

	PRINCETON PLASMA PHYSICS LABORATORY ES&H DIRECTIVES	
	ES&HD 5008 SECTION 3 <b>Laser Safety</b>	
Approved	Date: 08/01/01	Revision 7
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## SECTION 3.0 LASER SAFETY

### 3.1 INTRODUCTION

Lasers emit intense, coherent, electromagnetic radiation that is potentially dangerous to the eye and skin. Other hazards associated with lasers that the laser operator must be cognizant of are electrical, fire, and chemical hazards. The PPPL laser safety program is designed to ensure the safety of all personnel and visitors. It is based on the latest edition of the American National Standards Institute, Inc. (ANSI) Z136.1, "American National Standard For the Safe Use of Lasers," which is the generally accepted safety standard for laser use.

### 3.2 SCOPE

This section on laser safety is intended to provide specific requirements and guidelines based on ANSI Z136.1 to ensure the safety of laser operators and other individuals likely to be exposed to laser hazards. In practice, the hazard classification of a laser is determined, and then the appropriate controls are applied taking into account the laser environment and the potential for excessive personnel exposure. Training and medical surveillance requirements are also included.

### 3.3 DEFINITIONS

**Authorized Laser Operator** - An individual who has met all applicable laser safety training, medical surveillance, and approval requirements for operating a laser or laser system.

**Aversion Response** - Movement of the eyelid or the head to avoid an exposure to a noxious stimulant or bright light. It can occur within 0.25 s, including the blink reflex time.

**Continuous Wave (cw)** - The output of a laser, operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser operating with a continuous output for a period 0.25 s is regarded as a cw laser.

**Controlled Area** - An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation and related hazards.

**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.

**Embedded Laser** - An enclosed laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission. Example: a class 1 laser printer may have an embedded class 3 laser, protected by the casing and designed to eliminate emissions.

**Energy (Q)** - The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers and is generally expressed in joules (J).

**Failsafe 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.

**Infrared Radiation** - Electromagnetic radiation with wavelengths that lie within the range 0.7  $\mu\text{m}$  to 1 mm.

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

**Irradiance (E)** (at a point of a surface) - Quotient of the radiant flux incident on an element of the surface containing the point at which irradiance is measured by the area of that element. Unit: watt per  $\text{cm}^2$ .

**Laser** - A device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. An acronym for Light Amplification by Stimulated Emission of Radiation.

**Laser Operator** - See Authorized Laser Operator.

**Laser Safe Operating Procedure** - A set of operating instructions for a particular laser or laser system. The procedure specifies measures which, if followed, will ensure safe and correct use of the laser or laser system.

**Laser Safety Officer (LSO)** - One who has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

**Laser System** - An assembly of electrical, mechanical, and optical components that includes one or more lasers.

**Maximum Permissible Exposure (MPE)** - The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure ( $\text{joules}/\text{cm}^2$ ) or irradiance ( $\text{watts}/\text{cm}^2$ ). The criteria for MPE are detailed in Section 8 of ANSI Z136.1.

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

**Optical Density ( $D_1$ )** - Logarithm to the base ten of the reciprocal of the transmittance:  
 $D_1 = -\log T$ , where T is the transmittance.

**Principal Authorized Laser Operator** - The authorized laser user who assumes responsibility for the control and safe use of a laser or laser system.

**Power** - The rate at which energy is emitted, transferred, or received. Unit: watts (joules per second). Also called radiant power.

**prf** - Abbreviation for pulse repetition frequency. (See repetitively pulsed laser.)

**Pulsed Laser** - A laser that delivers its energy in the form of a single pulse or a train of pulses. The duration of a pulse is regarded to be  $\leq 0.25$  s.

**Q-Switched Laser** - A laser that emits short ( $\sim 30$  ns), high-power pulses by means of a Q-switch.

**Radiant Exposure (H)** - Surface density of the radiant energy received. Unit: joules per  $\text{cm}^2$ .

**Radiant Flux ( $\Delta$ )** - Power emitted, transferred, or received in the form of radiation. Unit: joule (J).

**Repetitively Pulsed Laser** - A laser with multiple pulses of radiant energy occurring in sequence with a prf  $\geq 1$  Hz.

**Specular Reflection** - A mirror-like reflection.

**Transmittance** - (T) The ratio of total transmitted radiant power to total incident radiant power.

**Ultraviolet Radiation** - Electromagnetic radiation that has wavelengths smaller than those of visible radiation; for the purpose of this section on laser safety, 0.2 to 0.4  $\mu\text{m}$ .

**Visible Radiation (Light)** - Electromagnetic radiation that can be detected by the human eye. This term is used commonly to describe wavelengths that lie in the range 0.4 to 0.7  $\mu\text{m}$ .

**Wavelength** ( $\gamma$ ) - The distance between two successive points on a periodic wave that have the same phase.

### 3.4 RESPONSIBILITIES

3.4.1 Department/Project/Division Heads are responsible to ensure that all employees under their direction follow the requirements and procedures in this section.

3.4.2 Supervisors are responsible for the enforcement of the requirements and procedures of this section. These include:

3.4.2.1 For all lasers

- A. Assurance that all laser operators complete the appropriate level of laser safety training before they are authorized to operate any laser.
- B. Assurance that the laser or laser facility is operated consistently with safe laser practices.

3.4.2.2 For class 3b and 4 lasers only

- G. Assurance that the Laser Safety Officer is notified prior to the acquisition or fabrication of a new laser so that a preliminary safety review can be made.
- B. Assurance that the Laser Safety Officer is notified prior to the initial operation of a new laser or laser facility so that a final safety analysis can be made.
- C. Assigning each individual laser to an individual (called the Principal Authorized Laser Operator) who will be responsible for the safe storage and use of that laser. The Laser Safety Officer must be notified by the supervisor whenever the laser is reassigned to a new Principal Authorized Laser Operator.
- D. Assurance that the laser or laser facility is operated consistently with applicable requirements, including those specified in Laser Safe Operating Procedures (LSOP), if required.
- E. Assurance that a safety review or analysis by the Laser Safety Officer is made prior to use whenever there is a change in location or conditions (such as modifications) which may affect the safe use of the laser.
- F. Assurance that all laser operators complete the full laser safety training and have a baseline medical evaluation before they are authorized to operate any class 3b or 4 laser.

3.4.3 Principal Authorized Laser Operators shall ensure that each laser for which they have responsibility is operated safely and in accordance with applicable requirements. These include:

3.4.3.1 For all lasers:

- A. Ensuring that each laser is stored securely and safely when not in use so that it is not usable by unauthorized personnel or under unauthorized conditions.
- B. Permitting only authorized laser operators to use the laser.

3.4.3.2 For class 3b and 4 lasers only:

- A. Notifying the Laser Safety Officer of the intent to procure a laser, and providing required information for safety reviews of lasers.
- B. Providing an approved written LSOP if required, and ensuring that the laser is used only under conditions and in locations that meet the requirements of the LSOP.
- C. Providing laser training specific to the laser for operators, in consultation with the Laser Safety Officer.
- D. Designating the newly trained operator to be an authorized laser operator.

3.4.4 Authorized Laser Operators shall (for all lasers):

- A. Meet all applicable requirements including those of training and medical surveillance before operating the laser.
- B. Operate lasers safely and in a manner consistent with safe laser practices, requirements, written LSOP's (if applicable), and guidance from the Laser Safety Officer.

3.4.5 The Occupational Medicine Office is responsible for coordinating a medical surveillance program, which specifically includes eye examinations and associated records for class 3b and 4 laser operators.

3.4.6 Human Resources is responsible for keeping laser safety orientation and training records and for scheduling and coordinating classes.

3.4.7 Purchasing/Procurement is responsible to ensure that all requisitions for purchase of class 3b and 4 lasers have been approved by the Laser Safety Officer.

3.4.8 Materiel Control (Receiving) is responsible for ensuring that class 3b and 4 lasers received are not released until cleared by the Laser Safety Officer.

3.4.9 The Laser Safety Officer (LSO) is responsible for the following:

3.4.9.1 For all lasers:

- A. Performing preliminary and final safety reviews of lasers and laser systems.
- B. Determining or verifying laser classifications.
- C. Providing guidance on requirements for laser warning signs.

3.4.9.2 For class 3b and 4 lasers only:

- A. Reviewing and approving Laser Safe Operating Procedures (LSOP's).

- B. Providing laser safety orientation and coordinating laser-specific training, as required.
- C. Providing Occupational Medicine with a list of laser operators as part of the Medical Surveillance program.
- D. Advising on laser protective equipment, including eyewear.

### 3.5 REQUIREMENTS

#### 3.5.1 General Safety Requirements

##### 3.5.1.1 For all lasers:

- A. Each laser and laser application shall meet the safety standards of ANSI Z136.1 or an equivalent level of safety as approved by the Laser Safety Officer. The requirements specific to each laser Class are listed and keyed to applicable sections of ANSI Z136.1 as shown in Table 1.
- B. All lasers shall carry a warning label containing the laser classification, type, and other information required by ANSI Z136.1. This label normally comes affixed to lasers that have been purchased commercially. The label shall not interfere with laser operation or mounting.
- C. Each PPPL employee operating a Class 2 or 3a laser shall read the PPPL training information for "Laser Pointers" (Appendix 2). A copy of Appendix 2 will be maintained in the Auditorium for the use of outside guests. Each operator of a Class 3b or 4 laser shall meet PPPL Laser Safety Orientation training and medical baseline evaluation requirements.

##### 3.5.1.2 For Class 3b and 4 lasers only:

- A. All class 3b and 4 lasers shall receive a preliminary safety review and approval by the Laser Safety Officer prior to acquisition or fabrication of the laser.
- B. These lasers shall receive a final safety review and approval by the Laser Safety Officer prior to initial use of the laser. The final review shall cover user qualifications, safe operations including electrical safety, area controls, and written procedures, if required.
- C. Class 3b or 4 lasers shall be used in controlled areas in order to restrict access of unauthorized personnel. The level of control depends on the laser class.
- D. Each controlled laser area shall be posted with an appropriate warning sign.
- E. Each operator of a Class 3b or 4 laser shall wear protective equipment (e.g., eyewear), as required.
- F. Written LSOP requirements shall be met.

#### 3.5.2 Laser Classifications, User Requirements, and Entry Controls

Each laser shall be classified according to the definitions of Section 3.3 of ANSI Z136.1. In addition to meeting the general requirements of Section 3.5.1 of this ES&HD, lasers must meet specific requirements based on laser class. Laser classifications and entry controls are summarized below along with a summary of essential PPPL requirements.

**Class 1** denotes exempt lasers or laser systems that cannot, under normal operating conditions, produce a beam hazard. Other hazards such as from chemicals or electricity may still exist.

Equipment such as laser printers that completely enclose the laser and laser beam are normally specified as Class 1. Opening the enclosure may invalidate the Class 1 rating, since many systems use higher class lasers which could pose greater hazards when exposed.

Class 1 lasers must be labeled, but are exempt from other requirements.

**Class 2** denotes low-powered visible-radiation lasers or laser systems. Visible continuous wave (cw) Helium-Neon (HeNe) lasers above Class 1, but not exceeding 1 mW radiant power, are common examples of this class. Because of the normal human aversion responses, these lasers normally do not present a hazard, but may present some potential for hazard if viewed directly for extended periods of time. Only lasers with visible beams may be members of this class.

Users are required to read and understand Appendix 2, and sign a Record of Training form with Human Resources prior to using Class 2 lasers or laser pointers, but are exempt from other requirements. The warning label or sign shall caution users to avoid staring into the beam or directing the beam toward the eye of individuals, and shall be placed on or near the laser in a conspicuous location.

**Class 3a** denotes lasers or laser systems that normally would not produce a hazard if viewed for only momentary periods with the unaided eye. They may present a hazard if viewed using collecting optics. Visible cw HeNe lasers above 1 milliwatt (mW), but not exceeding 5 mW radiant power, are common examples of this class. Low powered invisible lasers may also be members of this class

Users are required to read and understand Appendix 2, and sign a Record of Training form with Human Resources prior to using Class 3a lasers or Laser Pointers, but are exempt from other requirements. The warning label or sign shall caution users to avoid staring into the beam or directing the beam toward the eye of individuals, and shall be placed on or near the laser in a conspicuous location. Lasers used as pointers in the auditorium or classrooms at PPPL are restricted to be no higher than Class 3a.

**Class 3b** denotes lasers or laser systems that can produce a hazard if viewed directly. This includes intrabeam viewing or specular reflections. Except for the higher power Class 3b lasers, this class laser will not produce hazardous diffuse reflections. Visible cw HeNe lasers above 5 mW, but not exceeding 500 mW radiant power, are examples of this class. Lasers in this class may have beams that are not visible to the human eye. An example of this is a Carbon Dioxide (CO<sub>2</sub>) laser above 9.6 mW but not exceeding 500 mW radiant power.

Users are required to have completed Laser Safety Orientation and have a medical baseline evaluation. Class 3b lasers shall be used in areas where entry by unauthorized personnel can be controlled. Entry into the area by personnel untrained in laser safety may be permitted by the laser operator if instructed as to safety requirements and are provided with protective eyewear, as needed.

**Class 4** denotes lasers or laser systems that can produce a hazard not only from direct or specular reflections, but also from a diffuse reflection. In addition, such lasers may produce fire and skin hazards. Class 4 lasers include any laser with a radiant power exceeding 500 mW (0.5 watts).

Users are required to have completed Laser Safety Orientation and have a medical baseline evaluation. Class 4 lasers shall be operated by authorized operators in areas dedicated to their use. Failsafe interlocks shall be used to prevent unexpected entry into the controlled area, and access shall be limited by the laser operator to persons who have been instructed as to safety

procedures and who are wearing proper laser protection eyewear (if required by written procedures) when the laser is capable of emission. Authorized operators are responsible to provide information and safety protection to untrained personnel who may enter the laser controlled area as visitors.

For pulsed systems, interlocks shall be designed so as to prevent firing of the laser by dumping the stored energy into a dummy load. For continuous wave lasers, the interlocks shall turn off the power supply or interrupt the beam by means of shutters.

### 3.5.3 Written Laser Safe Operating Procedures (LSOPs)

- A. An approved written LSOP is required for certain lasers that are high powered or that emit invisible radiation. However, the Laser Safety Officer may recommend or require a written procedure for any laser or laser application where it is deemed necessary for ensuring adequate safety controls.
- B. The following Class 3b lasers require an approved written procedure:
  - 1. Those that produce beams invisible to the eye.
  - 2. Continuous wave (cw) lasers that produce visible beams with greater than 15 mW power. (HeNe lasers with 15 mW or less normally do not require a written procedure. However, all other safety requirements apply.)
- C. All Class 4 lasers and laser systems require a written LSOP.
- D. Required written LSOP's are prepared by the principal authorized laser operator. The procedure shall follow the outline in Appendix 1 and shall receive Laser Safety Officer and line management approval before the laser is operated.
- E. The LSOP shall be updated whenever changes are made to personnel or procedures. Updates must be reviewed by the LSO and line management.

### 3.5.4 Laser Safety Training

- A. All new users of Class 2 and Class 3a lasers and laser pointers shall read an information sheet (Appendix 2) and sign a training form with Human Resources. This will provide all of the training required by ANSI Z136.1.
- B. All new users of Class 3b and Class 4 lasers shall attend a Laser Safety Orientation course. This course shall include, but not be limited to; laser classification, biological effects, safety requirements, and recommended safe practices. An exam must be passed for successful completion of the laser safety course and certification.
- C. All users of Class 3b and Class 4 lasers shall be re-certified in Laser Safety at intervals not to exceed three years. Re-certification can be accomplished by either attending the Laser Safety Orientation and passing the exam, or by directly challenging the exam.
- D. All users of lasers requiring written LSOPs shall complete additional training specific to the safe operation of the laser or laser system they are required to operate. The specific training requirements shall be defined in the written LSOP. The principal authorized laser operator shall perform the training and document it on the Human Resources "Record of Training" form for all laser operators trained on the laser.

### 3.5.5 Laser Medical Surveillance

- A. All employees who use class 3b or 4 lasers come under the laser medical surveillance program, which is operated by the PPPL Occupational Medicine Office. The medical surveillance program consists of a baseline medical evaluation required for all users, and a follow up exam only if a suspected exposure to laser radiation occurs.
- B. A termination of employment eye exam is also recommended for all laser users to ensure that no damage to the eyes has occurred from laser radiation prior to leaving the Lab.

### 3.5.6 Laser Personal Protective Equipment

- A. All personnel who work in areas where there is radiation from Class 3b or Class 4 lasers shall wear approved laser eyewear if the potential exists for exposure in excess of the MPE. Exceptions may be approved if wearing protective eyewear produces a greater safety hazard than when it is not worn. Exceptions shall be noted in written procedures or otherwise be approved by the Laser Safety Officer.
- B. The Laser Safety Officer shall review and approve protective eyewear to assure that it is appropriate for the use for which it is intended. The eyewear to be used will depend on the wavelength(s) and intensity of the accessible radiation.
- C. In some cases, other protective equipment, such as clothing to protect the skin, may be required. Such requirements shall be addressed in written LSOPs.

### 3.5.7 Laser Warning Signs

- A. Laser warning signs shall meet the standards of ANSI Z136.1. Class 1 lasers do not require a sign. Class 2 and 3a laser pointers do not require signs.
- B. The word CAUTION shall be used with all Class 2 and Class 3a lasers. The word DANGER shall be used with all Class 3b and Class 4 lasers. Examples are shown in Figure 1.
- C. Precautionary instructions and protective actions, shall be printed at Position 1 (see Figure 1), for example:

Class 2: Laser Radiation - Do Not Stare Into Beam. Do Not Direct the Beam Towards the Eye of Individuals.

Class 3: Laser Radiation - Avoid Direct Exposure to Beam.

Class 4: Laser Radiation - Avoid Eye or Skin Exposure to Direct or Scattered Radiation.

Additional precautionary instructions and protective actions that may be required at Position 1 are: Invisible Laser Radiation; Knock Before Entering; Do Not Enter When Light Is On; Restricted Area; etc.

- D. Laser information is printed at Position 2. This includes the type of laser (Ruby, HeNe, etc.) or the emitted wavelength, pulse duration (if appropriate), and the maximum output.
- E. The class of the laser is printed at Position 3.
- F. All warning signs and labels shall be displayed conspicuously in locations where they best will serve to warn individuals of potential safety hazards. Normally, warning signs are posted at entryways (e.g., on doors) to laser controlled areas. Warning labels are affixed to the lasers in a conspicuous location.

- H. Posted laser warning signs shall be removed by the laser operator if the laser has been removed from the room or area.

### Laser Requirement Summary

<u>This Requirement...</u>	<u>...for these lasers</u>				
Warning Label	1	2	3a	3b	4
Warning Sign		2	3a	3b	4
Registered with the Laser Safety Officer				3b	4
Read & Sign Information Sheet		2	3a		
Laser Safety Orientation Course				3b	4
Laser Safe Operating Procedure				3b*	4
Medical Surveillance				3b	4

\* if invisible to the eye, or if cw laser, visible beams > 15 mW power.

#### 3.5.8 Laser Safety Electrical Requirements

- A. The requirements of this sub-section are supplementary to ES&HD 5008, Section 2.0, "Electrical Safety," and the determinations of the Laser Safety Officer that are documented in the LSOP. They provide acceptable methods of compliance with the electrical requirements of ANSI Standard Z136.1. Examples include:

1. Fail-safe Control Systems
2. Barriers and Safety Interlocks
3. Safety Interlocks for Transmission Lines
4. Remote-control Interlocks
5. Laser Activation Warning Systems and Annunciators
6. Grounding Methods
7. Temporary Bypassing of Safety Interlocks
8. Safety Watch and CPR certified personnel

- B. Types of Hazards

In addition to the hazards identified in Section 3.7 of this ES&HD, electrical hazards include or are a consequence of:

1. Inadequate shock-reaction space
2. Induced voltages in closed magnetic circuits
3. High impedances in grounding conductors
4. Improper tagging practices

- C. Design and Construction Practices

Ancillary apparatus for lasers shall be designed and constructed in accordance with the safety requirements specified elsewhere in the requirements of ES&HD 5008, specifically Section 2, Chapter 5, and Section 2, Chapter 6.

1. A fail-safe control system shall maintain its protective function when activated by control device (interlock) or by failure of the power supply.
2. Fail-safe control systems shall be analyzed successfully using the Single Failure Criterion of IEEE Standard 379 before completion of the design.

3. Energy barriers, where required in the Laser Safe Operating Procedures (LSOPs) and where readily removable, shall have their positions monitored by initial control devices, such as limit, photocell, or proximity switches, which shall be considered part of the personnel-safety interlock system for the laser.
4. Personnel, equipment, and service access-door positions shall be monitored where required in the LSOP by initial control devices having hardwired final control elements arranged to de-energize the power supply for the Laser upon unauthorized access attempts.
5. Where transmission-line enclosures are used, plug and receptacle or pin and socket connectors having one end shorted should be run parallel to transmission-line enclosures and across breaks to ensure continuous enclosure while the beam is operating.
6. Remote control of Class 3b or Class 4 beam operation shall be delegated by sequentially-keyed local-remote control stations. The sequential keying shall be considered part of the personnel-safety interlock system for the laser.
7. Visual indicators used in laser-activation warning systems and annunciators shall have self-checking features, such as push-to-test lights, included in the system design.
8. Laser control elements and devices and emission delay periods shall be listed in the LSOP, Part III, together with any exceptions to the applicable safety-related design criteria accepted by the Laser Safety Officer.
9. Where single-point grounding systems are used with laser power supplies, systems, or structures, their design criteria shall be documented and approved by Electrical Safety of the ES&H Division. Covered copper braid or flat copper bar shall be considered for use as grounding conductors in circuits having fast rise-times.

#### D. Operating Criteria

Ancillary apparatus for Lasers shall be operated in accordance with the safety requirements specified in the requirements of ES&HD 5008, Section 2, Chapters 5 and 6. The following requirements shall also apply:

1. Capacitor banks that are associated with Lasers shall meet the requirements of Section 2, Chapter 6, appropriate to their voltage and energy ratings.
2. Laser specific safety training, when required by the LSOP, shall include capacitor bank accessor certification and orientation to the safety tagging procedures of ESH-016, "Control of Hazards/Energy Sources-Safing/Lockout/Tagout."
3. Periodic safety inspections shall be performed on personnel safety interlock systems and capacitor banks within operational laser systems.

### 3.6 SAFE LASER PRACTICES

The following control measures are recommended as a guide to safe laser use. Some of the measures may be required, particularly in the case of high powered lasers or lasers that emit invisible radiation. See Section 3.5 Requirements, ANSI Z136.1 and Table 1.

#### 3.6.1 Recommended Work Area Controls

- A. A laser should be isolated from areas where the uninformed and curious would be attracted by its operation. Doors should be closed or locked to keep out unwanted onlookers.

- B. The illumination in the area should be as bright as practicable in order to constrict the eye pupils of users.
- C. The laser should be set up so that the beam path is not at normal eye level, i.e., so it is below 4.5 feet or above 6.5 feet.
- D. Where practical, the laser system or beam should be enclosed to prevent accidental exposure to the beam.
- E. The potential for specular reflections should be minimized by shields and by removal of all unnecessary shiny surfaces.
- F. Windows to hallways or other outside areas should be provided with adequate shades or covers.
- G. The main beams and reflected beams should be terminated or dumped. Note that this is required for any accessible laser for which the MPE could be exceeded.
- H. Electrical installation must satisfy the requirements of Section 2 of ES&HD 5008.
- I. The active laser never should be left unattended unless it is a part of a controlled environment.
- J. Good housekeeping should be practiced to ensure that no specular reflector is left in or near the beam.
- K. Warning devices should be installed for lasers with invisible beams to warn of operation.

### 3.6.2 Recommended Laser Use Controls

- A. Avoid looking into the primary beam at all times.
- B. Do not aim the laser with the eye; direct reflections could cause retinal damage.
- C. Avoid looking at the pump source.
- D. Clear all personnel from the anticipated path of the beam.
- E. Before operating the laser, warn all personnel and visitors of the potential hazard, and ensure all safety measures are satisfied.
- F. Be especially cautious around lasers that operate at frequencies not visible to the human eye.
- G. Do not wear bright, reflective jewelry or other objects.
- H. Use proper eye protection. Keep in mind:
  - 1. No matter how good the glasses, no protection is provided unless they are worn.
  - 2. All safety glass lenses may shatter, and all plastic lenses may melt when the maximum irradiance or radiant exposure for the particular lens is exceeded.
  - 3. Laser safety glasses may not provide eye protection with other than the laser for which they are specified, unless the frequency produced is the same and power output is not greater.

### 3.7 ASSOCIATED (NON-BEAM) LASER HAZARDS

Depending on the type of laser used, associated hazards other than those from beam radiation may be involved. Such hazards to personnel, if they exist, should be addressed in written LSOPs.

- A. Atmospheric Contamination
  - 1. Vaporized target material: Materials may include carbon monoxide, ozone, lead, mercury, lithium, and other metals.
  - 2. Gases from flowing gas lasers or by-products of laser reactions such as fluorine, hydrogen-cyanide, and many others.
  - 3. Gases or vapors from cryogenic coolants.
- B. Chemicals - Chemicals, including dyes and solvents, from certain dye lasers have been shown to be carcinogenic, toxic, or otherwise hazardous.
- C. Cryogenic Coolants - Cryogenic liquids, such as liquid nitrogen or hydrogen, may cause burns.
- D. Electrical Hazards - The potential for electrical shock is present in most laser systems. Pulsed lasers utilize capacitor banks for energy storage and cw lasers generally have high voltage DC or RF electrical power supplies.
- E. Explosive Hazards - The potential exists for explosions at capacitor banks or optical pump systems during the operation of some high power lasers. Explosive reactions of chemical laser reactants or other gases used within the laser laboratory could cause damage to equipment or injury to personnel.
- F. Jewelry - The use of jewelry (watches, rings, etc.) is often an overlooked source of exposure to a beam reflected by a mirror-like surface.
- G. Ultraviolet Radiation - Either direct or reflected from flash lamps and cw laser discharge tubes may cause eye injury. Usually, ultraviolet radiation is a problem only when quartz tubing or windows are used.
- H. Visible Radiation (non-laser) - High luminance radiation emitted from unshielded pump lamps may cause eye injury.
- I. X rays - Potentially hazardous X rays may be generated from high voltage (over 15kV) power supply tubes.

### 3.8 REFERENCES

American National Standard for the Safe Use of Lasers, ANSI Z136.1.

Code of Federal Regulations 21 CFR 1040.1.

## Appendix 1

### OUTLINE FOR LASER SAFE OPERATING PROCEDURES

The following is an example outline which is to be used as a guide in preparing written laser safe operating procedures (LSOP's). While the specific numbering of sections is not critical, all of the following information must be included. A written procedure is to include all lasers in a laser system, including alignment lasers. **This LSOP must be reviewed and revised whenever changes in personnel or to the system occur.**

#### I. INTRODUCTION

1. Location of laser or laser system (site, building, room).
2. Diagram of area layout (attachment).
3. Description of (each) laser, including classification, lasing medium, and beam characteristics (divergence, aperture diameter, pulse length, repetition rate, and maximum output, as applicable).
4. Purpose/application of beam(s).

#### II. HAZARDS

1. Identification of the hazards (beams, electrical, chemical, etc.).
2. Analysis of hazards (target area, absorbing media, beam path, severity of potential accidents, etc.).

#### III. CONTROLS

1. Access controls (door interlocks, signs, signals).
2. Beam controls (key-lock, enclosures, shutters, stops).
3. Electrical controls (light on power supply, HV signs).
4. Eye protection (medical surveillance requirements, type of eyewear, optical density required for beam).
5. Other.

#### IV. OPERATING PROCEDURES

1. Initial preparation of laboratory environment for normal operation (key position, warning lights on, interlock activated, identification of personnel).
2. Personnel protection requirements (eyewear, protective barriers).
3. Target area.
4. Countdown procedures.
5. Shutdown procedures.
6. Special procedures (alignment, safety tests, interlock bypass, emergency, etc.).

**Appendix 1 (cont'd)**

## V. TRAINING

1. Laser Safety Orientation requirements.
2. Laser-specific safety training requirements.
3. Training maintenance and repair personnel.

## VI. RESPONSIBILITIES

1. Supervisory (include emergency contact).
2. Operators and support personnel.

## VII. MISCELLANEOUS

1. Rules for visitors during laser operation.
2. Procedures in case of accident.
3. Other (maintenance, adjustment, special precautions, etc.).

## Appendix 2

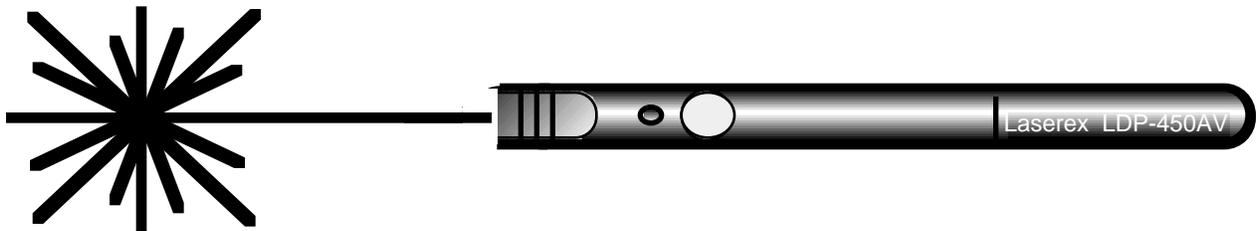
**THE LASER POINTER**

**LASER** is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

A laser is a device that produces an intense, coherent, directional beam of light. Although a laser pointer produces only low powered visible radiation, there are safety requirements which should be observed when using any type of laser:

1. **NEVER** look into the laser beam.
2. **NEVER** point the laser at anyone else.
3. **NEVER** aim a laser pointer at a highly reflective surface.

Not following the safety rules above could cause permanent damage to the retina of the eye(s) of the person exposed to the laser.



This document must be **READ** and **UNDERSTOOD** prior to using any Class 2 or 3a Laser.

## Definitions Pertaining to Appendix 2

### Definitions

**Laser** - An acronym for Light Amplification by Stimulated Emission of Radiation. A device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels.

**Coherence** - A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous function. In a laser beam, not only are the waves in step (spatial coherence), but the wavelengths of all the waves are the same and in phase (temporal coherence). Ordinary light is incoherent since not all the waves are in step at any given distance from the source. For this reason ordinary incoherent light spreads out rapidly and loses its energy within a very short distance. Laser light retains its energy over very long distances and may present an eye hazard if it is powerful enough to cause injury.

**Aversion response** - Closure of the eyelid, or movement of the head to avoid an exposure to a noxious stimulant or bright light. The aversion response to an exposure from a bright laser source is assumed to occur within 0.25 seconds, including the blink reflex time.

Table 1

## ANSI Z136.1 Control Measures for the Laser Classes

<u>Controls</u>	<u>Laser Classification</u>				
	<u>1</u>	<u>2</u>	<u>3a</u>	<u>3b</u>	<u>4</u>
Protective Housing (4.3.1)	X	X	X	X	X
Without Protective Housing (4.3.1.1)	LSO shall establish Alternate Controls				
Interlocks on Protective Housing (4.3.2)			X	X	X
Service Access Panel (4.3.3)					X
Key Switch master (4.3.4)	—	—	—	•	X
Viewing Portals (4.3.5.1)	—	o	o	o	o
Collecting Optics (4.3.5.2)	—	o	o	o	o
Totally Open Beam Path (4.3.6.1)	—	—	—	X	X
Limited Open Beam Path (4.3.6.2)	—	—	—	X	X
Remote Interlock Connector (4.3.7)	—	—	—	•	X
Beam Stop or Attenuator (4.3.8)	—	—	•	•	X
Activation Warning Systems (4.3.9)	—	—	—	•	X
Emission Delay (4.3.9.1)	—	—	—	—	•
Class 3b Laser Controlled Area (4.3.10.1)	—	—	—	X	—
Class 4 Laser Controlled Area (4.3.10.2)	—	—	—	—	X
Laser Outdoor Controls (4.3.11)	—	—	—	X	X
Temporary Laser Controlled Area*	—	—	—	—	—
Remote Firing & Monitoring (4.3.13)	—	—	—	—	•
Labels (4.3.14)	—	X	X	X	X
Area Posting (4.3.15)	—	•	•	X	X
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Administrative & Procedural Controls (4.4)	—	X	X	X	X
Standard Operating Procedures (4.4.1)	—	—	—	•	X
Output Emission Limitations (4.4.2)	—	—	LSO Determination		
Education and Training (4.4.3)	—	•	•	X	X
Authorized Personnel (4.4.4)	—	—	—	X	X
Alignment Procedures (4.4.5)	—	X	X	X	X
Eye Protection (4.4.6)	—	—	—	•	X
Spectator Control (4.4.7)	—	—	—	•	X
Service Personnel (4.4.8)	—	—	—	X	X
Laser Demonstration (4.5.1)	—	X	X	X	X
Laser Fiber Optics (4.5.2)	—	X	X	X	X

LEGEND Numbers in parentheses ( ) indicate appropriate section in ANSI Standard Z136.1-1993,  
 X- Shall, •- Should, — No requirement, - Shall if Embedded Class 3b or Class 4,  
 o- Shall if MPE is exceeded, \*- During Service Only

Figure 1

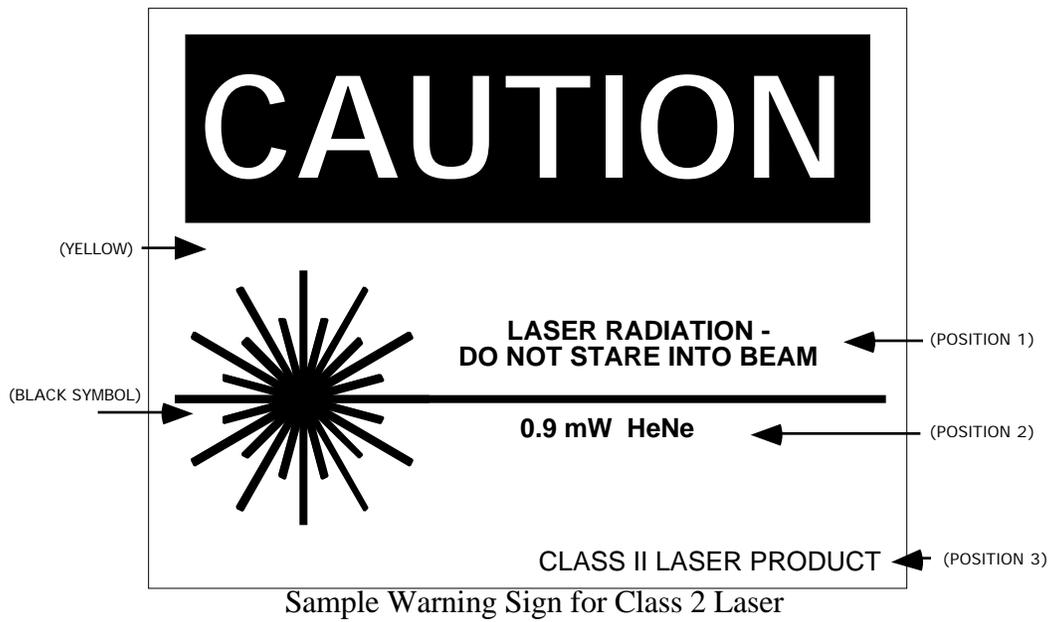


Figure 2

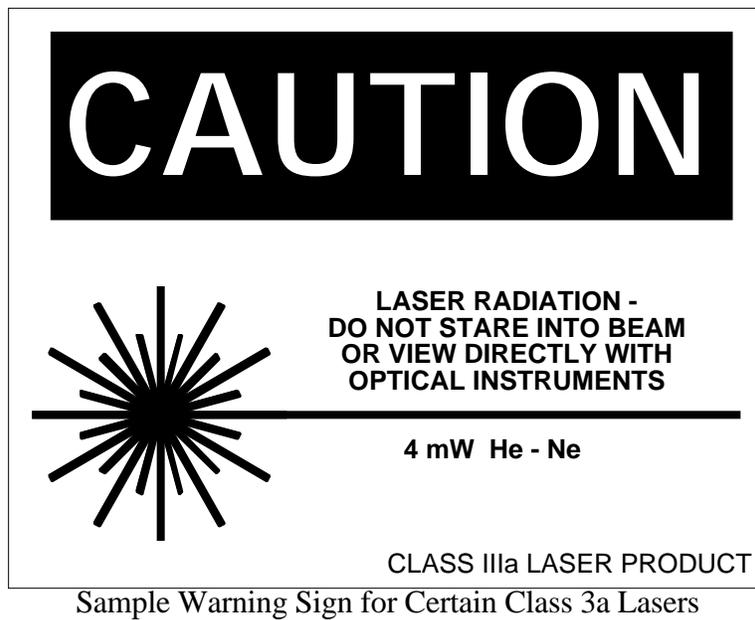
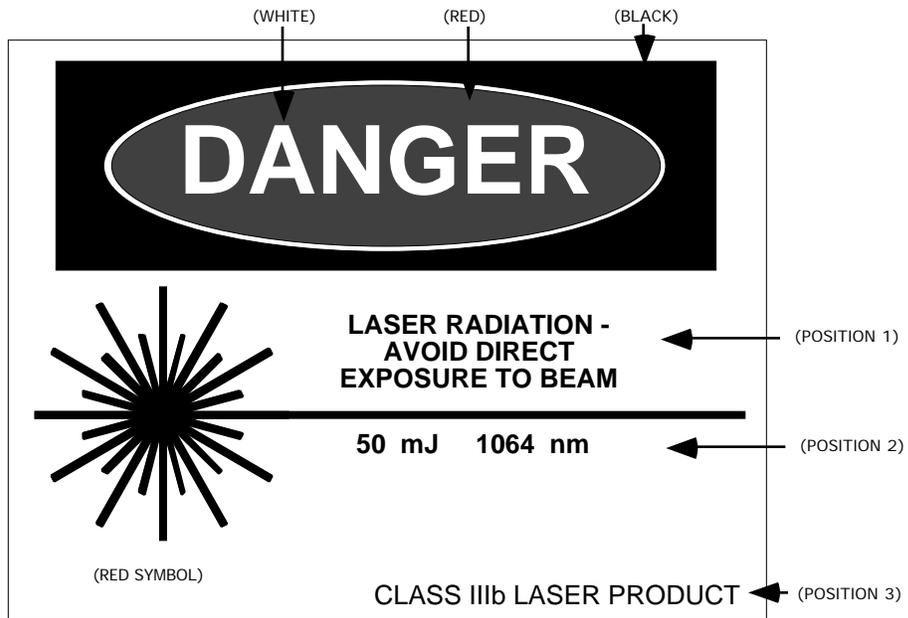
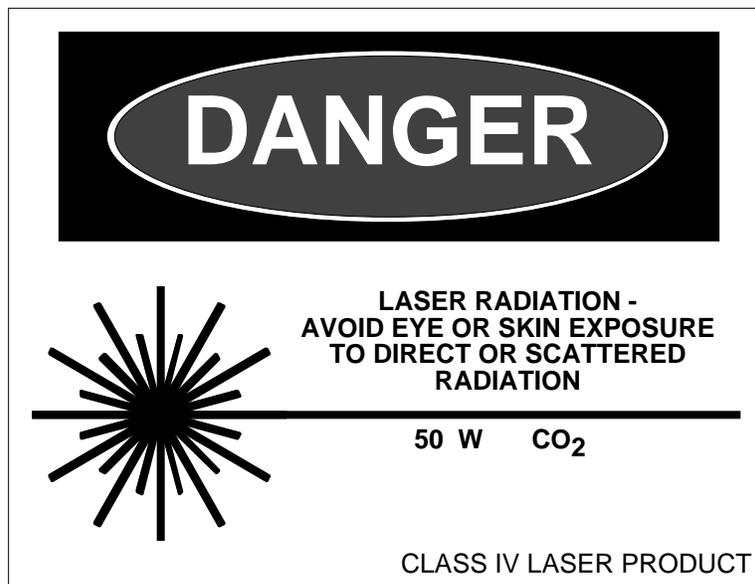


Figure 3



Sample Warning Sign for Class 3b Laser

Figure 4



Sample Warning Sign for Class 4 Lasers