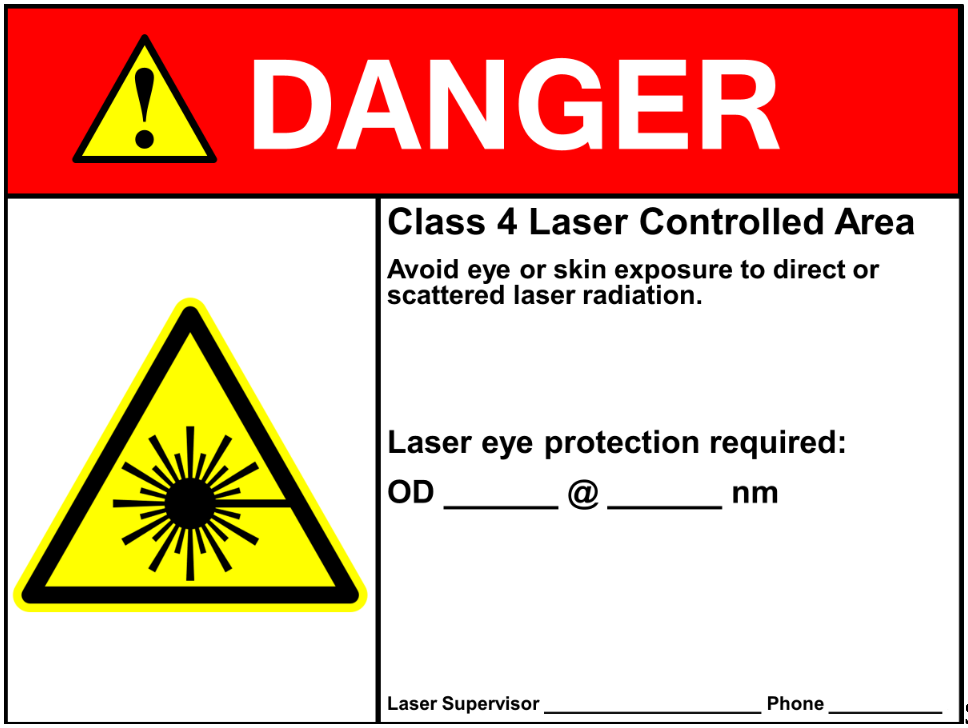
Source: Laser Institute of America, Laser Safety Guide, 12th Edition 2015.

APPENDIX H: LASER CONTROLLED AREA WARNING SIGNS

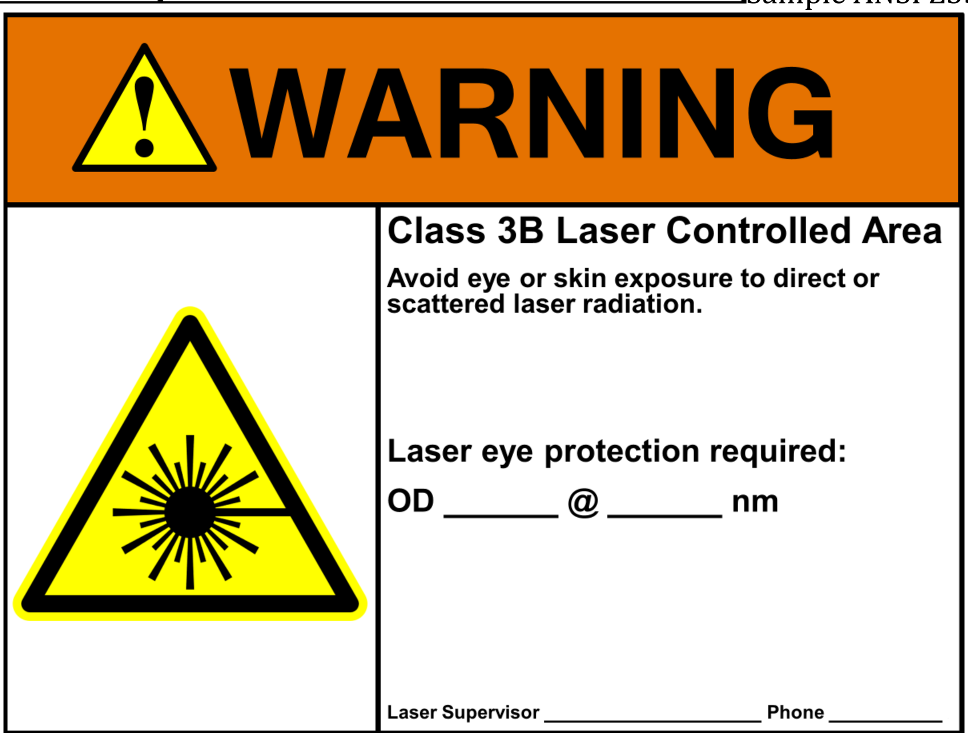
Design of Signs: In accordance with ANSI Z535. Laser controlled area warning signs shall be of the three panel format unless additional panels are needed for a second language. The top panel shall contain the safety alert symbol as well as the signal word. The other two panels shall contain the laser radiation hazard symbol and the message panel.

NOTE: Although not required by the ANSI standard, area warning signs for classes other than 3B or 4 use the signal word CAUTION.

Existing laser controlled area signs prepared in accordance with previous versions of ANSI Z136.8 (prior to 2014) are not considered to fulfill the requirements of ANSIZ138.8-2022. Contact Academic LSO to update or obtain new signs.

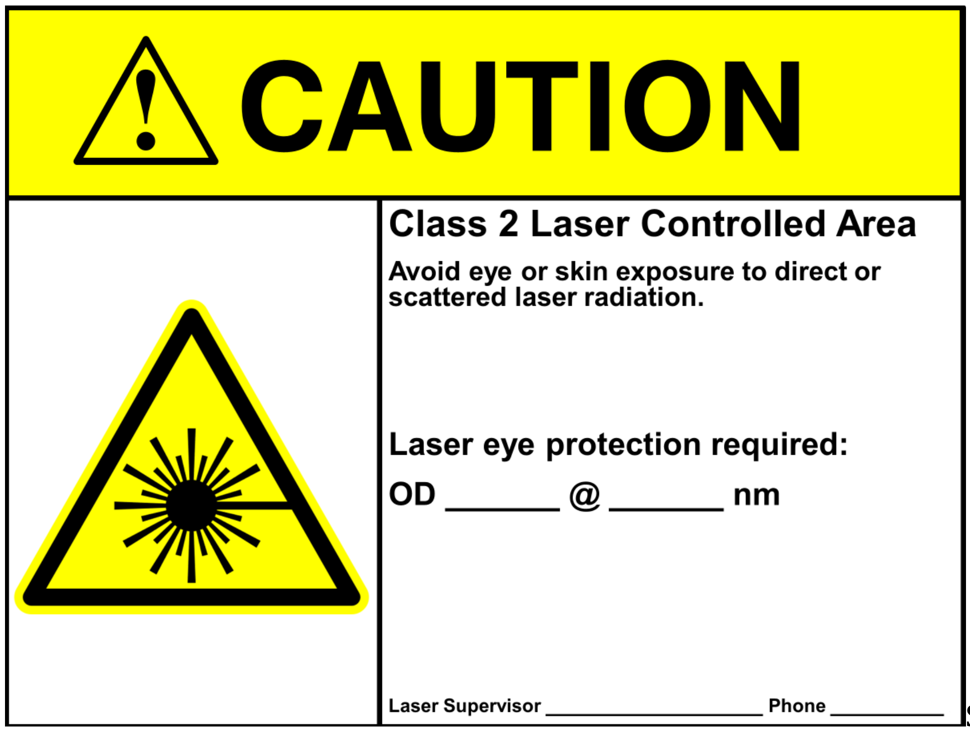


Sample ANSI Z535.2



Compliant Class 4

Sample ANSI Z435.2 Compliant Class 4 and 3B



Sample ANSI Z535.2 Compliant Class 2, 2M, 3R

APPENDIX I: NON-BEAM HAZARDS

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

All written laser safety manuals shall address NBH as well as beam hazards. The following non-beam hazards can be found associated with laser operations. This section is intended to alert researchers of the potential for these hazards and is not intended as a full discussion. Supporting details can be found in ANSI Z136.1, available from the LSO in EHS. Research labs are encouraged to seek the assistance of safety, radiation safety, and industrial hygiene personnel for addressing the safety measures required for these hazards.

H.1 Electrical Hazards

An electrical shock hazard can occur from contact with exposed utility power utilization, device control, and power supply conductors operating at potentials of 50 volts and above. Individuals involved in such uses must be trained in electrical safety and in proper lockout-tagout procedures.
http://ehs.virginia.edu/ehs/ehs.es/es.loto.html

- Class 3B and 4 lasers should have a separate circuit and local cut-off switch (breaker) for the circuit.
- Label and post electrical high voltage hazards and switches. Clearly identify the main switches to cut-off power. Before working on a laser, de-energize the machine. Positively disconnect it, if there is more than one source of power, disconnect them all. Lock out and tag the disconnect switches so that power is not reconnected while you are working on the laser.
- Have at least two persons in an area while working on high-energy power systems.

Keep cooling water connections away from main power and high voltage outlets and contacts. Use double hose clamps on cooling water hoses. Inspect cooling water hoses and connections and power cables and connectors periodically as part of a regular equipment inspection.

Ref: Electrical Safety in Laser Laboratories from "Electrical Safety Policy", LED 61-00-01-AIA published by the Lawrence Livermore National Laboratory.

H.2 Laser-Generated Air Contaminants (LGAC)

LGAC's may be generated when certain Class 3B and Class 4 lasers beams interact with matter. Characteristics of the contaminants depend upon the target material, cover gas, and beam irradiance. The LSO will coordinate with the EHS Occupational Health and Safety (OHS) Group to ensure proper evaluation and recommendation of appropriate controls, if necessary.

H.3 Collateral and Plasma Radiation
Refers to radiation produced by system components other than the primary laser beam. The LSO will coordinate with various departments within EHS, including Radiation Safety and the OHS Group to ensure proper evaluation and recommendation of appropriate controls, if necessary.

H.3.1 X-Radiation (Ionizing Radiation)
May be produced from electrical components of laser systems greater than 15 kV and from laser-metal induced plasmas.

H.3.2 Ultraviolet (UV) and Visible Radiation
May be generated from laser discharge tubes and pump lamps. Can cause skin and eye damage.

H.3.3 Radiofrequencies (RF)
Some lasers contain RF excited components.

H.3.4 Plasma Radiation
Created during certain processes and may contain hazardous UV and blue light emissions.

H.4 Fire Hazards
Class 4 laser beams represent a fire hazard, and under some situations it is possible that Class 3 lasers can initiate fires. Use flame retardant materials wherever applicable with all laser applications. Users should be aware that opaque laser barriers, e.g. curtains, can be designed to offer a range of protection, however, they normally cannot withstand high irradiance levels for more than a few seconds without some damage, e.g., production of smoke, open fire, or penetration. Operators of Class 4 lasers should also be aware of the ability of unprotected wire insulation and plastic tubing to catch on fire from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths. Other factors related to fire safety, such as egress and fire sprinkler location must be considered when designing a laser laboratory. Contact UVA EHS Fire Safety for additional guidance.

H.5 Explosion Hazards
High-pressure arc lamps, filament lamps, and capacitor banks in laser equipment must be enclosed in housings which can withstand the maximum explosive pressure resulting from component disintegration.

H.6 Compressed Gases
Individuals who work with compressed gases must take Compressed Gas Training. Refer to the training module "Chemical Safety-Compressed Gas Cylinder and Regulator Safety" at the EHS website *Safety, Training & Recordkeeping (STAR) system*. Contact EHS at 982-4911 for more details regarding use of compressed gases or for training information.

H.7 Laser Dyes and Solvents
Laser dyes are complex fluorescent organic compounds which, when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. PIs/LSC must ensure that all individuals who work with laser dyes and solvents receive appropriate training on hazardous material handling, storage, and disposal. Additional information can be found in the UVA Chemical Hygiene Plan.

Note: The use of dimethylsulfoxide (DMSO) as a solvent for cyanine dyes in dye lasers should be discontinued if possible. DMSO aids in the transport of dyes through the skin and into the blood stream.

H.8 Noise
A good "rule of thumb" for determining if your work area or activity requires hearing protection is as follows. If you have difficulty hearing or understanding a "normal" tone of voice at a distance of about three feet, noise levels are probably exceeding safe levels and you should be using hearing protection. Please contact EHS at 982-4911 for an evaluation.

H.9 Waste Disposal
Dispose of all wastes in accordance with the relevant guidelines. Contact the EHS Chemical Waste Program at 982-4911 for additional help.
http://ehs.virginia.edu/ehs/ehs.chemicalsafety/chemicalsafety.cwc.html

H.10 Limited Work Space
Limited workspace can be a problem especially while working near or around mechanical or high voltage equipment. Fire and electrical safety requirements are a minimum aisle width of 24” with 36” clearance around electrical panels . In all cases there must be sufficient room for personnel to turn around and maneuver freely.

H.11 Ergonomics
Consider ergonomic principles in laser system designs, such as positioning of the laser system and area illumination.

APPENDIX J: VISITOR SIGN-IN SHEET LASER SAFETY AWARENESS TRAINING

LASER SAFETY AWARENESS ORIENTATION

DATE:	
Principal Investigator:	Lab Location Bldg, Room:
Orientation provided by:	

I have been informed of the safety hazards related to the operation of a laser in this laboratory. The following information was presented to me, and I understand the nature of the hazard and measures to take to avoid exposure:

- √Risk of significant eye and/or skin injury
- √Location of the laser and the laser beam
- √The laser controlled area and nominal hazard zone – locations where entry is restricted
- √Correct use of Laser Protective Eyewear and other protective equipment if needed
- √Laser operation is allowed only by authorized, trained and documented individuals selected by the PI and approved under the University's Laser Safety Program
- √When the laser is in operation, the laser controlled area is restricted to authorized individuals ONLY unless escorted by an authorized individual and such access is approved by the PI

NAME	SIGNATURE	Organization	Email Address

APPENDIX K: ASPECTS OF A LASER HAZARD ANALYSIS

Source: ANSI Z136.8

3. Hazard Evaluation and Classification

3.1 General.

A laser controlled area (LCA) is any area, permanent or temporary, that contains hazardous laser operations. Hazards associated with the laser operation must be evaluated and mitigated by the use of appropriate control measures at the boundaries of and within the LCA. Several aspects of the laser or laser system application influence the total laser hazard evaluation and the application of control measures to the laser, the equipment, and the people. In research, development, or testing environments, these aspects consist of:

a) The capability of the laser or laser system to injure people.

b) The beam path (e.g., in air or vacuum), its configuration (e.g., open beam, fiber optic, level of enclosure) and the factors applied to beam (e.g., non-linear optics, pulse compression, or amplification).

c) Process interactions between the beam and materials during operation, e.g., rapid oxidation, ionizing radiation or laser generated air contaminants (LGACs).

d) The location in which the laser is used (i.e., unrestricted, restricted, controlled, inaccessible, or exclusion).

e) The personnel who may use or be exposed to laser radiation.

3.2 Laser Beam Path.

In the research, development, or testing setting, the parameters of the laser beam may change along its beam path. Therefore, any hazard evaluation will need to consider such changes. This can include changes in wavelength, pulse duration and accessibility to the beam.

3.2.1 Nominal Hazard Zones. The nominal hazard zone (NHZ) is that region identified and confined within the LCA in which the irradiance or radiant exposure of the laser beam may exceed the MPE. The NHZ may be the entire LCA. Every effort should be made to contain the NHZ to a smaller sub-area within the LCA using engineering controls, such as perimeter guards, enclosures, beam blocks, barriers, and curtains. When the NHZ is smaller than the LCA, the NHZ should be clearly identified and have appropriate labels or signs. The LSO may specify the implementation of control measures to protect personnel from exposure to laser radiation above the MPE within the NHZ. Calculations may indicate the NHZ is either smaller or larger than the actual LCA; for ease of operation the LSO can then define the LCA as the NHZ. The LSO shall use one of the following methods to define the NHZ:

3.2.1.1 If the laser radiation is contained within a specific location, then the specific location is defined as the NHZ.

3.2.1.2 Based upon calculations utilizing: 1) the appropriate laser range equations, and 2) the performance specifications provided by the laser or laser system manufacturer, the NHZ can be defined.

3.2.1.3 Declare the entire use area and all locations contained within as the NHZ. Control measures are required within the NHZ, which may include fully enclosing the NHZ when this area is limited in size (see Section 4.3.10 of ANSI Z136.1-2007). Viewing the main beam or a specular laser target with an optical instrument is potentially hazardous due to the instrument's light-gathering capability (see Appendixes B4.2, B6.4.3, and B6.6.3; and Examples 22-24, 45, and 53 in ANSI Z136.1-2007). Therefore, the use of such optical systems may effectively increase the NHZ boundaries and must be considered in the overall hazard analysis.

3.2.2 Indoor Laser Operations. The laser and beam path are considered when evaluating an indoor laser operation whether the beam is enclosed or operated in a restricted or controlled location. Consider all optics (e.g., lenses, mirrors, fiber optics) that are a permanent part of the beam path in this evaluation. The LSO in conjunction with the user should follow the step-by-step procedure described below when evaluating the NHZ for indoor use:

Step 1. Determine and evaluate all possible beam paths and reflections. Include multiple beam paths due to lack of fixed positioning and unintended beam paths due to unstable mounts, bearing wear, vibration and re-alignment, for example.

Step 2. Check for and contain stray reflections.

Step 3. Determine the likelihood for operation or maintenance personnel being within the LCA during operation.

Step 4. Determine whether optical aids such as eye loupes or hand magnifiers will be used within 10 cm of a highly diverging beam.

Contact UVA LSO at 982-4911 for copies of referenced sections in ANSI Z136.1

Step 5. Determine whether non-beam hazards exist.

3.2.3 Outdoor Laser Operations. Define the extent of several potentially hazardous conditions by considering all optics that are a permanent part of the beam path. The LSO should consider the guidance found in ANSI Z136.6 and follow the step-by-step procedures given below in steps 1 through 8.

Step 1. Determine the NHZ of the laser. Calculations of radiant exposure or beam irradiance as a function of range can be made with the range equation (an example can be found in Appendix B of ANSI Z136.1).

These calculated ranges are only estimates beyond a few hundred meters, since uncertainties arise from atmospheric effects (for example, scintillation due to turbulence).

Step 2. Evaluate potential hazards from transmission through windows and specular reflections. Specular surfaces ordinarily encountered (for example, windows and mirrors in vehicles and windows in buildings) are oriented vertically and will usually reflect a horizontal beam in a horizontal plane.

> NOTE—As much as 8% of the beam's original irradiance or radiant exposure can be reflected toward the laser from a clear glass window that is oriented perpendicular to the beam. If the beam strikes a flat, specular surface at an angle, a much greater percentage of the beam can be reflected beyond, or to the side of, the target area. If the beam strikes a still pond or other similar surface at a grazing angle, effective reflectivity also may approach 100%. Specular reflective surfaces, such as raindrops, wet leaves, and most other shiny natural objects, seldom reflect hazardous radiant intensities beyond one meter from these reflectors.

Step 3. Determine whether hazardous diffuse reflections exist (see Table 3 and Examples 47 - 55 in Appendix B6.6 in ANSI Z136.1-2007). Determine the corresponding NHZ.

Step 4. Determine whether the beam will visually interfere with critical tasks. Refer to ANSI Z136.6 for more information on operation of visible laser systems outdoors at night.

Step 5. Evaluate the stability of the laser platform to determine the extent of lateral range control and the lateral constraints that should be placed on the beam traverse. Determine the corresponding NHZ during operation.

Step 6. Consider the likelihood of people being in the NHZ.

Step 7. Determine whether optical aids such as telescopes or binoculars could be used within or near the beam path.

Step 8. Determine if visible lasers will be used near airports at night. Levels of laser irradiance as low as 50 $nW{\cdot}cm^{-2}$ may be of concern. Refer to ANSI Z136.6 for the most complete guidance or the latest revision of FAA Order 7400.2 for additional guidance.

Contact UVA LSO at 982-4911 for copies of referenced sections in ANSI Z136.1

APPENDIX L: DEFINITIONS

Source: ANSI Z136.8

2. Definitions

The definitions of the terms listed below are based on a pragmatic rather than a basic approach. Therefore, the terms defined are limited to those actually used in this standard and its appendixes and are in no way intended to constitute a dictionary of terms used in the laser field as a whole.

absorption. Transformation of radiant energy to a different form of energy by interaction with matter.

accessible emission limit (AEL). The maximum accessible emission level permitted within a particular laser hazard class.

accessible optical radiation. Optical radiation to which the human eye or skin may be exposed for the condition (operation, maintenance, or service) specified.

administrative controls. Control measures incorporating administrative means (e.g., training, safety approvals, LSO designation, and Standard Operating Procedures [SOP]) to mitigate the potential hazards associated with laser use.

alpha max. The angular subtense of an extended source beyond which additional subtense does not contribute to the hazard and need not be considered. This value is 100 mrad for retinal thermal effects and 110 mrad for the retinal photochemical effects. Symbol: α_{max}

alpha min. The angular subtense of a source below which the source can be effectively considered as a point source. The value of alpha min is 1.5 mrad. Symbol: α_{min}

aperture. An opening, window, or lens through which optical radiation can pass.

apparent visual angle. The angular subtense (α) of the source as calculated from source size and distance from the eye. It is not the beam divergence of the source.

attenuation. The decrease in the radiant flux as it passes through an absorbing and/or scattering medium.

authorized personnel. Individuals approved by management to operate, maintain, service, or install laser equipment.

average power. The total energy in an exposure or emission divided by the duration of the exposure or emission.

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

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

beam diameter. The distance between diametrically opposed points in that cross-section of a beam where the power per unit area is $1/e$ (0.368) times that of the peak power per unit area.

C_A. Correction factor that increases the MPE in the near infrared (IR-A) spectral band (700-1400 nm) based upon reduced absorption properties of melanin pigment granules found in the skin and in the retinal pigment epithelium.

C_B. Correction factor that increases the MPE in the red end of the visible spectrum (450-600 nm), because of greatly reduced photochemical hazards.

C_C. Correction factor that increases the MPE for ocular exposure because of pre-retinal absorption of radiant energy in the spectral region between 1150 and 1400 nm.

C_E. Correction factor used for calculating the extended source MPE for the eye from the point source MPE.

C_P. Correction factor that reduces the MPE for repetitive pulse exposure of the eye.

carcinogen. An agent potentially capable of causing cancer.

certified laser. A laser product that has been built to the laser product performance standard (CFR 29, part 1040.1) and such documentation has been submitted to the CDRH.

coagulation. The process of congealing by an increase in viscosity characterized by a condensation of material from a liquid to a gelatinous or solid state.

coherent. A beam of light characterized by a fixed phase relationship (spatial coherence) or single wavelength, i.e., monochromatic (temporal coherence).

collateral radiation. Any electromagnetic radiation, except laser radiation, emitted by a laser or laser system that is physically necessary for its operation.

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.

NOTE—Normal or prescription eyewear is not considered collecting optics.

collimated beam. Effectively, a "parallel" beam of light with very low divergence or convergence.

Condition 1. Pertains to optically aided viewing of collimated beams through telescopes or binoculars.

Condition 2. Pertains to optically aided viewing of sources with highly divergent beams through magnifiers or eye loupes or unaided viewing with or without strong accommodation.

NOTE—Condition 2 has slightly different measurement conditions in IEC 60825-1.[2]

continuous wave (CW). In this standard, a laser operating with a continuous output for a period ≥ 0.25 seconds is regarded as a CW laser.

controlled area (laser). 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.

controlled location. An area where the access, occupancy, and activities of people within are subject to strict control and supervision. By inference, controlled locations are restricted locations with laser radiation hazards at Class 4 with additional control measures specified by the laser operator, the LSO, and the employer management.

cornea. The transparent outer layer of the human eye that 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 400 and 1050 nm, and 20 kHz for wavelengths between 1050 and 1400 nm.

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.

divergence. In this standard, 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

effective energy. Energy, in joules, through the applicable measurement aperture. Symbol: Q_{eff}

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[2] IEC 60825-1, Safety of laser products - Part 1: Equipment classification and requirements. International Electrotechnical Commission, Geneva.

effective power. Power, in watts, through the applicable measurement aperture. Symbol: Φ_{eff}

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

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.

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 controls. Methods of protecting others from exposure to laser radiation that requires no training on the behalf of those who may be exposed, e.g., interlocks and barriers.

energy. The capacity for doing work. Energy content is commonly used to characterize the output of pulsed lasers. Unit: joules (J). Symbol: Q

epithelium (of the cornea). The layer of cells forming the outer surface of the cornea.

erythema. For the purposes of the standard, redness of the skin due to exposure to laser radiation.

exclusion location. An area where occupancy by people is possible but is denied by the LSO during the operation of the laser system.

extended source. A source of optical radiation with an angular subtense at the cornea larger than α_{min}. See also *point source*.

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 1.5-1.8 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.

field of view. The full solid angle from which a detector's active area receives radiation.

focal length. The distance from the secondary nodal point of a lens to the secondary focal point. For a thin lens imaging a distant source, the focal length is the distance between the lens and the focal point.

focal point. The point toward which radiation converges or from which radiation diverges or appears to diverge.

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

hertz (Hz). The unit that expresses the frequency of a periodic oscillation in cycles per second.

inaccessible location. An area where occupancy is not possible due to its dimensions.

infrared radiation. Electromagnetic radiation with wavelengths that lie within the range 700 nm to 1 mm.

installation. Placement and connection of laser equipment at the appropriate site to enable intended operation.

integrated radiance. The integral of the radiance over the exposure duration, expressed in joules-per-centimeter-squared per-steradian ($J{\cdot}cm^{-2}{\cdot}sr^{-1}$).

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

iris. The circular pigmented structure that lies between the aqueous and lens 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 ($W{\cdot}cm^{-2}$). Symbol: E

joule (J). A unit of energy. 1 joule = 1 Newton·meter; 1 joule = 1 watt · second.

Lambertian surface. An ideal (diffuse) surface whose emitted or reflected radiance is independent of the viewing angle.

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

laser barrier. A device used to block or attenuate to safe levels 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.

laser diode. A laser employing a forward-biased semiconductor junction as the active medium.

laser personnel. Persons who routinely work around hazardous laser beams. This standard requires such persons to be protected by engineering controls and administrative procedures.

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 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 that includes a laser.

lesion. An abnormal change in the structure of an organ or part due to injury or disease.

limiting angular subtense. See *alpha min.*

limiting aperture diameter. The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation and classification. Symbol: D_f

limiting cone angle. The cone angle through which radiance or integrated radiance is averaged when photochemical effects are considered in hazard evaluation and classification. Symbol: γ

limiting exposure duration. An exposure duration that is specifically limited by the design or intended use(s). Symbol: T_{max}

macula. 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 emitting a laser beam).

maintenance. Performance of those adjustments or procedures (specified in the user information provided by the manufacturer, and considered preventative to maintain optimal performance of the laser system) that are to be carried out by the user to ensure the intended performance of the product. It does not include *operation* or *service* as defined in this section.

maximum permissible exposure (MPE). The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

measurement aperture. The aperture used for classification of a laser to determine the effective power or energy that is compared with the AEL for each laser hazard class.

meter. A unit of length in the international system of units; currently defined as the length of a path traversed in a vacuum by light during a period of 1/299792458 seconds. Typically, the meter is subdivided into the following units:

centimeter (cm)	=	10^{-2} m
millimeter (mm)	=	10^{-3} m
micrometer (μm)	=	10^{-6} m
nanometer (nm)	=	10^{-9} m

minimum viewing distance. The minimum distance at which the eye can produce a focused image of a diffuse source, usually assumed to be 10 cm.

monochromatic light. Having or consisting of one color or wavelength.

nominal hazard zone (NHZ). The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

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.

normative appendix. An appendix that contains information required to implement the standard and is therefore officially part of the standard. Normative appendixes are placed after the body of the standard for reasons of convenience or to create a hierarchical distinction.

ocular fundus. The concave interior of the eye consisting of the retina, the choroid, the sclera, the optic disk, and blood vessels as seen upon ophthalmoscopic examination.

OEM. Original equipment manufacturer.

open beam path. A laser beam path where any portion of the beam is accessible without defeating an engineering control.

operation. The performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include *maintenance* or *service* as defined in this section.

ophthalmoscope (funduscope). An instrument for examining the interior of the eye.

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 *magnified viewing* and *telescopic viewing.*

optical density. The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength:

$$OD = \log_{10} (1/\tau_\lambda)$$

where τ_λ is the transmittance at the wavelength of interest. Symbol: OD, $D(\lambda)$, or D_λ

photochemical effect. A biological effect produced by a chemical action brought about by the absorption of photons by molecules that directly alter the molecule.

photosensitizers. Substances that increase the sensitivity of a material to exposure by optical radiation.

pigment epithelium (of the retina). The layer of cells that contain brown or black pigment granules next to and behind the rods and cones.

plasma radiation. Black-body radiation generated by luminescence of matter in a laser generated plume.

point source. For purposes of this standard, a source with an angular subtense at the cornea equal to or less than alpha-min (α_{min}), i.e., ≤ 1.5 mrad.

point source viewing. The viewing condition whereby the angular subtense of the source, α, is equal to or less than the limiting angular subtense, α_{min}.

power. The rate at which energy is emitted, transferred, or received. Unit: watts (W); 1 watt = 1 joule-per-second.

procedural controls. Methods or instructions that specify rules, or work practices, or both, that implement or supplement engineering controls and which may specify the use of personal protective equipment.

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. Typical units:

microsecond (μs)	=	10^{-6} s
nanosecond (ns)	=	10^{-9} s
picosecond (ps)	=	10^{-12} s
femtosecond (fs)	=	10^{-15} s

Symbol: t

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

pulsed laser. A laser that 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.

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

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

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

radian (rad). A unit of angular measure equal to the angle subtended at the center of the circle by an arc whose length is equal to the radius of the circle (sr). 1 radian ~ 57.3 degrees; 2π radians = 360 degrees.

radiance. Radiant flux or power output per unit area per unit solid angle expressed in watts-per-centimeter squared per-steradian ($W \cdot cm^{-2} \cdot sr^{-1}$). Symbol: L

radiant energy. Energy emitted, transferred, or received in the form of radiation. Unit: joules (J). Symbol: Q

radiant exposure. Surface density of the radiant energy received. Unit: joules-per-centimeter squared ($J \cdot cm^{-2}$). Symbol: H

radiant flux. Power emitted, transferred, or received in the form of radiation. Unit: watts (W). Symbol: Φ . Synonym: *radiant power*.

radiant power. Power emitted, transferred, or received in the form of radiation. Unit: watts (W). Symbol: Φ. Synonym: *radiant flux*.

radiometry. For the purposes of this standard, the measurement of infrared, visible, and ultraviolet radiation.

reflectance. The ratio of total reflected radiant power to total incident power. Also called "reflectivity."

reflection. Deviation of radiation following incidence on a surface.

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

refractive index (of a medium). The ratio of the velocity of light in a vacuum to the phase velocity in the medium. Symbol: *n*

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

restricted location. An area where access is granted for authorized people and limited for the general public through administrative and engineering control measures. Laser radiation hazards at Class 3B levels or greater may be present and control measures are required. Administrative controls include posted warning signs, attending training, and following established standard operating procedures (SOPs) for laser system(s). Engineering controls include access control measures such as lockable doors, barriers, defeatable interlocks, and curtains to prevent laser radiation from leaving the restricted location.

retina. The sensory tissue that receives the incident image formed by the cornea and lens of the human eye.

retinal hazard region. Optical radiation with wavelengths between 400 and 1400 nm, where the principal hazard is usually to the retina.

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

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

scintillation. The rapid changes in irradiance levels in a cross-section of a laser beam.

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

service. The performance of procedures, typically defined as repair, to bring the laser or laser system or laser product back to full and normal operational status. It does not include *operation* or *maintenance* as defined in this section.

shall. The word *shall* is to be understood as mandatory.

should. The word *should* is to be understood as advisory.

solid angle. The three-dimensional angular spread at the vertex of a cone measured by the area intercepted by the cone on a unit sphere whose center is the vertex of the cone. Unit: steradian (sr).

source. A laser or a laser-illuminated reflecting surface.

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.

steradian (sr). The unit of measure for a solid angle. There are 4π steradians about any point in space.

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

T_1. The exposure duration (time) at which MPEs based upon thermal injury are replaced by MPEs based upon photochemical injury to the retina.

T_2. The exposure duration (time) beyond which extended source MPEs based upon thermal injury are expressed as a constant irradiance.

T_{max}. The total expected or anticipated exposure duration. T_{max} may differ depending upon its use.

telescopic viewing. Viewing an object from a long distance with the aid of an optical system that increases the visual size of the image. The system (e.g., binoculars) generally collects light through a large aperture thus magnifying hazards from large-beam, collimated lasers.

testing. The act of measurement, evaluation, verification or assessment of any properties or parameters of a laser or laser system, i.e., life time test or beam specifications.

thermal effect. An effect brought about by the temperature elevation of a substance due to laser exposure.

threshold limit (TL). An expression of the "resistance factor" for beam penetration of a laser protective device, i.e., 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 (e.g., laser protective eyewear filters, protective windows, and barriers) at or below the TL will limit beam penetration to levels at or below the applicable MPE. Unit: $W \cdot cm^{-2}$ or $J \cdot cm^{-2}$.

t_{min}. For a pulsed laser, the maximum duration for which the MPE is the same as the MPE for a 1 ns exposure. For thermal biological effects, this corresponds to the "thermal confinement duration" during which heat flow does not significantly change the absorbed energy content of the thermal relaxation volume of the irradiated tissue.

transmission. Passage of radiation through a medium.

transmittance. The ratio of transmitted power (energy) to incident power (energy).

ultraviolet radiation. In this standard, electromagnetic radiation with wavelengths between 180 and 400 nm (wavelengths 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.

unrestricted location. An area where access is not limited. By default, no laser radiation hazards exist (Class 1), and these locations can be occupied by the general public, visitors, and spectators without implementing control measures (administrative, engineering, and personal protective equipment).

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 window(s).

visible radiation (light). The term is used to describe electromagnetic radiation that can be detected by the human eye. In this standard, this term is used to describe wavelengths that lie in the range 400 to 700 nm. Derivative standards may legitimately use 380 – 780 nm for the visible radiation range.

watt (W). The unit of power or radiant flux. 1 watt = 1 joule-per-second.

wavelength. The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (e.g., the distance from crest to crest or trough to trough).

work practices. Procedure(s) used to accomplish one or more tasks.