Washington State University – Health Sciences Campuses

Laser Safety Program

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I. Objective

The objective of the Washington State University Health Sciences Laser Safety Program is to provide controls and safety guidance for WSU Health Sciences campus research and educational activities involving lasers. The laser safety policy SPPM 4.50 is based on standards promulgated by Washington Administrative Code (WAC) 296-62-09005, ANSI Z136.1, and applies to all lasers and laser systems, whether purchased, borrowed, fabricated, or brought in for use by others. Refer to SPPM 4.50 for formal guidelines. This section of the Laboratory Safety Manual is meant to provide basic information on laser operation and safety practices only.

II. Assignment of Responsibility

Laser safety is the responsibility of all faculty, staff, and students who are directly or indirectly involved in the use of lasers.

A. Department chair/director

Department chair or director responsibilities include ensuring that the Laser Safety Policy is implemented.

B. Supervisor/principal Investigator (Unit laser safety officer)

The supervisor/principal investigator (PI) is the unit laser safety officer. Supervisor/PI responsibilities include:

1) Review the WSU Laser Safety Guide/Template for units with Class I and II lasers and take specific precautions to ensure the safest workplace possible.
2) Complete, implement, and follow the WSU Laser Safety Guide/Template for units with Class III and IV Lasers. Once complete, the template becomes the unit's written laser safety program.
3) Review and update the unit's laser safety program, as necessary.
4) Complete an Incident Report to report any accident or injury associated with lasers (see SPPM 2.24).

C. Operator

Laser operator responsibilities include:

1) Know the requirements for safe operation of the laser. Follow the safety procedures provided in the laser manufacturer's manual and the WSU Laser Safety Guide/Template or the unit's laser safety program.
2) Perform only those operations and procedures authorize by the supervisor/PI (unit laser safety officer).

3) Restrict access to controlled areas and ensure that only trained or properly escorted personnel are allowed access into controlled areas when lasers are in operation.
4) Report all accidents and injuries to the supervisor/PI.

D. Environmental health & safety (EH&S)

Environmental Health and Safety responsibilities include:

1) Update the WSU Laser Safety Guide/Template as appropriate.
2) Environmental Health and Safety provides copies of the guide/template upon request.
3) Review unit laser safety programs.
4) Assist in determining maximum permissible exposure limits, nominal hazard zones, laser-controlled areas, and proper personal protective equipment (eyewear optical density).
5) Provide training and/or training materials, upon request.

III. Procedures

A. Laser Hazard Classification

To provide a basis for laser safety requirements, all lasers and laser systems in the United States are classified according to the ANSI Z136.1 standard and the Federal Laser Products Performance Standard (FLPPS). The manufacturer is responsible for determining the laser classification. The builder must classify custom-built and modified lasers. The ANSI Z136.1 standard is enforced by the Occupational Safety and Health Administration (OSHA). The Laser Products Performance Standard is enforced by the Centers for Devices and Radiological Health (CDRH), a part of the Food and Drug Administration (FDA). The following section describes the classification for continuous-wave lasers. The same hazard levels also apply to pulsed lasers with pulse duration of less than 0.25 seconds but classification is more complex.

1. Class 1, 1M Lasers

Class 1 lasers are low-powered (less than 1mW) and do not emit hazardous radiation under normal operating conditions because they are completely enclosed. Class 1 lasers are exempt from any control measures. Equipment, such as laser printers and laser disc players, are examples of this class. These lasers may present hazards if the housing is breached for maintenance (See Embedded Lasers).

2. Class 2, 2M Lasers

   Class 2 lasers are visible continuous wave (CW) and repetitive-pulse lasers or laser systems which can emit accessible radiant energy exceeding the appropriate Class 1 AEL but less than 1 mW. The human aversion response or blink reflex, which occurs within 0.25 seconds, provides adequate protection for Class 2 lasers. However, it is possible to overcome the aversion response and stare into the Class 2 laser long enough to damage the eye. Class 2 lasers are typically exempt from control measures other than having a protective housing and label. Equipment such as some visible continuous wave Helium-Neon lasers and some laser pointers are examples of Class 2 lasers.

3. Class 3R Lasers

   Class 3R lasers are systems with power levels of 1 to 5 mW that normally would not produce a hazard if viewed for only momentary periods with the unaided eye. They can pose severe eye hazards when viewed through optical instruments (e.g., microscopes, binoculars, or other collecting optics). Class 3R lasers must be labeled. Equipment, such as some visible continuous wave Helium-Neon lasers and some solid-state laser pointers, are examples of Class 3R lasers. It is recommended that no pointers over Class 3R be used.

4. Class 3B Lasers

   Class 3B lasers are systems with power levels of 5 mW to 500 mW for continuous wave lasers or less than 10 J/cm2 for a 0.25 s pulsed laser. These lasers produce an eye hazard if viewed directly. This includes intrabeam viewing or specular reflections. Higher power lasers in this class will also produce hazardous diffuse reflections. See the specific usage requirements for Class 3B lasers.

5. Class 4 Lasers

   Class 4 lasers are systems with power levels greater than 500 mW for continuous wave lasers or greater than 10 J/cm2 for a 0.25 s pulsed laser. These lasers may produce eye, skin and fire hazards through intrabeam viewing, specular or diffuse reflections and the direct beam itself. See the specific usage requirements for Class 4 lasers for further information.

6. Embedded Laser

   Embedded lasers are found in laser products with lower class ratings. Laser printers, CD players, and laser welders may have Class 3B or Class 4 lasers in their protective and interlocked housings. When such a laser system is used as intended, the lower laser class applies. When such a system is opened (e.g., for service or alignment) and the embedded laser beam is accessible, the requirements for the higher class of the embedded laser must be implemented.

Type	Description	Examples	Beam Hazard
Class 1	Completely enclosed or very low power (0.4 W for visible lasers)	CD player, laser printer	Incapable of causing injury during normal operation.
Class 1M	Completely enclosed or very low power (0.4 W for visible lasers)	Laser scanners, etchers	Incapable of causing injury unless collecting optics are used
Class 2	Visible lasers emitting less than 1mW radiant power	Some laser pointers	Visible lasers incapable of causing injury in .25 seconds.
Class 2M	Visible lasers emitting less than 1mW radiant power	Laser levels, survey equipment	Visible lasers incapable of causing injury in .25 seconds unless collecting optics are used.
Class 3R	1 to 5 mW	Most alignment lasers and laser pointers	Marginally unsafe for intrabeam viewing; up to 5 times the class 2 limit for visible lasers or 5 times the class 1 limit for invisible lasers.
Class 3B	Output power between 5 and 500 mW.	Analytical and research applications, embedded lasers	Eye hazard for intra beam viewing
Class 4	Above 500 mW	Surgical lasers, cutting, welding, research lasers	Eye and skin hazard for both direct and scattered exposure.

B. Laser Safety Hazards

- Improperly used laser devices are potentially dangerous. Effects can range from mild skin burns to irreversible injury to the skin and eye. The biological damage caused by lasers is produced through thermal, acoustical and photochemical processes.

- Thermal effects are caused by a rise in temperature following absorption of laser energy. The severity of the damage is dependent upon several factors, including exposure duration, wavelength of the beam, energy of the beam, and the area and type of tissue exposed to the beam.

- Acoustical effects result from a mechanical shockwave, propagated through tissue, ultimately damaging the tissue. This happens when the laser beam causes localized vaporization of tissue, causing the shockwave analogous to ripples in water from throwing a rock into a pond.

- Beam exposure may also cause photochemical effects when photons interact with tissue cells. A change in cell chemistry may result in damage or change to tissue. Photochemical effects depend greatly on wavelength.

- The following table summarizes the probable biological effects of exposure of eyes and skin to different wavelengths.

Photobiological Spectral Domain	Eye	Skin
Ultraviolet C (200 nm - 280 nm)	Photokeratitis	Erythema (sunburn) Skin Cancer Accelerated skin aging
Ultraviolet B (280 nm - 315 nm)	Photokeratitis	Increased pigmentation
Ultraviolet A (315 nm - 400 nm)	Photochemical cataract	Pigment darkening Skin burn
Visible (400 nm - 780 nm)	Photochemical and thermal retinal injury	Pigment darkening Photosenstive reactions Skin burn
Infrared A (780 nm - 1400 nm)	Cataract and retinal burn	Skin burn
Infrared B (1.4μm - 3.0 μm)	Corneal burn, aqueous flare, cataract	Skin burn
Infrared C (3.0 μm - 1000 μm)	Corneal burn only	Skin burn

C. Laser Usage Requirements

1. General Requirements

- Class 1 and 2 lasers may be used for the intended purposes of their manufacturer without restrictions. Any direct eye exposure to these types of lasers should be avoided.
- Class 3R, Class 3B, and Class 4 shall carry a warning label containing the laser classification, type, and other warnings required by ANSI Z136.1 or assign an equivalent level by the builder. These requirements also apply to non-commercially built lasers that are used at Washington State University campuses.
- All laser operators must complete training specific to the type of laser they operate.
- All lasers must be operated according to the applicable ANSI Z136.1 safety standards and in a manner consistent with safe laser practices. Laser Safety Standard Operating Procedures (SOPs) are required for Class 3B lasers and for all Class 4 lasers.
- Each Class 3B and Class 4 laser shall be used in a controlled area that restricts access to unauthorized personnel. The controlled laser areas must be posted with appropriate warning signs.
- Each operator of a Class 3B or Class 4 laser must wear protective equipment (e.g., eye wear and clothing) as appropriate.

2. Engineering Controls

All lasers require a protective housing. All Class 3B and Class 4 lasers must be equipped with engineered safety features such as:

- Protective housing interlock system that prevent emission of laser radiation when the housing is open.
- Viewing portals in the protective housing must be equipped with filters and attenuators that keep escaping light below the Maximum Permissible Exposure (MPE) limit.
- Optical instruments for viewing the laser system must be equipped with filters and attenuators and interlocks to keep exposures below the MPE limit for all conditions of operation and maintenance.
- Class 4 lasers shall also be equipped with a removable master key switch if provided by the manufacturer. The laser shall not be operable when the key is removed.
- The lasers should be equipped with electrical connections that allow for an access control system and remote shut-off devices. When the terminals are open-circuited, the laser must not emit any radiation in excess of the MPE. Class 4 laser systems must be equipped with an integral and permanently attached beam stop or attenuator capable

of preventing the emission of laser light in excess of the MPE limit when the beam is not required.

3. Class 3B and 4 Laser-Controlled Area

The following items are required for Class 3B laser-controlled areas:

- Posted with the appropriate warning sign(s).
- Operated by qualified and authorized personnel.
- Under the direct supervision of an individual knowledgeable in laser safety.
- Have any potentially hazardous beam terminated in a beam stop of an appropriate material.
- Have only diffuse reflective materials in or near the beam path, where feasible.
- Have personnel within the controlled area provided with the appropriate eye protection if there is any possibility of viewing the direct or reflected beams.
- Have the laser secured such that the beam path is above or below eye level of a person in any standing or seated position, except as required for medical use.
- Have all windows, doorways, open portals, etc. from an indoor facility be either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the appropriate ocular MPE.
- Require storage or disabling (for example, removal of the key) of the laser or laser system when not in use to prevent unauthorized use.

In addition to the items listed for Class 3B areas, the following are required for Class 4 lasers:

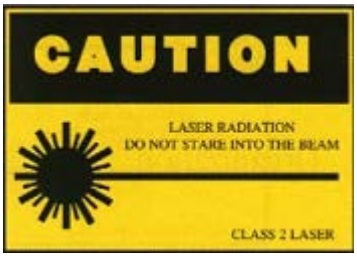
- Personnel who enter a Class 4 controlled area during laser operation shall be adequately trained, provided with appropriate protective equipment, and follow all applicable administrative and procedural controls.
- Class 4 area/entryway safety controls shall be designed to allow both rapid egress by laser personnel at all times and admittance to the laser-controlled area under emergency conditions.
- For emergency conditions there shall be a clearly marked “Panic Button” (remote controlled connector or equivalent device) available for deactivating the laser or reducing the output to the appropriate MPE levels.
- Area or entryway safety controls to deactivate the laser or reduce the output to the appropriate MPE levels in the event of unexpected entry into the laser-controlled area.

- These controls may be non-defeatable, defeatable or procedural as determined by the LSO.
- Temporary Laser Controlled Area

Where removal of panels or protective housings, over-riding of protective housing interlocks, or entry into the NHZ becomes necessary (such as for maintenance and service) a temporary laser-controlled area shall be set up. The temporary laser-controlled area shall be posted on the outside with a Notice sign and with the appropriate warning sign (Class 3B or Class 4) inside the controlled area to warn of the potential hazard.

D. Warning Labels and Signs

ANSI Z136.1 requires that lasers and laser systems have appropriate warning labels and that the areas in which they operate be posted with appropriate warning signs. For further information contact EH&S at 509-335-3041. The figures below are examples of laser warning signs:



E. Laser safety training

- All Class 3B or Class 4 laser users are required to complete laser safety training. EH&S is available to assist with development of your laboratory specific training programs and offers templates, guides and canned presentations for adaption to your needs.
- In addition, all laser operators must be trained on the usage of each specific laser to be used. The Principal Investigator, vendor, or other qualified individual may provide this training. Records of this training must be maintained.
- Before operating a Class 3B, Class 4 laser, or an embedded Class 3B or Class 4 laser with the protective housing removed, a person must:
- Review the Laser Safety Guide for that laboratory.
- Receive from the Principal Investigator a thorough review of the laser equipment to be used and the administrative requirements, alignment procedures and applicable SOPs.
- Review the operating and safety instructions furnished by the manufacturer.
- Utilize appropriate personal protective equipment.

F. Personal Protective Equipment

In addition to engineering and administrative controls, personal protective equipment for skin and/or eyes is often necessary when working with Class 3B or Class 4 lasers.

1. Eye Protection

   Eye protection suitable to the laser must be provided and worn within the laser control area if there is a potential for exceeding the MPE limit if the beam is viewed. Protective eyewear may include goggles, face shields, spectacles or prescription eyewear using special filter materials or reflective coatings.

   No single type of eyewear will provide protection against all wavelengths of laser radiation; therefore, eye protection should:
   - Provide enough visibility to move about safely.
   - Be able to withstand the maximum power of laser radiation likely to be encountered.
   - Be able to absorb the specific wavelength of radiation that is being used.
   - Be clearly labeled with wavelength they are designed for, the optical density at that wavelength, together with the maximum power rating.
   - Be inspected periodically by the laser operator to ensure that pitting, cracking and other damage will not endanger the wearer.

Lasers that can be tuned through a range of wavelengths present special problems. Broad band laser goggles may provide the level of protection required but they must be chosen with great care. Contact EH&S for assistance with choosing the correct protective equipment.

2. Skin Protection

   - Skin injuries from lasers primarily fall into two categories: thermal injury (burns) from acute exposure to high power laser beams and photochemically induced injury from chronic exposure to scattered ultraviolet laser radiation.
   - Thermal injuries can result from direct contact with the beam or specular reflections. These injuries (although painful) are usually not serious and are normally easy to prevent through proper beam management and hazard awareness.
   - Photochemical injury may occur over time from ultraviolet exposure to the direct beam, specular reflections, or even diffuse reflections. The effect can be minor or severe sunburn, and prolonged exposure may promote the formation of skin cancer. Proper protective eyewear and clothing may be necessary to control UV skin and eye exposure.

- 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 the laser is running in the ultra-violet. Very large peak powers with pulsed ultra-violet laser can be particularly dangerous.
- Other protective equipment includes window drapes designed to prevent the escape of the laser beam outside of the room that it is in. The type of drape used must be appropriate to the laser. Some laser beams such as that from a CO2 laser do not penetrate glass and therefore do not require the use of window drapes.
- Contact EH&S for further information on protective equipment.

NOTE: All employees required to wear personal protective equipment must undergo a certified hazard assessment for PPE use and receive specific PPE training per Washington State Department of Labor and Industries regulations. This assessment and training is the responsibility of the individual PI/lab supervisor. Please contact EH&S for further information.

G. Exposure Incident

- If an exposure incident occurs, the affected individual(s) must inform their supervisor and an Online Incident Report Form must be completed and submitted online within 24 hours. Failure to do so may result in a denial of the claim. If the incident occurs outside of regular clinic hours, individual(s) should be seen at the Emergency Room. A Supervisor's Accident Investigation Report may also be necessary.

H. Definitions

Aversion Response (Blink Response) – The closure of the eyelid or movement of the head to avoid exposure to a noxious stimulant of bright light. It generally occurs within 0.25 seconds, which includes 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 that is operated with a continuous output for a period of 0.25 seconds or greater 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 spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

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

Fail-Safe Interlock – An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

Infrared Radiation – Electromagnetic radiation with wavelengths that lie within a range of 700 nm to 1 mm.

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

Irradiance (E) – Radiant power incident per unit area upon a surface, expressed in watts per square centimeter (W/cm^2).

Laser – Light Amplification by Stimulated Emission of Radiation. A device that produces an intense, coherent, directional beam of light by stimulated emission of electronic or molecular transitions to lower energy levels.

Laser Operator – An individual who has met all applicable laser safety training and approval requirements for operating a laser or laser system.

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

Nominal Hazard Zone (NHZ) – 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 (Di) – Logarithm to the base ten of the reciprocal of the transmittance: $Di = \log T$, where T is the transmittance.

Power – The rate at which energy is emitted, transformed, or received in Watts/second or Joule/second. Also called the radiant power.

Principal Investigator – The individual who is responsible for the laboratory space.

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 less than 0.25 seconds.

Q-Switched Laser – A laser that emits short (~30 nanoseconds), high-power pulses by means of a Q-switch. A Q-switch produces very short, intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Radiant Exposure (H) – Surface density of the radiant energy received (Joules/cm^2).

Radiant Flux (F) – Power emitted, transferred, or received in the form of radiation, expressed in Watts (also called radiant power).

Repetitively Pulsed Laser – A laser with multiple pulses of radiant energy occurring in sequence with a frequency of 1 Hz.

Specular Reflection – A mirror-like reflection typically resulting from a shiny, flat surface.

Standard Operating Procedure (SOP) – A set of operating instructions. The procedure specifies measures which, if followed, will ensure safe and correct use or performance of a task or procedure (such as operating a laser or laser system, or use of a chemical).

Transmittance – The ratio of total transmitted radiant power to the total incident radiant power.

Ultraviolet Radiation (Light) – Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of laser safety, 180 nm to 400 nm.

Visible Radiation (Light) – Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range of 400 nm to 700 nm.

Watt – The unit of power or radiant flux. 1 watt = 1 Joule per second.

Wavelength – The distance between two successive points on a periodic wave that have the same phase.