LASER SAFETY MANUAL

University of Pittsburgh

Prepared by the
University of Pittsburgh
Department of Environmental Health and Safety
and the University Safety Committee

March 2010

INTRODUCTION

The 2007 version of ANSI Z 136.1 changed the classification system for many lasers.

However, the impact upon safe use is minimal. Products most likely affected are 1-5 mW laser pointers, expanded beam laser products and those with highly divergent beams. Any laser product previously labeled as a Class 3a product can safely be treated as a Class 3R if the beam diameter is less than 7 mm. The new classifications consider optically aided viewing of a highly divergent beam—as from a diode laser or fiber pigtail source. Such a highly diverging beam could be collected by an eye loupe or other optical device and rendered more hazardous.

There is no requirement to reassess lasers that were previously classified. However, a laser product with a highly diverging beam that may have been "over classified" by the old system can be reclassified under the updated classification system.

Products that were previously Class 1 remain Class1. A few products previously in Class 3a or3b could now be class 1M. In some current standards, Class 1 has been termed "eye safe" and this applies even under the worst case condition with optically aided viewing. Class 1M has been referred to as "eye safe" except with optical aids. All lasers of low risk emitting visible radiation are Class 2 or 2M, due to the aversion response. Class 2M did not previously exist,, but some lasers that were safe for momentary viewing only without optical aids were in Class 3a and had a caution label, these would now be Class 2M.

The transitional-zone, Class 3R ("R" for Reduced Requirements) is largely composed of lasers formerly Class 3a and Class 3B emitting less than 5 mW.

Overall, only laser products with highly expanded beams actually have different control measures under this revised Standard.

TABLE OF CONTENTS

PAGE

1. PURPOSE

1.1. Purpose

The Laser Safety Program for the University of Pittsburgh provides guidance to faculty, staff and students for the safe use of lasers and laser systems in research, education, and medical science. All individuals utilizing laser-producing equipment should familiarize themselves with this document and with the applicable sections of the ***American National Standard for the Safe Use of Lasers (ANSI Z136.1-2000) and American National Standard for the Safe Use Of Lasers In Educational Institutions (ANSI Z136.5 2000).***

1.2. Objectives

The objectives of the University of Pittsburgh Laser Safety Program are to:

- identify potential hazards associated with lasers, laser systems, and laser operations and to prescribe suitable means for the evaluation and control of these hazards,
- investigate all laser accidents and institute immediate corrective action to prevent recurrence,
- provide guidance for compliance with Federal regulations and ANSI Standards.

2. RESPONSIBILITIES

2.1. University Laser Safety Officer (LSO)

An individual shall be designated as the University Laser Safety Officer (LSO) with the authority and responsibility to monitor and enforce the control of laser hazards, and to effect the evaluation and control of hazards associated with Class 3b or Class 4 lasers or laser systems.

The LSO shall:

- Classify, or verify classifications, of lasers and laser systems.
- Evaluate hazards of laser work areas, including the establishment of Nominal Hazard Zones (NHZ) as defined by ANSI.
- Ensure that the prescribed control measures are in effect, and recommend or approve substitute or alternate control measures .
- Conduct periodic audits to ensure compliance with this Program and applicable standards. (See Appendix D for Audit Form)
- Approve standard operating procedures, alignment procedures, and other procedural control measures, including signage.
- Recommend or approve protective equipment (e.g., eyewear, clothing, barriers, screens) used for personnel safety.

- Approve Class 3b and Class 4 laser installation facilities and laser equipment prior to use. These approval procedures also apply to the modification of existing laser facilities and equipment.
- Ensure that safety education and training is provided to laser area personnel.

2.2. Department Chairperson

The Department Chairperson has overall responsibility for the implementation of the Laser Safety Program within his/her Department. The Department Chairperson will appoint Department Laser Supervisors as appropriate. The University Laser Safety Officer (LSO) will coordinate efforts with the Department Chairperson or designee to ensure that adequate safety measures are taken and all Class 3b or 4 lasers under his/her control are registered with the LSO.

2.3. Department Laser Supervisor

The Department Laser Supervisor has responsibility for laser safety procedures within his/her department or laboratory, including:

- meeting with the LSO and the Department Chairperson to design adequate administrative and engineering controls for each laser or laser system,
- submitting to the LSO laser equipment information for design of control measures,
- submitting to the LSO the names of laser users within his/her department. implementing control measures designated by the LSO
- reporting laser-related accidents to the LSO and Department Chairperson,
- preparing standard operating procedures for Class 3b or Class 4 laser or laser system and ensuring that they are implemented by laser users,
- ensuring that all users of lasers within their department have received adequate training.

2.4. Laser User

The Laser User is responsible for:

- attending required laser safety training programs,
- complying with the safety rules, personal protective equipment requirements, and operating procedures for the laser equipment ,
- reporting any laser-related accident to his/her Department Laser Supervisor

3. LASER SAFETY

3.1. Classification of lasers and laser systems

To provide a basis for laser safety requirements, all lasers,and laser systems are designated into classes. The manufacturer provides the classification and labeling of commercial lasers or laser systems. The LSO, in cooperation with the Department Laser Supervisor, determines the classification of all lasers and laser systems manufactured or modified for internal use (i.e. research lasers).

Laser and Laser System Hazard Classification Definitions

Lasers and laser systems are classified on the power or energy output and potential for causing biological or physical damage to the eye or skin during intended use.

3.1.1. Class 1 Lasers and 1M Laser Systems

Class 1 and 1M lasers or laser systems are considered incapable of producing accessible damaging levels of emissions. Most lasers in this class maintain an enclosure, which, by virtue of design, prohibits access to laser radiation. These lasers are safe under reasonably foreseeable conditions of operation. These lasers are exempt from control measures. This exemption applies only to emitted laser radiation hazards and not to other potential non-beam hazards.The maximum exposure duration is assumed to be no mors than 30,000seconds except for infrared systems where 100 seconds shall be used.

3.1.2. Class 2 and 2M Visible Lasers and Laser Systems

Visible lasers or laser systems which are capable of emitting accessible laser radiation exceeding the Class 1 accessible emission limit (AEL) for the maximum duration inherent in the design of the laser, but not exceeding the Class 1 AEL for any applicable pulse duration <0..25 seconds and not exceeding an average radiant power of 1mW.

3.1.3. Class 3R and Class 3B Lasers and Laser Systems

a. Class 3R Lasers

Class 3R lasers and laser systems are normally not hazardous when viewed momentarily with the naked eye, but pose severe eye hazards when viewed through optical instruments that collect and focus the laser onto the eye or skin. These emit visible or invisible light with a power of 1-5 mW.

b. Class 3B Lasers

Class 3B lasers or laser system will cause injury upon direct viewing of the beam and specular reflections. The shortest intrabeam exposure can cause injury. The power output of Class 3B lasers(outside the retinal hazard range{<0.4nm or >1.4nm}) is 5-500 mW for continuous wave lasers, or less than 0.125 J for a .25 second pulsed system. For visible and near infrared lasers the power output

cannot exceed 0.5W for continuous lasers or 0.03 J per pulse. Hazard control measures mentioned in Section 5 of this manual must be implemented.

3.1.4. Class 4 Lasers and Laser Systems

Class 4 laser and laser systems produce a hazardous direct or specular reflected beam and may be a fire hazard. Class 4 lasers may also produce a diffuse reflection hazard. For Class 4 Lasers, the emitted power exceeds 500 mW.

3.1.5. Embedded Lasers

Lasers or laser systems (of higher classes) which are intended for a specific use may be designated Class 1 by the LSO on the basis that use for a limiting exposure duration of less than 30,000 sec will be incapable of producing damaging levels of emissions. A Class 2, Class 3, or Class 4 laser or laser system contained in a protective housing ("embedded") and operated in a lower classification (Class 1, Class 2, or Class 3) shall require specific control measures to maintain the lower classification.

4. HAZARD ASSESSMENT

Four aspects of the application of a laser or laser system influence the total hazard evaluation and , thereby, influence the application of control measures:

- Capability of the laser or laser system for injuring personnel,
- Environment in which the laser is used,
- Personnel who may be exposed to laser radiation,
- Non-beam hazards associated with the laser or laser system.

4.1. Laser Characteristics

The capability of the laser or laser system for injuring personnel is characterized primarily by the class of the laser.

In addition to the laser classification, the nominal hazard zone (NHZ) associated with Class 3b and Class 4 lasers and laser systems must be determined. The NHZ describes the space within which the level of direct, reflected, or scattered radiation during normal operation exceeds the appropriate Maximum Permissible Exposure(MPE), and is determined from the following characteristics of the laser:

- power (continuous wave, repetitively-pulsed lasers) or energy (pulsed lasers) output,
- beam diameter,
- beam divergence,

- pulse repetition frequency,
- wavelength,
- beam path (including reflections),
- beam profile,
- maximum anticipated exposure duration.

4.2. Environment

It is extremely important to consider the operating environment of the laser to determine the appropriate control measures. As a minimum, consider the:

- number of lasers or laser systems,
- degree of isolation of laser (laboratory, operating room),
- probability of the presence of uninformed, unprotected, transient personnel,
- permanence of beam path(s),
- permanence of specular reflecting objects in or near the beam path,
- the use of optics (e.g., lenses, microscopes, optical fibers).

4.3. Personnel

The personnel who may be in the vicinity of a laser and its emitted beam influence the total hazard evaluation, and in some cases may warrant additional control measures.

An Authorized employee is one who is approved by the Department Chairperson, Department Laser Supervisor, or designee to install, operate or service laser equipment.

The following are considered when qualifying Authorized Personnel:

- maturity of judgment and reliability of the laser user(s),
- general level of training and experience of the laser user(s), e.g., whether the users are students, scientists, service personnel,
- awareness of spectators that potentially hazardous laser radiation may be present, and of relevant safety precautions,
- number and location of individuals relative to the primary beam or reflections, and the potential for accidental exposure,
- other non-beam hazards which may cause the individuals to react unexpectedly, or which influence the choice of protective equipment for personnel.

4.4. Non-Beam Hazards

In addition to direct hazards to the eyes and skin associated with exposure to the laser beam, it is important to address other hazards associated with the use of lasers, such as:

a. Laser generated airborne contaminants
b. Fire and Explosion Hazards
c. Collateral and ''plasma'' Radiation Hazards
d. Electrical Hazards
e. Compressed gases
f. Chemical hazards of laser dyes
g. Noise

5. CONTROL MEASURES

Control measures are implemented to reduce the possibility of human exposure to laser radiation and associated hazards. For all lasers and laser systems use, it is recommended that:

- the minimum laser radiation required for the application be used,
- the beam height be maintained at a level other than the normal position of the eye of a person in the standing or seated position.

A distinction needs to be made between operation, maintenance and service when considering control measures as each poses unique hazards.

5.1 Engineering Controls

Although commercial laser products will be certified by the manufacturer and will incorporate some engineering controls, the use of additional controls shall be considered in order to reduce the potential for hazard associated with some lasers and laser systems. Potential controls could include:

- Protective housings,
- Controls for laser operation without protective housings,
  - access restriction,
  - eye protection or other types of Personal Protective Equipment(PPE),
  - area controls,
  - barriers, shrouds, beam stops, etc., to block or sufficiently attenuate a beam to below the MPE,
  - administrative and procedural controls,
  - education and training.
- Interlocks on removable protective housings,

- Cover windows leaving the Laser Controlled Area with non-reflective or diffuse reflective material.
- Service access panels (require special tool for entry or interlocked),
- Key control,
- Viewing portals, display screens, and collecting optics,
- Beam Paths,
  - Totally unenclosed beam path controls,
  - Limited open beam path controls,
  - Enclosed beam path control
  - Not directed toward any doors
  - Not directed upward at any time during alignment or operation
- Remote interlock connector,
- Beam stop or attenuator,
- Laser activation warning systems,
- Emission delay systems,
- Indoor laser controlled area,
- Remote laser firing and monitoring,
- Equipment labels,
- Area posting signs.

a. Engineering Controls for Class 3B Lasers
Required:

Protective Housing
Interlocks on Removable Protective Housings
Service Access Panels
Establish NHZ
Laser Controlled Area
Equipment Labels
Laser Area Warning Signs

Recommended:

Key Control
Remote Interlock Connector
Beam Stop or Attenuator
Activation Warning System

b. Engineering Controls for Class 4 Lasers
Required:

Protective Housing

Interlocks on Removable Protective Housings
Service Access Panels
Establish NHZ
Laser Controlled Area
Equipment Labels
Laser Area Warning Signs
Key Control
Remote Interlock Connector
Beam Stop or Attenuator
Activation Warning System
Emergency Stop Button

5.2 Administrative and Procedural Controls

Administrative and procedural controls are methods or instructions which specify rules, work practices, or both, which implement or supplement engineering controls. The specified engineering control measures for Class 3b and 4 laser systems, upon review and approval by the LSO, may be replaced by procedural, administrative or other alternate engineering controls which provide equivalent protection. Unless otherwise specified, administrative and procedural controls shall apply only to Class 3b and 4 lasers and laser systems.

a. Standard Operating Procedures (SOP) (Class 3b, Class 4)

A written SOP is required for each Class 3b or Class 4 laser system. These SOP's shall be maintained with the laser equipment for reference by the operator and maintenance or service personnel. All information from the laser manufacturer must be available with the SOP.

b. Output Emission Limitations (Class 3R, Class 3b, Class 4)

If, in the opinion of the LSO, excessive power or radiant energy is accessible during operation or maintenance of a Class 3R, Class 3b or Class 4 laser, the LSO shall take action to reduce the levels of accessible power or radiant energy to that which is commensurate with the required laser application.

c. Education and Training (Class 2, Class 2M, Class 3R, Class 3B, Class 4)

Education and training shall be provided for University operators, maintenance, and service personnel of Class 3b, and Class 4 lasers or laser systems. The level

of training shall be commensurate with the level of potential hazard. Personnel must be trained on the SOP for the specific laser(s) they will be using.

d. Authorized Personnel (Class 3b, Class 4)
Class 3b or Class 4 lasers or laser systems shall be operated at all times under the direct supervision of an experienced, trained operator who shall maintain visual surveillance of conditions and terminate laser emission in the event of equipment malfunction or any other condition of unsafe use. These systems shall be maintained or serviced only by authorized personnel. The supervisor of the laser or laser system shall determine and post the list of authorized University personnel outside of the laser laboratory.

e. Alignment Procedures (Class 2, Class 2M, Class 3R, Class 3B, Class 4)
Beam alignment poses the highest potential for injury. Alignment of Class 2, 2M, 3r, 3b, or Class 4 laser optical systems shall be performed in such a manner that the primary beam, or a specular or diffuse reflection of a beam, does not expose the eye to a level above the applicable MPE. Written SOP's outlining alignment methods shall be approved for Class 3b and Class 4 laser systems. The use of low power visible lasers (Class 1 or Class 2) for path simulation of higher power visible or invisible lasers (Class 3b or Class 4) is recommended.

f. Protective Equipment (Class 3b, Class 4)
Protective equipment (protective eyewear, barriers, windows, clothing and gloves) specifically selected for suitable protection against laser radiation may be required when other control measures are inadequate to eliminate potential exposure in excess of the applicable MPE. This equipment will be provided by the University.

g. Spectators (Class 3b, Class 4)
Spectators shall not be permitted within a laser controlled area which contains a Class 3b or Class 4 laser or laser system unless:

- appropriate approval from the Department Laser Supervisor or Department Chairperson has been obtained,
- the degree of hazard and avoidance procedure has been explained,
- appropriate protective measures are taken.

h. Service Personnel (All laser classes)

During periods of service or maintenance, control measures appropriate to the class of the embedded laser shall be implemented when the beam enclosures are removed and beam access is possible. A temporary laser controlled area shall be established by service personnel that provides safety requirements for all personnel both within and outside of the area appropriate to the laser or laser system. A notice sign shall be posted outside the temporary laser controlled area to warn of the potential hazard.

5.3 Protective Equipment

Enclosure of the laser equipment or beam path is the preferred method of control. However, when these control measures do not provide adequate means to prevent access to direct or reflected beams at levels above the MPE, it may be necessary to use personal protective equipment.

5.3.1. Protective Eyewear

Eye protection devices which are specifically designed for protection against radiation from Class 3b or Class 4 lasers shall be required and their use enforced by the supervisor of the laser equipment when controls are inadequate to eliminate potential exposure in excess of the applicable MPE.

Laser eye protection attenuates the amount of light reaching the eye. In many research and laboratory situations there may be times when complete engineering controls may not be possible. In these situations, laser eye protection has shown to be a successful defense against eye injury.

When selecting the appropriate eyewear, beam wavelength, power, optical density, maximum permissible exposure and nominal hazard zones, must all be taken into consideration. Use **ANSI Z136.1 (Table 4 - Simplified method for choosing laser eye protection)** to determine Optical Density requirements for laser eye protection. Since exposure may include direct or diffusely scattered laser beam emissions, it will be important to choose eyewear appropriate to the parameters of the laser system.

In general, eye protection will afford adequate protection against medium power, Class 3 lasers but will seldom provide sufficient protection against direct beam viewing of CW lasers exceeding 10 W in power or pulsed lasers exceeding 10 to 100 J in output energy.

One pair of laser eyewear may not provide adequate protection from multiple wavelengths produced by a laser. The laser user must be conscious of which type

of eye protection is appropriate for each different wavelength which may be used in the operation of the laser.

5.3.2. Laser Protective Equipment

Protective equipment shall be chosen which reduces any transmitted laser radiation to levels below the applicable MPE level.

- Laser Protective Windows: reduce any transmitted laser radiation through protective window to levels below the applicable MPE.
- Laser Protective Barrier and Curtains: block or prevent the laser light from exiting the area at levels above the applicable MPE level.
- Skin Protection: opaque gloves, tightly woven fabrics, etc. protect skin from laser burns or injury.

	CLASSIFICATION						
CONTROLS FOR LASER SYSTEMS	1	1M	2	2M	3R	3B	4
1. Classify	X	X	X	X	X	X	X
2. Equipment Warning Label	R	R	X	X	X	X	X
3. Interlocks on Removable Protective Housing	^	^	^	^	^	X	X
4. Primary beam precautions			X		X	X	X
5. LSO Notification						X	X
6. Laser Safety Training		R	R	R	R	X	X
7. Controlled Area						X	X
8. Entryway Safety Controls						R	X
9. Laser Area Warning Signs and Activation Warning Signs					R	X	X
10. Area supervised by a Laser System Supervisor, Authorized Laser Operators assigned					R	R	X
11. Readily visible indication(light) that laser is in operation						R	X
12. Beam stop or attenuator						R	X
13. Protective eye wear						R*	X
14. Startup warning						R	X
15. Alignment Procedures	^	^	^	^	^	X	X
16. SOP						R	X
17. Locks/ Remote Interlock connector						R	X

6. LASER SAFETY TRAINING PROGRAMS

Laser safety training is required for all users working with Class 3b and Class 4 lasers and laser systems containing embedded class 4 lasers. Laser safety training is highly recommended for users working with Class 1, Class 2, and Class 3a lasers and laser systems. Users shall include University faculty, staff and students working with lasers and laser systems as operators, technicians, engineers, maintenance and service personnel. A guide for the organization of a training program is outlined below. The supervisor of the laser or laser system is responsible for ensuring that all users are properly trained. Training assistance is available for the University LSO and the Department of Environmental Health and Safety.

Laser Safety Training Program Outline

Only qualified and authorized personnel are permitted to operate a Class 3b or 4 laser. The Department Laser Supervisor must determine the employee's/student's operational qualifications. Each person who operates a laser must receive laboratory/laser system-specific training and general laser safety training. The Department Laser Supervisor or his/her designee who is familiar with the laser/laser system, must provide the laboratory/laser system specific training prior to that worker using that laser.

This training must be documented and consist of:
- Description of the laser system,
- Review of operating procedures and emergency procedures,
- Review of the SOP for use and set-up and alignment, if applicable,
- Selection and use of personal protective equipment, if required
- Identification and proper use of engineering controls,
- Identification of administrative controls, including warning signs and lights,
- Identification of non-laser safety hazards associated with the laser system.

General Laser safety training should consist of:
- Laser Bioeffects
- Eye Hazards
- Skin Hazards
- Non-beam hazards from high power lasers
- Laser safety standards and hazard classifications
- Safety procedures and control measures for each laser classification

7. LASER SAFETY AUDITS AND INVESTIGATIONS

7.1 Authorized laser supervisors and operators must report all laser incidents or accidents to the Laser Safety Officer (4-9505) immediately. An investigation will be conducted to

identify the root cause and contributing factors to the incident , to estimate employee exposures, and to identify corrective action(s) to prevent recurrence.

7.2 All laser supervisors and operators are expected to review their open beam laser system(s) and experimental layout(s) before each use to verify that all safety controls, components, and equipment operate properly, and to confirm the equipment and components have not been modified. All malfunctioning equipment shall be repaired and laser system modifications corrected before energizing the laser.

7.3 The Laser Safety Officer conducts laser safety audits with the authorized laser supervisor or one of their designated operators to assess compliance with hazard control strategies. The Laser Safety Officer will issue a written report of findings to the authorized laser supervisor.

7.4 Audits are performed for all newly acquired lasers, new laser laboratories, or other lasers that have not been evaluated by the Laser Safety Officer. These initial laser safety audits collect information about personnel and equipment, evaluate administrative, engineering, and non-beam hazard controls, and assesses available and required personal protective equipment.

7.5 Periodic laser safety audits are performed on class 3b and 4 open beam systems to ensure compliance with the Laser Safety Program.

Laser Safety
Self-Audit Checklist

Building _____ Room _____ Principal Investigator _____
Audit Performed by _____ Date _____

	Y	N	NA	COMMENTS
A. Administrative				
1. Lasers are classified appropriately				
2. Standard operating procedures are available				
3. Alignment procedures are available				
4. Viewing cards are used for alignment				
5. Laser users attended appropriate training				
6. Lasers are included in inventory				
B. Labeling and Posting				
1. Certification label present				
2. Class designation and appropriate warning label present				
3. Radiation output information on label				
4. Aperture label present				
5. Appropriate warning/danger sign at entrance to laser area				
6. Warning posted for invisible radiation				
C. Control Measures				
1. Protective housing present and in good condition				
2. Beam attenuator present				
3. Laser table below eye level				
4. Beam is enclosed as much as possible				
5. Beam not directed toward doors or windows				
6. Beams are terminated with fire-resistant beam stops				
7. Surfaces minimize specular reflections				
8. Controls are located so that the operator is not exposed to beam hazards				
D. Personal Protective Equipment				
1. Eye protection is appropriate for wavelength				
2. Eye protection has adequate OD				
3. Warning/indicator lights can be seen through protective filters				

E. Class 3b and 4 Lasers				
1. Interlocks on protective housing				
2. Service access panel present				
3. Limited access to spectators				
4. Nominal hazard zone determined				
5. Operators do not wear watches or reflective jewelry while laser is operating				
6. Viewing portals present where MPE is exceeded				
F. Class 4 Lasers				
1. Failsafe interlocks at entry to controlled area				
2. Area restricted to authorized personnel				
3. Laser may be fired remotely				
4. If present, curtains are fire-resistant				
5. Area designed to allow rapid emergency egress				
6. **Pulsed –** interlocks designed to prevent firing of the laser by dumping the stored energy into a dummy load				
7. **CW –** interlocks designed to turn off power supply or interrupt the beam by means of shutters				
8. Operators know not to wear ties around the laser				
G. Non-Beam Hazards				
1. High voltage equipment appropriately grounded				
2. High voltage equipment located away from wet surfaces or water sources				
3. High voltage warning label in place				
4. Compressed gases secured				

A. Administrative

1. Lasers are classified by the manufacturer, but must be reclassified by the LSO and principal investigator if the system is altered or constructed in the laboratory. Class 2 designates lasers in the visible range (400-700 nm) where radiant power does not exceed 1 mW. Class 3r designates visible lasers with 1 – 5 mW radiant power. Class 3b designates lasers with radiant power ranging 5 mW – 500 mW. Class 4 lasers have radiant power exceeding 500

mW.
2. Self-explanatory
3. Self-explanatory
4. Self-explanatory
5. All faculty, staff and students operating Class 3b or 4 lasers must attend training.
6. All lasers must be included in the University laser inventory maintained by EH&S. Any new laser system must be reported to EHS at 624-9505.

B. Labeling and Posting

1. The manufacturer's certification label must be affixed to the laser housing.
2. The laser housing must bear a sticker which includes the class designation and appropriate warnings.
3. The laser labeling must include the output radiant energy or power.
4. Self-explanatory.
5. At the entrance to the room, the following signage is necessary:
   Class 2 or 2M: CAUTION, Laser Radiation (or laser symbol), Do Not Stare Into Beam
   Class 3r: DANGER, Laser Radiation (or laser symbol), Avoid Direct Eye Exposure
   Class 3b: DANGER, Laser Radiation (or laser symbol), Avoid Direct Exposure To Beam
   Class 4: DANGER, Laser Radiation (or laser symbol), Avoid Eye or Skin Exposure to Direct or Scattered Radiation
6. If laser is not visible range (e.g., not 400-700 nm), warning sign should be posted stating that the beam is not visible.

C. Control Measures

1. Self-explanatory
2. Self-explanatory
   Laser table should be set up such that the beam is below eye level when sitting or standing.
3. Self-explanatory
4. Self-explanatory
5. Self-explanatory
6. Self-explanatory
7. Self-explanatory
8. Self-explanatory

D. Personal Protective Equipment

1. Eye protection should bear markings indicating the optical density and wavelength that the eyewear protects
2. Optical density must be appropriate for the laser system.
   $OD = \log_{10}$ (anticipated worst case exposure in W/cm^2 or J/cm^2)/MPE
3. Self-explanatory

E. Class 3b and 4 Lasers

1. Interlocks must be provided on removable parts of the housing.
2. Service access panels should be interlocked or require a tool for removal.
3. Spectators must be provided appropriate personal protection and be warned of the associated hazards of the laser.
4. The Nominal Hazard Zone must be calculated and marked to warn individuals within the NHZ that protective equipment is needed.
5. Watches and reflective jewelry may create hazardous specular reflections.
6. Recommended.

F. Class 4 Lasers

1. It is strongly recommended that interlocks be placed at entryways to the controlled area such that the laser system shuts down upon entry of unauthorized personnel.
2. Self-explanatory. Visitors or spectators must be warned of hazards and given protective equipment.
3. It is strongly recommended that the laser be monitored and fired remotely.
4. Self-explanatory.
5. Self-explanatory.
6. Self-explanatory
7. Self-explanatory
8. Ties may accidentally get into the path of the beam

G. Non-Beam Hazards

1. Self-explanatory.
2. Self-explanatory. Operators should take care not to handle electrically charged equipment when hands are wet or sweaty.
3. Self-explanatory.
4. Cylinders should be secured to the wall or to a stationary object to avoid tipping or falling.

8. Laser Warning Signs and Labels

Sign dimensions (letter size, color, etc.) shall be in accordance with applicable standards**.** Figures 1 to 7 show signs for entryways to laser areas or laboratories. Figure 8 shows a sample sign for a temporary laser controlled area.

Where multiple lasers exist in the same room, affix a single sign corresponding to the laser with the highest hazard potential to the entrance doors.

Figure 1
Sample Warning Sign for Class 2 and Class 2M lasers

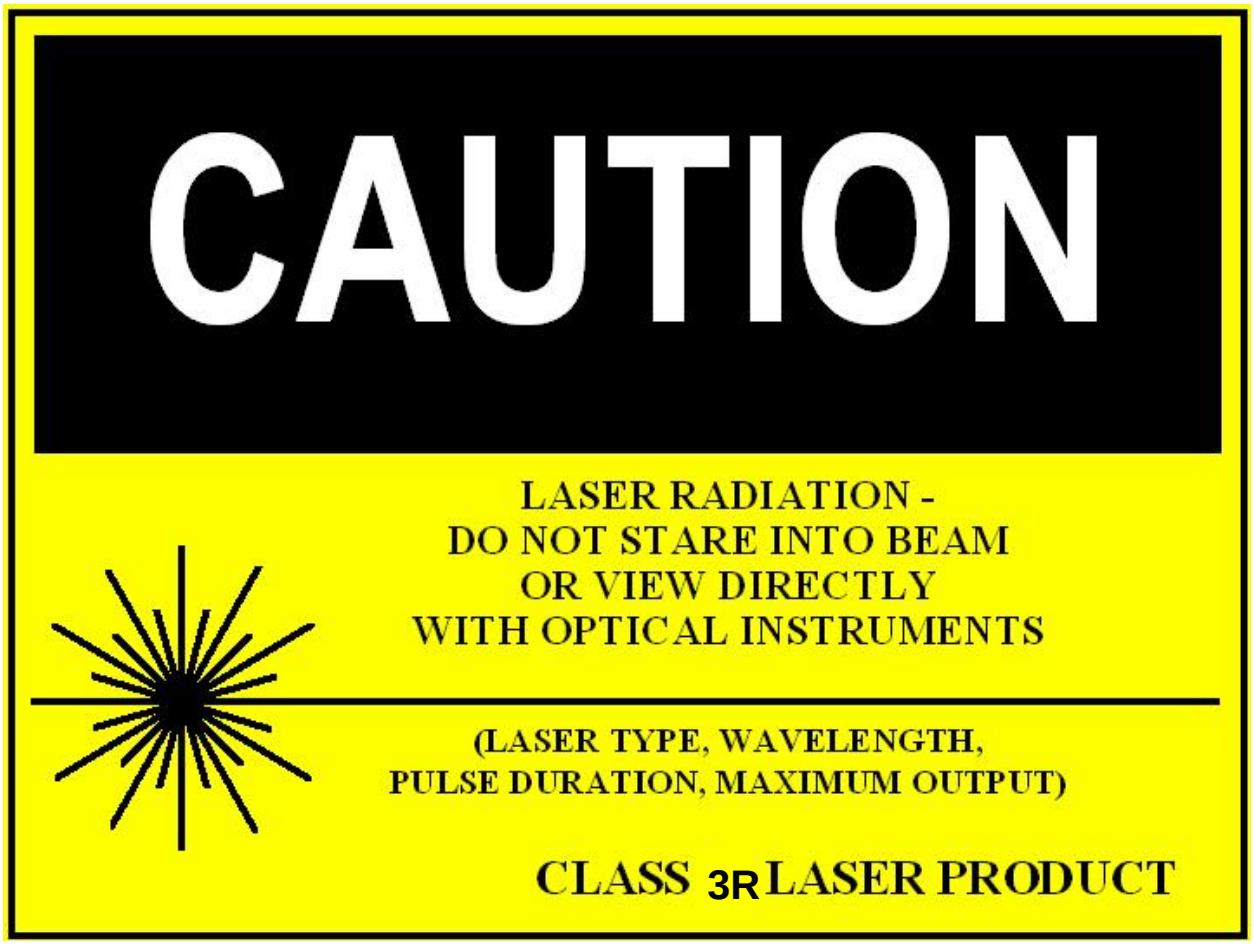

Figure 2
Sample Warning Sign for Class 3R lasers (below MPE)

Figure 3
Sample Warning Sign for Class 3R lasers (above MPE)

Figure 4
Sample Warning Sign for Class 3b lasers

Figure 5
Sample Warning Sign for Class 4 lasers

(Yellow "CAUTION")

(Black square behind "CAUTION")

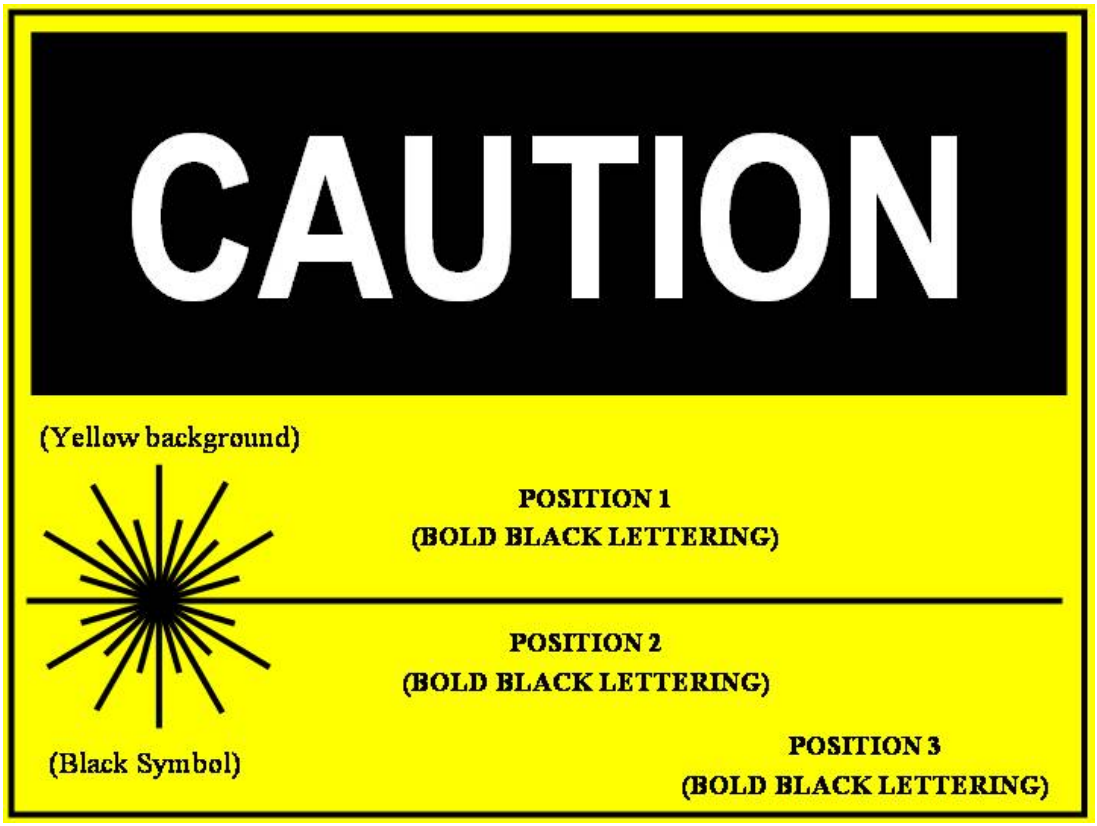

Figure 6
Blank template for "CAUTION" laser warning signs

Position 1: Special Precautionary instructions or protective action that may be applicable (Invisible Laser Radiation; Knock Before Entering; Do Not Enter When Light is On; Restricted Area, etc.)

Position 2: Type of Laser (Nd:YAG, Helium-Neon, etc.), emitted wavelength, pulse duration, and maximum output.

Position 3: The class of the laser or laser system.

(White "DANGER)
(Red oval behind "DANGER")
(White Ring around Red oval)
(Black Square behind all)

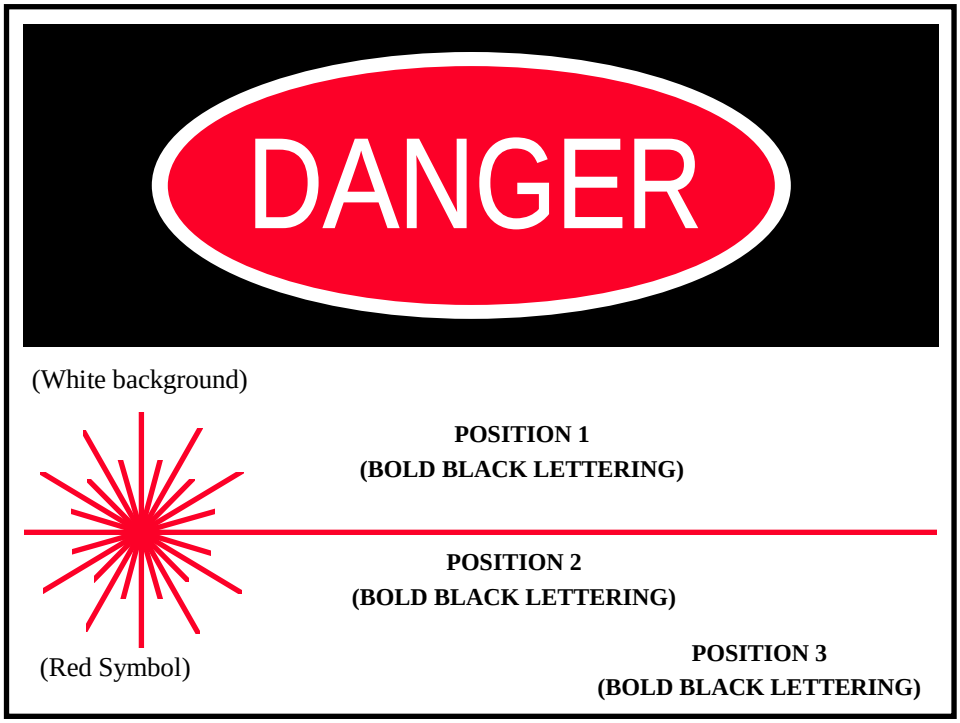

Figure 7
Blank template for "DANGER" laser warning signs

Position 1: Special Precautionary instructions or protective action that may be applicable (Invisible Laser Radiation; Knock Before Entering; Do Not Enter When Light is On; Restricted Area, etc.)

Position 2: Type of Laser (Nd:YAG, Helium-Neon, etc.), emitted wavelength, pulse duration, and maximum output.

Position 3: The class of the laser or laser system.

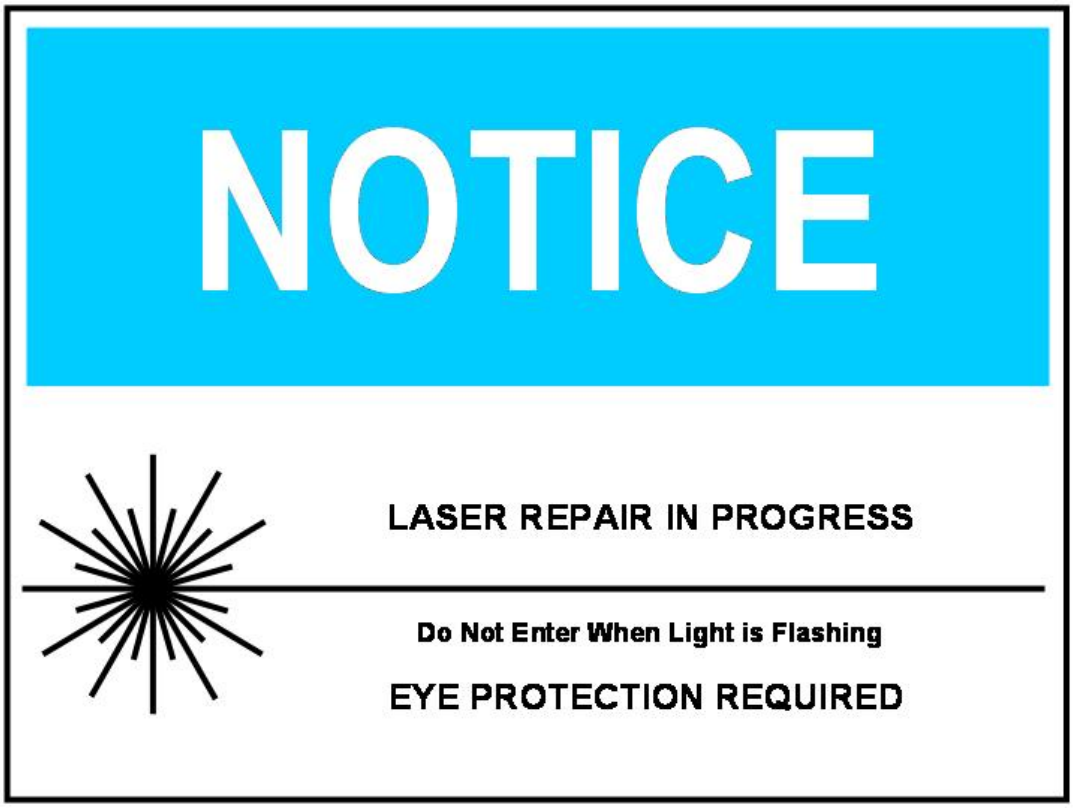

Figure 8
Sample Warning Sign for Temporary Controlled Area