Carnegie Mellon University

Environmental Health and Safety (EHS)

Laser Safety Program

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1. Introduction

a. **Purpose**

The Carnegie Mellon University Laser Safety Program is intended to establish a high level of safety and health for all individuals who are involved in the use of lasers and laser systems. This document incorporates the recommendations and requirements outlined in the *American National Standard for Safe Use of Lasers* (ANSI Z136.1-2007) and is applicable to all individuals involved in the use of lasers and laser systems at Carnegie Mellon University.

b. **Scope**

This document provides guidance in all areas of occupational health and safety as it relates to the use of lasers and laser systems. This document covers all University faculty, staff, students, and visitors that may reasonably anticipate being present or working in areas containing lasers and laser systems.
This document will be reviewed and updated annually by the Department of Environmental Health and Safety (EHS) at Carnegie Mellon University in conjunction with the University's Laser Safety Committee. Implementation of this document is coordinated and compliance monitored by EHS and specifically, the Laser Safety Officer. Additional information related to laser safety practices and procedures can be found at the EHS website. Questions or concerns can be addressed to safety@andrew.cmu.edu.

2. Responsibilities

The Responsibilities of the personnel involved in laser use and laser safety shall be as follows:

a. **EHS**

Administration of the Carnegie Mellon University Laser Safety Program

b. **Laser Safety Officer (LSO)**

i. Classification or verification of the classification of lasers and laser systems
ii. Maintaining the University laser inventory records
iii. Evaluating the hazards of laser work areas, including the establishment of Nominal Hazard Zones, where applicable
iv. Ensuring that the prescribed control measures are in effect
v. Recommending or approving substitute or alternate control measures
vi. Periodically auditing the functionality of the laser controls
vii. Approval of standard operating procedures, alignment procedures and other procedures that may be part of the requirements of this program
viii. Ensuring the preparation and updating of written laser program documents
ix. Recommending or approving protective equipment used for personnel safety

x. Periodically auditing protective equipment to verify its integrity
xi. Approving laser area signs and equipment labels
xii. Approving Class 3B, and 4 Laser installation facilities and laser equipment prior to use
xiii. Ensuring that safety education and training is provided to laser area personnel
xiv. Overseeing the Medical Surveillance Program, including determining the need for medical surveillance, by employee, specifying the requirements of any needed medical surveillance, etc.
xv. Overseeing the investigation of any laser-related accidents or exposure incidents.

c. **Department Head**
   i. The overall implementation of the Laser Safety Program within his or her Department.
   ii. The identification of Departmental Laser Representative(s), as needed.

d. **Principal Investigators (PI)**
   i. Ensuring that all users of lasers within their jurisdiction have received training specified by this Program; submit names of all laser users to the LSO.
   ii. Responsible for the safety of the users of their laser equipment.
   iii. Providing unit specific safety training for the lasers in their control (including physical hazards, health hazards, and emergency procedures).
   iv. Enforcing the requirements of the University Laser Program within their responsibility areas.
   v. Attending laser safety training as required.
   vi. Participating in a Medical Surveillance Program, where appropriate.
   vii. Assisting in the design of both administrative and engineering controls.
   viii. Providing an accurate and up-to-date inventory to the LSO at least annually.
   ix. Submitting a request to the LSO for each laser or laser system via email to EHS.
   x. Identifying laser hazards present in the work area, implement appropriate hazard controls (including ANSI approved signs and labels) and correct any identified unsafe conditions.
   xi. Developing and submitting to the LSO the current Standard Operating Procedures (SOPs) for each Class 3B and Class 4 Laser or laser system.
   xii. Identifying all authorized personnel who are eligible to operate or maintain a Class 3B or Class 4 Laser or laser system.
   xiii. Keeping copies of all current SOPs, trainings, inspections and investigations.
   xiv. Maintaining a copy of this written program in the workplace.

xv. Reporting any laser-related accident or exposure (Class 3B or 4) to the LSO and the Department Head; investigate with the LSO, any laser related exposure incidents

e. **Laser User**
   i. Attending required laser safety training as specified.
   ii. Reading and being familiar with the essentials of the written Laser Safety Program documents.
   iii. Complying with the safety rules and operating procedures.
   iv. Participating in a medical surveillance program, if appropriate.
   v. Reporting any laser-related accident to his or her supervisor.

3. Inventory

A key element of a successful Laser Safety Program is a complete and up-to-date inventory of all applicable laser systems. **Principal Investigators** are responsible for submitting an accurate and up-to-date laser inventory for all class 3B and 4 lasers and laser systems to the LSO at least annually. At a minimum, the following criteria should be identified for each laser or laser system:

- Laser manufacturer, model number, serial number
- Laser type (gas or medium, pulsed or continuous)
- Wavelength(s) of laser light
- Laser location, responsible researcher(s)
- Output power

4. Laser Classification

Lasers are classified according to their potential to cause biological damage. The pertinent parameters are:

- Laser output energy or power
- Radiation wavelengths
- Exposure duration
- Cross-sectional area of the laser beam at the point of interest.

In addition to these general parameters, lasers are classified in accordance with the *accessible emission limit* (AEL), which is the maximum accessible level of laser radiation permitted within a particular laser class.

The ANSI standard laser hazard classifications are used to signify the level of hazard inherent in a laser system and the extent of safety controls required. These range from Class 1 lasers (which are inherently safe for direct beam viewing under most conditions) to Class 4 lasers (which require the strictest controls). The laser classifications are described below.

a. **Class 1-Exempt Lasers**
   i. **Class 1 Laser**

Cannot, under normal operating conditions, produce damaging radiation levels. These lasers must be labeled, but are exempt from the requirements of the Laser Safety Program. A laser printer is an example of a Class 1 laser.

ii. **Class 1M Lasers**
Cannot, under normal operating conditions, produce damaging radiation levels unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam). This may be due to a large beam diameter or divergence of the beam. Such lasers must be labeled, but are exempt from the requirements of the Laser Safety Program other than to prevent potentially hazardous optically aided viewing.

b. **Class 2-Low Power Visible Lasers**

i. **Class 2 Lasers**
Low power lasers or laser system in the visible range (400 - 700 nm wavelength) that may be viewed directly under carefully controlled exposure conditions. Because of the normal human aversion responses, these lasers do not normally present a hazard, but may present some potential for hazard if viewed directly for long periods of time.

ii. **Class 2M Lasers**
Low power lasers or laser system in the visible range (400 - 700 nm wavelength) that may be viewed directly under carefully controlled exposure conditions. Because of the normal human aversion responses, these Lasers do not normally present a hazard, but may present some potential for hazard if viewed with certain optical aids.

c. **Class 3-Medium Power Lasers and Laser Systems**

i. **Class 3 Lasers**
Medium power lasers or laser systems that require control measures to prevent viewing of the direct beam. Control measures emphasize preventing exposure of the eye to the primary or specularly reflected beam. Lasers above 5 mW, but not exceeding 500 mW radiant power, are in this class.

ii. **Class 3R (replacement for Class 3A)**
Denotes lasers or laser systems potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffuse-reflection hazard. They may present a hazard if viewed using collecting optics.

iii. **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 diffuse reflections.

d. **Class 4-High Power Lasers and Laser Systems**
A Class 4 Laser is a high power laser or laser system 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 all lasers in excess of Class 3 limitations.

If there is no identifier label on the laser system, or if the laser has been modified or otherwise used in a way different from the intended use, the laser classification must be determined from performance characteristics by the LSO and the PI. Also, in lieu of the recent change in classification schemes, the LSO will assist you in updating your laser systems with the appropriate identifier label.

5. Control Measures

Any 3B or 4 Laser must be operated at all times under the direct supervision of a trained operator, unless control measures are in place that would prevent employee overexposure to the beam or its associated hazards. No user shall be exposed to laser radiation in excess of the Maximum Permissible Exposure (MPE) nor to any unsafe conditions as identified in the hazard analysis.

The determination of appropriate control measures for all laser systems shall be based on the specifications in the current revision of ANSI Z136.1, *Standard for Safe Use of Lasers*. Any variance from these specifications requires written permission from the LSO.

a. **General Laser Safety Recommendations and Requirements**
   i. Class 1 Lasers may be used for purposes intended by their manufacturers without restrictions.
   ii. Class 2, Class 3B and Class 4 Lasers shall bear a warning label containing the laser classification, type and other warnings.
   iii. Class 3B and Class 4 Lasers shall be registered in the equipment module of BioRAFT
   iv. Purchases of Class 3B or Class 4 Lasers shall be approved by the LSO before the orders are placed.

b. **Engineering Controls**
   i. All lasers require a protective housing.
   ii. Beams shall be enclosed as much as is operationally practical. Items to consider may include curtains, side shields, partitions or entryway mazes.
   iii. All Class 3B and Class 4 Lasers shall be equipped with protective housing fail-safe interlock systems to prevent emission of laser radiation when the housing is open.

iv. Viewing portals in the protective housing shall be equipped with filters and attenuators that keep escaping light below the MPE limit.
v. Optical instruments for viewing laser systems shall be equipped with filters, attenuators and interlocks to keep exposures below the MPE limit for all conditions of operation and maintenance.
vi. Class 3B and Class 4 Lasers shall adhere to the following engineering controls guidelines:
    1. Lasers shall be equipped with removable master key switches and must not be operable when the keys are removed.
    2. Lasers shall be equipped with electrical connections allowing the lasers to be controlled by area interlock systems and remote shut-off devices.
    3. When terminals are open-circuited, lasers must not emit any radiation in excess of the MPE.
    4. Class 4 Laser systems must have integral and permanently attached beam stops or attenuators capable of preventing the emission of laser light in excess of the MPE limit when the laser system outputs are not required, such as during warm-up procedures.

c. **Laser Control Areas**

Class 3B and Class 4 Lasers shall only be operated in laser control areas approved by the LSO. Laser control areas confine laser hazards to well-defined spaces that are entirely under the control of laser users. The control areas shall be equipped with the prescribed safety features. The Class 3B Laser controlled area shall be:

i. Controlled to permit lasers and laser systems to be operated only by trained personnel.
ii. Be posted with appropriate warning sign(s) at the entryway.
iii. Be operated in a manner such that the path is well defined.
iv. Be well defined and controlled if the laser beam must extend outdoors.

In addition to the above, a Class 3B controlled area should:

i. Be under the direction of an individual knowledgeable in laser safety.
ii. Be located so that access to the area by spectators is limited and requires approval.
iii. Have any potentially hazardous beam terminated in a beamstop of an appropriate material.
iv. Have only diffusely reflecting materials in or near the beam path where feasible.
v. Provide personnel within the laser-controlled area with the appropriate eye protection as specified in the “Protective Equipment” section of this program.

In addition to the requirements of the Class 3B Laser controlled area the Class 4 Laser controlled area shall incorporate one of the following:

i. Non-defeatable (non-override) safety latches, entryway or area interlocks (e.g., electrical switches, pressure sensitive floor mats, infrared or sonic detectors) shall be used to deactivate the laser or reduce the output to levels at or below the applicable MPE in the event of an unexpected entry into the laser controlled area.

ii. Defeatable area or entryway safety controls shall be used if non-defeatable area/entryway safety controls limit the intended use of the laser or laser system. For example, during normal usage requiring operation without interruption (e.g., long-term testing, medical procedures, surgery), it is clearly evident that there is no laser radiation hazard at the point of entry, override of the safety controls shall be permitted to allow access to authorized personnel provided that they have been adequately trained and provided with adequate personal protective equipment.

iii. When safety latches or interlocks are not feasible or are inappropriate, for example during medical procedures, surgery, etc., the following shall apply:
   1. All authorized personnel shall be adequately trained and adequate personal protective equipment shall be provided upon entry.
   2. A door, blocking barrier, screen, curtains, etc. shall be used to block or attenuate the laser radiation at the entryway. The level of laser radiation at the exterior of these devices shall not exceed the applicable MPE, nor shall personnel experience any exposure above the MPE immediately upon entry.
   3. At the entryway, there shall be an activation warning system indicating that the laser is energized and operating at Class 4 levels.

6. Administrative Controls

a. Standard Operating Procedures

Principal Investigators are required to develop written Standard Operating Procedures (SOPs) for all Class 3B and 4 Laser applications. At a minimum, SOPs shall contain the following information:

i. General Safety Precautions and Nominal Hazard Zone (NHZ) description.
ii. Personal Protective Equipment (PPE) requirements and use.
iii. Start-up, use, and shut-down procedures.
iv. Alignment procedures.
v. Interlock testing.
vi. Emergency procedures.

Standard Operating Procedures shall be specific to each laser or laser system. SOPs must be submitted to the LSO for review and must be approved by the

LSO prior to implementing them. Once approved, SOPs must be submitted to the LSO every three years for periodic review, or when significant changes have been made.

b. **Alignment Procedures**

Alignment of Class 2, 3R, 3B or Class 4 Laser optical systems (mirrors, lenses, beam deflectors, etc.) shall be performed in such a manner that the primary beam or a specular reflection of a beam does not expose the eye to level about the applicable MPE.

For Class 3B and Class 4 Lasers, alignment should be done only by experienced and trained personnel. In addition, the following actions should be taken:

i. Exclude unnecessary personnel from the laser area during alignment.
ii. Whenever possible, use low-power visible lasers for path simulation of higher-power visible or invisible lasers.
iii. Wear protective eyewear and clothing to the extent feasible.
iv. When aligning invisible (and in some cases visible) laser beams, use beam display devices such as converter viewers or phosphor cards to locate beams.
v. Perform alignment tasks the use high-power lasers at the lowest possible power level.
vi. Use a shutter beam or beam block to block high-power beam at the source except when actually needed during the alignment process.
vii. Use a laser-rated beam block and/or laser protective barriers in conditions where alignment procedures could stray into areas with uninvolved personnel.
    1. Place beam blocks behind optics (e.g. tuning mirrors) to terminate beams that might miss mirrors during alignment.
    2. Locate and block all stray reflections before proceeding to the next optical component or section.
    3. Be sure all beams and reflections are properly terminated before high-power operation.

c. **Work Practice Controls**

i. The laser shall be isolated from areas where untrained or unauthorized persons may be attracted by its operation.
ii. Doors shall be closed and secured when unattended to keep out unauthorized personnel.
iii. The laser shall be set up so that the beam path is either above or below normal eye level (below 4.5 ft. or above 6.5 ft.).
iv. The laser beam shall be enclosed to the extent practical.
v. The potential for specular reflections shall be minimized with shielding and by removal of all unnecessary reflective surfaces.

vi. Windows to hallways or other outside areas should have adequate shades or covers.
vii. The main beams and reflected beams shall be terminated or dumped.
viii. Electrical installation must meet electrical safety standards. The active laser should never be left unattended, unless it is a part of a controlled environment.
ix. Do not wear bright, reflective jewelry or other objects.
x. Avoid looking at the pump source.
xi. Securely mount the laser system on a stable platform to maintain the beam in a fixed position during operation and limit beam traverse during adjustments.
xii. Confine primary beams and dangerous reflections to the optical table.
xiii. Clearly identify beam paths and ensure that they do not cross populated areas or traffic paths.

d. **Protective Equipment**

i. **Eyewear**

Eye protection suitable to the laser class shall be provided and worn within the laser control area during operation and alignment if there is a potential for exceeding the MPE limit. Protective eyewear may include goggles, face shields, spectacles or prescription eyewear using special filter materials or reflective coatings. Exceptions may be approved in the written SOPs or by the LSO if the eyewear produces a greater hazard than when eye protection is not worn, such as in low-light situations.

No single type of eyewear will provide protection against all wavelengths of laser radiation; therefore, eye protection should:

1. Provide enough visibility to move about safely.
2. Withstand the maximum power of laser radiation likely to be encountered.
3. Absorb the specific wavelength of radiation that is being used.
4. Be clearly labeled with its designed wavelength, the optical density at that wavelength and the maximum power rating.
5. Be inspected by the laser operator to ensure that pitting, cracking and other damage will not endanger the wearer.

When not in use, eyewear must be properly stored in areas away from dust, heat and direct light.

ii. **Skin Protection**

Clothing such as gloves and covers for the forearms may be required to protect the skin if laser intensity and wavelength warrant such protection. This is most important if lasers are running in the ultraviolet region. Very large peak powers with pulsed ultraviolet lasers may be particularly

dangerous. The LSO can assist in identifying protection equipment that is appropriate for the intended use. This equipment shall be addressed in the written SOP.

iii. **Warning Signs**
Each entrance to a facility that contains a Class 3B or 4 Laser shall be posted with an appropriate laser warning sign. ANSI Z136.1 recommends that signs and labels conform to a standard design, format and content. Contact the LSO for information regarding the appropriate signage type and format.

7. Training

Carnegie Mellon requires training for the users of 3B and 4 Lasers. Training consists of a general training class (performed by EHS) and site specific training, as needed (performed by the user supervisor and/or the LSO or his/her designee).

Note: The general training class requirement does not apply to users of confocal microscopes as there should be no circumstance when they are exposed to a hazardous laser beam. However, site-specific training is still required. Training for users of Class 3B and 4 Lasers shall address:

- Fundamentals of laser operation
- Laser and laser system classifications
- Bio-effects of laser radiation on the eye and skin
- Significance of specular and diffuse reflections
- Non-beam hazards (electrical, chemical, reaction by-products, etc.)
- Control measures, including signs and labels and protective equipment
- Overall responsibilities of management and employees
- Requirements for imbedded lasers, modified lasers

Additional training topics for users of Class 3B and Class 4 Lasers shall include:

- Medical monitoring
- Nominal hazard zones
- Non-beam hazards
- Review of SOPs

8. Medical Surveillance

Laser operators or individuals who work routinely in laser environments containing a Class 3B or Class 4 Laser have the option of enrolling in a medical surveillance program. The medical surveillance evaluation includes the following:

- Ocular history interview
- Visual acuity test
- Color vision test

The purpose of the medical surveillance is to establish a baseline against which damage can be measured in the event of an accident, and to identify workers who may be at special risk from chronic laser exposures.

Medical surveillance evaluations should occur:
- Initially, prior to beginning one's laser activities,
- In the event of any laser exposure, and
- At the end of one's laser exposure potential, or when the subject leaves the university.

To receive a medical surveillance form, contact EHS.

9. Exposure Incidents and Emergency Procedures

In the event of an overexposure of a person to laser radiation, the following steps should be taken:
- ***Immediately*** contact University Police at 412-268-8182 or 8-8182 to ensure that the effected person(s) receive(s) medical treatment.
- Contact EHS and report the incident by calling (412) 268-5609.
- If the incident involves chemical hazards, follow lab emergency response protocol on Emergency Response Guide posted in the lab.

10. Inspections

All Class 3B and Class 4 Laser equipment will be audited by the LSO on an annual basis, or sooner, if conditions change as to use or hazards associated with the unit.

11. Non-beam Hazards

Beam hazards of a laser system are only one concern in using lasers. The other associated hazards described shall be understood to ensure the safe use of a laser or laser system. Contact the LSO for specific training requirements associated with working around these hazards.

a. **Chemicals and Compressed Gases**

Dyes, reagents or compressed gases are often used in laser systems. These materials are often hazardous and must be handled appropriately. Personnel who will be using these materials must receive chemical safety training before use. Please visit the EHS training website to sign up for the training.

b. **Laser Generated Air Contaminants (LGACs)**

Air contaminants may be generated when certain Class 3B or Class 4 beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend greatly upon target material, cover gas and beam irradiance. LGACs must be exhausted via local exhaust ventilation of other types of exhaust ventilation systems. Contact EHS for more information.

c. **Electrical Hazards**
Lethal electrical hazards may be present, especially around high power laser systems. To reduce electrical hazards, high voltage sources and terminals must be enclosed unless the work area is restricted to qualified persons only. Whenever feasible, power must be turned off and all high-voltage points grounded before working on power supplies. Capacitors must be equipped with bleeder resistors, discharge devices or automatic shorting devices. Appropriate lockout/tagout procedures must be determined and the requirements of

Carnegie Mellon University's *Energy Control Procedure* must be followed at all times; personnel performing lockout/tagout must be trained and authorized. This training can be arranged by contacting EHS.

Operators are not to stand on metal floors or in water while working with live electronic equipment. Accessible, non-current carrying metallic parts of laser equipment must be grounded. Electrical circuits should be evaluated with respect to fire hazards.

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

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

f. **Cryogenics**
Cryogenic liquids (especially liquid nitrogen) may be used to cool the laser crystal and associated receiving and transmitting equipment. Liquefied gases are capable of producing skin burns and may replace the oxygen in small unventilated rooms. The storage and handling of cryogenic liquids must be performed in a safe manner. Insulated handling gloves should be worn and eye

protection must be worn. Adequate ventilation must be present in areas where cryogenic liquids are used.

g. **Noise**
Noise levels in laser laboratories can exceed safe limits because of high voltage capacitor discharges. Hearing protection may be required. Contact EHS for more information.

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

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

j. **Ergonomics**
There may be ergonomic hazards associated with the operation, maintenance or service of the laser system. Ergonomic hazards such as awkward postures could contribute to improper actions if not addressed. Contact EHS for more information.

12. Revisions

Date	Documented Changes	Initials
3/2020	Updated Format	MAS
3/11/2021	Updated Format and Accessibility Update	MAS
10/14/2022	Removed record keeping section and updated EHS phone number	AJL
10/23/2023	Reviewed – not update necessary	AJL
10/21/2024	Reviewed – not update necessary	AJL