Laser Safety Guidance

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I. Introduction:

A Laser is any device that produces radiant energy predominantly by stimulated emission. A laser system is an assembly of electrical, mechanical, and optical components which includes a laser and is subject to the provisions of this guide. High safety standards are essential when using lasers. The nature of the precautions needed may vary considerably depending on the type and power output of the laser in use. This is a general overview of the regulations in place to protect personnel from the hazards of lasers.

This document provides guidance for compliance with applicable State and Federal regulations along with the American National Standard for the Safe Use of Lasers, ANSI Z136.1-2014, Center for Devices and Radiological Health (CDRH), Food and Drug Administration, Occupational Safety and Health Administration (OSHA) and is recognized as a minimum standard for laser safety. This document is intended to be used in conjunction with the information found in the CASE Laser Slide presentation. The ANSI Laser Hazards and related standards include the following references:

- ANSI Z87.1-1989: Practice for Occupational and Educational Eye and face protection
- ANSI Z136.1-2014 American National Standard for the Safe Use of Lasers
- ANSI Z136.2-1988 American National Standard for the Safe Use of Optical Fiber Communications Systems Utilizing Laser Diodes and LEDs
- ANSI Z136.3-1996 American National Standard for the Safe Use of Lasers in the Health Care Environment
- ANSI Z136.5-2000 Safe Use of Lasers in Educational Institution
- ANSI Z136.6-2000 Safe Use of Lasers Outdoors
- FAA 7400.2D Guidelines for Use of Lasers Outdoors (this is not a title)
- FDA, 21 CFR Subchapter J: Federal Laser Product Performance Standard OSHA Technical Manual (TED 1-0.15A), Section 111- Chapter 6, (January 1999)
- CDRH: Federal Laser Product Performance Standard 1976

II. Regulatory Requirements:

The safe use of lasers is administered by state and federal regulatory agencies according to the consensus provisions stated in the "Standard for the Safe Use of Lasers, ANSI Z136.1-2000", which is published by the American National Standards Institute (ANSI). The manufacture and registration of lasers are regulated by the U.S. Food and Drug Administration (FDA). These state and federal regulations are legally binding and require the maintenance of certain records and the fulfillment of certain obligations by all primary investigators.

Best practices currently comply with the requirements of ANSI, the FDA, and the Massachusetts Department of Health Radiation Control Program (MRCP), which registers lasers facilities and laser light shows in the Commonwealth of Massachusetts.

A. Federal Regulations:

The Occupational Safety and Health Administration (OSHA) has established regulations to ensure that the employer has done due diligence to ensure a safe place of employment that is free from hazards that could cause death or serious injury. Since lasers can cause injury The OSH act of 1970 general duty clause is followed and enforced. Other federal regulations do apply to specific laser uses.

Manufacturers of electronic radiation-emitting products sold in the United States are responsible for compliance with the Federal Food, Drug, and Cosmetic Act (FFDCA), Chapter V, Subchapter C - Electronic Product Radiation Control. Manufacturers of laser products are responsible for compliance

with all applicable requirements of Title 21 Code of Federal Regulations (Subchapter J, Radiological Health) Parts 1000 through 1005. Laser products that are marketed within the United States of America (USA) must be registered with the Center for Devices and Radiological Health (CDRH), a department belonging to the FDA. These regulations, 21 CFR Part 1040, are also known as the Federal Laser Product Performance Standard (FLPPS). Specific guidance for FLPPS implementation is covered in ANSI/Laser Institute of America (LIA) Z136.1.

For more information regarding the federal regulations of lasers follow the link to the OSHA website. Laser Hazards - Overview | Occupational Safety and Health Administration (osha.gov)

B. State Regulations**:**

The Commonwealth of Massachusetts specified its own rules and regulations for the control of lasers and laser systems in code regulation 105 Code of Massachusetts Regulations 121 (105 CMR121). This regulation has required all laser users to follow the American National Standards Institute document titled "ANSI Z136.1 the American National Standard for Safe Use of Lasers." Laser users must comply with the applicable requirements of both state and federal regulations.

III. Safety Fundamentals:

A. Classifications:

- Class 1
  - Not capable of producing damaging radiation levels during operation or maintenance.
  - Class 1 lasers are sealed in an enclosure that prohibits or limits access to the laser radiation (i.e., a laser printer). Beam power is less than 0.4 uW for visible CW lasers.
  - Exempt from control measures
- Class 2
  - All Class 2 lasers operate within the visible region of the spectrum (400-700 nm)
  - Output is not intended to be viewed (for example, a grocery scanner)
  - Eye protection is normally afforded by the aversion response to bright light (blink).
  - Class 2 lasers shall have a "Caution" sign posted on the outside of the door.
- Class 3R
  - Power output is up to 5 times greater than Class II - 5m W.
  - Laser or laser systems that would not normally produce a hazard if viewed for only a moment with the unaided eye (for example a laser pointing device).
- Class 3B
  - Maximum power output is less than 500 mW.
  - CW lasers operate between the upper Class 3R limits (5mW) and the maximum power for Class 3B lasers (500 mW).
  - Diffuse reflections are usually not hazardous. However, lasers or laser systems may produce a hazard if viewed directly through intra-beam viewing or specular reflections.
  - Class 3B lasers shall have a "Danger" sign posted on the outside of the door.
- Class 4
  - Power exceeds Class 3B limits of 500mW.
  - High-powered lasers and laser systems capable of causing severe eye damage with short-duration exposures (0.25 seconds) to the direct, secularly, or diffusely reflected beam.
  - Can ignite flammable and combustible materials.
  - May produce laser-generated air contaminants or hazardous plasma radiation.
  - Class IV lasers shall have a "Danger" sign posted on the outside of the door.

Note: Class 3B & 4 devices used in Massachusetts must be registered with Radiation Control Program.

Laser Classification Scheme

Class	Basis for classification	Signage
Class 1 SAFE Visible/non visible	Lasers which are safe under reasonably foreseeable conditions of operation. Generally a product that contains a higher laser class system but access to the beam is controlled by engineering means.	**CLASS 1 LASER PRODUCT**
Class 1M SAFE WITHOUT VIEWING AIDS 302.5 to 4000nm	Protection for the eyes is normally provided by the natural aversion response, including the blink reflex, which takes approximately 0.25 seconds. Beams are either highly divergent or collimated but with a large diameter. May be hazardous if optics are used within the beam.	**CLASS 1 LASER PRODUCT**
Class 2 LOW POWER Visible only	For CW lasers, protection of the eyes is normally afforded by the natural aversion response, including the blink reflex, which takes approximately 0.25 seconds. (These lasers are not intrinsically safe) AEL = 1mW for a CW laser.	**LASER RADIATION DO NOT STARE INTO BEAM CLASS 2 LASER PRODUCT**
Class 2M SAFE WITHOUT VIEWING AIDS Visible only	Safe under reasonably foreseeable conditions of operation. Beams are either highly divergent or collimated but with a large diameter. May be hazardous if optics are used within the beam.	**LASER RADIATION DO NOT STARE INTO BEAM CLASS 2 LASER PRODUCT**
Class 3R LOW/MEDIUM POWER 302.5nm to 1mm	Risk of injury is greater than for the lower classes but not as high as for class 3B. Up to 5 times the AEL for Class 1 or Class 2.	**LASER RADIATION AVOID DIRECT EYE EXPOSURE CLASS 3R LASER PRODUCT**
Class 3B MEDIUM/HIGH POWER Visible/non visible	Direct intrabeam viewing of these devices is always hazardous. Viewing diffuse reflections is normally safe provided the eye is no closer than 13cm from the diffusing surface and the exposure duration is less than 10 seconds AEL = 500mW for CW lasers	**LASER RADIATION AVOID EXPOSURE TO BEAM CLASS 3B LASER PRODUCT**
Class 4 HIGH POWER Visible/non visible	Direct intrabeam viewing is hazardous. Specular and diffuse reflections are hazardous. Eye, skin and fire hazard.	**LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION CLASS 4 LASER PRODUCT**

B. Laser Hazards:

1. Beam Hazards:

When laser radiation is incident upon the body, some of the radiation is absorbed by the body tissues. If the radiant exposure is high enough, this can cause injury. The parts of the body the most at risk of injury from laser radiation are the eyes and the skin. The amount of radiation absorbed will depend on wavelength, tissue type, power of the beam, size of the irradiated area, and duration of exposure. The collimated beam of a laser and its high irradiance can result in large amounts of energy being transmitted to very small areas of the eye and skin. Damage to the body is produced by several mechanisms and interactions which include:

- Thermal effects
- Acoustic transients
- Photochemical effects
- Chronic exposure

The eye is the most vulnerable to laser radiation and injuries occur at much lower power levels than for the skin. This is because the human eye is designed to transmit, focus and detect light. Due to the nature of laser radiation, if a beam entering the eye were to fill a fully dilated pupil, the resulting increase in radiant energy falling on the retina compared to that on the front of the eye may be as high as a factor of 500,000. This is known as the 'optical gain'. Exposure to these extremely high levels of energy can cause permanent damage to the eye. Structures of the eye are affected differently, depending on the wavelength of the laser beam. Some wavelengths may be entirely absorbed in the surface of the eye causing damage to the cornea.

2. Non-Beam Hazards:

- **Electrical:** from high voltage power supplies.
- **Chemical:** lasing mediums such as toxic gases/liquids, fume/particulate material generated by the laser process, and ozone generation.
- **Mechanical:** handling heavy workpieces, installation of heavy ancillary equipment such as gas cylinders, and moving machinery.
- **Fire:** Direct and diffuse laser beams from high-power class 4 lasers can ignite certain materials.
- **X-Rays and Electromagnetic Interference:** The interaction of high-energy laser radiation with heavy metals can generate X-rays.
- **Ultraviolet (UV):** UV light produced during metal cutting will burn the cornea, akin to the damage to the eye caused by "welder's flash."

C. Control Measures:

A risk assessment must be carried out in line with the ANSI standards and must be completed by an individual who fully understands the hazards associated with the work being completed to determine control measures that will reduce the risks.

1. Engineering Controls:

Features incorporated by the manufacturer/supplier or added by the user to prevent access to hazardous levels of laser radiation. Engineering controls are hardware controls that will help prevent beam exposure. They decrease human error by making a system more failsafe. Engineering controls include:

- Beam enclosures
- Beam tubes
- Beam stops
- Protective barriers, guards, and panels

- Interlocked access panels, etc.

2. Administrative Controls:
   Administrative and procedural controls are a method or instructions that lay out safe work practices and rules. The following is a list of controls to help decrease the chances of exposure to a laser beam (if applicable to your laser):

   - Standard operating procedures (SOP) and alignment procedures
   - Education and (re)training via CITI Program
   - Authorization of select personnel to operate or be around the laser,
   - Eliminate spectators in a laser laboratory
   - Remove optically enhancing devices from a laser lab (binoculars, microscopes, etc., prescription eyeglasses are not considered enhancing devices).
   - Required protective clothing will be specified and shall be provided to laser workers.
   - Use of the buddy system for laser use is recommended as a safe work practice One responsibility of the laser user is to follow and abide by all laser safety controls.

3. Personal Protective Equipment (PPE):
   Protective eyewear should be appropriate for the power and wavelength of the laser used and the wavelength range and optical density must be marked on the equipment. An assessment of the PPE's suitability in providing the appropriate level of protection should be undertaken by PI.

   Eye protection is required for Class 3B and 4 lasers when engineering and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE. The use of laser-protective eyewear is especially important during alignment procedures since most laser accidents occur during this process. Protective eyewear must be labeled with the absorption wavelength and optical density (OD) rating at that wavelength

4. Laser signage: posted on the doors and must contain:
   - The laser symbol
   - Laser type (ex. Nd: Yag)
   - Safety alert symbol
   - Laser class (ex. 4),
   - Special precautionary instruction (eyewear required, etc.)
   - Signal words;
     - "Danger" used for classes 3R,3B, and 4,
     - "Caution" used for classes 2 and 2M,
     - "Notice" used for the temporary laser-controlled area.

D. Training:

The Principal Investigator for the laboratory must ensure that University staff and students responsible for setting up and using lasers must have received laser safety training provided via the CITI Program. The Principal Investigator must provide training on the practical use of the laser and its auxiliary devices before allowing a staff member or student to use a laser without direct supervision. Undergraduate and postgraduate students who work with lasers under the supervision of an experienced staff member or student must receive a laser safety briefing from the experienced member of the laboratory staff before being permitted to use any laser. Records must be kept of all safety training and briefings.

IV. Roles and Responsibilities:

A. Laser Safety Officer (LSO):

1. Establish and maintain laser safety procedures/local rules.
2. Provide training to members of staff in the safe use of lasers.
3. Audit and inspect laser devices for safety.
4. Assist users with laser risk assessments.
5. Ensure prescribed control measures are implemented and are effective.
6. Investigate incidents and accidents.
7. Post the laboratory doors with the proper laser warning signs.
8. Recommend or approve PPE.
9. Maintain records of laser locations, class, owners, and users as provided by the PIs.

B. Primary Investigator:

1. Register all lasers devices within the laboratory which are required for research use, or are considered greater than class 2, or are considered a laser cutting device. Note: all new lasers require LSO inspection and must be documented for inventory.
2. Notify the LSO of each modified laser and of each laser transferred or disposed.
3. Ensure risk assessments are undertaken for all laser use within their laboratory.
4. Ensure all laser users successfully complete safety training and provide practical training in the laboratory on the safe use of all components of the laser.
5. Maintain an up-to-date laser inventory and list of all laser workers in the laboratory.
6. Provide, implement, and enforce all safety recommendations and requirements for the safe use of lasers by all laser users in the lab and especially those noted in ANSI Standard Z136.1-2014, section 4.3.10.1/.2, p19.
7. Ensure the proper laser warning signs are affixed at all entryways and within the laboratory. (Note: The LSO must be contacted before a laser warning sign is posted on a door or within a laboratory. ANSI standard Z136.1-2000 has specific wording that must appear on laser warning signs.)
8. Ensure there are no uncontrolled reflections or refractions.
9. Ensure the types of beam dumps, safety curtains, or barriers will not catch fire while absorbing the laser energy of interest.

C. Laser Operator Responsibilities

1. Follow laboratory engineering, administrative, alignment, and SOPs.
2. Keep the PI informed of any departure from established safety including all-over exposure incidents.

D. Environmental Health and Safety

1. Conduct periodic laser laboratory/facility inspections to ensure laser safety requirements are met.
2. Aid in evaluating laser hazards: minimizing beam and non-beam hazards.
3. Recommend laser safety controls (administrative, engineering, and PPE).
4. Maintain records of laser locations, class, owners, and users as provided by the PIs.
5. Conduct and or coordinate laser safety training for laser operators and incidental personnel.
6. Investigate accidents involving lasers and follow up as necessary to preclude recurrence

E. Academic Staff:

1. To observe the rules and schemes of work.
2. Recognize and adhere to the laboratory signage and applicable written safety protocols.
3. Leave no laser experiments running unattended.
4. Do not enter areas that contain unfamiliar equipment.