Laser Safety Guideline

**APPROVAL:**

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<th>Approval/signature on file</th>
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<tr>
<td>EH&amp;S Manager</td>
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<td>Approval/signature on file</td>
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<tr>
<td>Chair, Institution Safety Committee</td>
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Date
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1. INTRODUCTION

The acronym LASER stands for Light Amplification by Stimulated Emission of Radiation. A laser is a device which when energized can emit a highly collimated beam of extremely intense monochromatic electromagnetic radiation. The intensity of the radiation that may be emitted and the associated potential hazards depend upon the type of laser, the wavelength of the energized beam, and the proposed uses of the laser system.

The safe use of laser systems depends upon the basic principles of safety: recognition, evaluation, and control of potential hazards. This guideline describes roles and responsibilities, laser registration, medical evaluation, laser hazards, and required hazard controls. This guideline applies to all PIs/supervisors, operators, and users of class 3b and 4 laser systems.

2. ROLES AND RESPONSIBILITIES

A. Laser Safety Officer (LSO)

The LSO is the EH&S Manager. The LSO has the following responsibilities:

- Oversees the WHOI laser safety program and maintains this Guideline.
- Performs periodic Laser safety inspections and identifies recommendations on laser hazards and controls, including protective eyewear required for the laser system being used and designation of nominal hazard zone (NHZ).
- Conducts laser safety training for laser workers.
- Coordinates baseline (pre-assignment) eye examinations.
- Investigates accidents involving laser systems and recommends corrective actions.
- Provides guidance for the registration of new installations, including transfer and decommissioning of lasers and laser systems.

B. PI/Supervisor

Each PI/Supervisor who has a Class 3b or 4 laser has the following responsibilities:

- Complying with the requirements of this Guideline.
- Informing the LSO of new laser installations or major changes within a laser installation, such as relocation or modification.
- Ensuring that laser workers are trained and obtain required eye examinations.
- Ensuring that the laser installation meets WHOI and Commonwealth of Massachusetts Laser Safety standards. Provide the necessary equipment and work environment for the safe use of lasers.
- Developing and posting standard operating procedures (SOPs) for Class 3b and 4 laser system(s) that are operational (see Appendix H for procedure template).
- Registration of all Class 3b and Class 4 laser systems with the Commonwealth of Massachusetts Department of Public Health - Radiation Control Program. Registration forms are available at the EH&S office.
C. Laser Users/Operators

All users and operators of Class 3b and 4 lasers are responsible for:

- Complying with all applicable requirements of this Guideline.
- Properly using all required protective equipment and obtaining laser eye exams.
- Conducting all laser activities in accordance with standard operating procedures, this guideline, and manufacturer’s recommendations.

3. LASER REGISTRATION

Managers and/or supervisors are responsible for registering all Class 3b and Class 4 lasers with the Commonwealth of Massachusetts Department of Public Health – Radiation Control Program, prior to operating these lasers. The registration forms are available from the EH&S office.

4. LASER SAFETY TRAINING

All persons working with Class 3b and Class 4 lasers are required to receive general laser safety training by the EH&S office. Laser-specific training is the responsibility of the cognizant PI/supervisor.
Appendix A - Definitions

Some definitions that may be applicable to this guideline are listed below. Additional definitions are available in ANSI Z136.1 (2000) and elsewhere.

**Absorption.** Transformation of radiant energy to a different form of energy by interaction with matter.

**Accessible emission limit (AEL).** The maximum accessible emission level permitted within a particular class.

**Attenuation.** The decrease in the radiant flux as it passes through an absorbing or scattering medium.

**Average power.** The total energy imparted during exposure divided by the exposure duration.

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

**Beam.** A collection of rays which may be parallel, divergent, or convergent.

**Beam diameter.** The distance between diametrically opposed points in that cross-section of a beam where the power per unit area is I/e (0.368) times that of the peak power per unit area.

**Coherent light.** Radiation in which there is a fixed phase relationship between any two points in the electromagnetic field. Coherence is a measure of the degree to which the emitted waves remain in phase.

**Continuous wave (cw).** The output of a laser which is operated in a continuous rather than a pulsed mode. In this program, a laser operating with a continuous output for a period of 0.25s 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 radiation hazards.

**Cornea.** The transparent outer coat of the human eye which covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

**Diffuse reflection.** A reflection from a “rough” surface that causes the incident radiation to reflect randomly in all directions.

**Diffraction.** Deviation of part of a beam determined by the wave nature of radiation and occurring when the radiation passes the edge of an opaque obstacle.

**Electromagnetic radiation.** The transport of energy in the form of electric and magnetic fields. X-ray, ultraviolet, visible and infrared radiation, and radio waves occupy various portions of the electromagnetic spectrum and differ in frequency, wavelength, and energy.

**Irradiance (E) (at the point of a surface).** Quotient of the radiant flux incident on an element of surface containing the point at which irradiance is measured, by the area of that element. Units are watt per square centimeter (W/cm²).

**Laser.** A device which produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. An acronym for Light Amplification Stimulated by Emission of Radiation.
Maximum permissible exposure (MPE). The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

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

Nominal ocular hazard distance (NOHD). The distance along the axis of the unobstructed beam from the laser to the human eye beyond which the irradiance or radiant exposure during normal operation is not expected to exceed the appropriate MPE.

Protective housing. An enclosure that surrounds the laser or laser system that prevents access to laser radiation above the applicable MPE level. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated optics and a work station and shall limit access to other associated radiant energy emissions and to electrical hazards associated with components and terminals.

Pulse duration. The duration of a laser pulse: usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.

Pupil. The variable aperture in the iris through which light travels to the interior of the eye.

Q-switch. A device for producing very short (<250ns) high power pulses.

Specular reflection. A mirror-like reflection.

Spectator. An individual who observes a laser or laser system in operation and also may lack appropriate laser safety training.
Appendix B - Laser Radiation Hazards

Review of repeated incidents have demonstrated that accidental eye and/or skin exposures to laser radiation and accidents related to the ancillary hazards of a laser or laser system, are most often associated with personnel involved with the use of these systems under the following conditions:

- Unanticipated eye exposure during alignment
- Misaligned optics
- Available eye protection not used
- Equipment malfunction
- Improper method of handling high voltage
- Operator unfamiliar with laser equipment
- Lack of protection for ancillary hazards
- Improper restoration of equipment following service
- Inadvertent beam discharge
- Insertion of flammable materials into beam path

The basic hazards associated with the use of lasers are categorized as follows:

1. **Skin & Eye:** Corneal or retinal burns are possible from acute exposure. Location and extent of injury is dependent upon wavelength and classification of laser. Corneal opacities (cataracts) or retinal injury may be possible from chronic exposures to excessive levels. Eye hazards are easily controlled with the use of appropriate laser safety eyewear or engineering safety controls, such as enclosures and barriers. Skin burns are possible from acute exposure to high levels of laser radiation in the infrared spectral region. Erythema (sunburn), skin cancer, and accelerated skin aging are possible in ultraviolet wavelength range.

2. **Electrical Hazards:** The most common hazard encountered in laser use is electric shock. Potentially lethal electrical hazards may be present, especially in high powered laser systems.

3. **Chemical Hazards & Airborne Contaminants:** Some material used in laser systems (excimer, dye, chemical lasers) may be hazardous or toxic. Laser generated air contaminants may be produced when certain Class 3b and 4 beams interact with matter. Exposure controls, such as local exhaust ventilation, may be required.

4. **Fire Hazards:** Solvents used in dye lasers may be extremely flammable. Ignition may occur via high voltage pulses or flash lamps. Direct beams and unforeseen specular reflections of high-powered CW infrared lasers are capable of igniting flammable materials during laser operation. Other potential fire hazards are electrical components and the flammability of Class 4 laser beam enclosures.

5. **Associated Hazards:** Associated hazards can include cryogenic coolant hazards, excessive noise from high-powered systems (e.g., capacitor bank discharges), and radiation from high-voltage power supplies. Whenever potentials in excess of 15 kV exist in a vacuum, x-ray radiation outside the enclosure should be evaluated.
Appendix C - Eye Protection & Exposure Limits

Laser irradiation of the eye may cause damage to the cornea, lens, or retina, depending on the wavelength of the light and the energy absorption characteristics of the ocular media. Lasers cause biological damage by depositing heat energy in a small area, or by photochemical processes. Infrared, ultraviolet, and visible laser radiation can cause damage to the eye.

1. Retinal Damage--Visible and Near Infrared (Spectral Region 400-1400nm)

Visible wavelengths penetrate through the cornea to be focused on a small area of the retina, the fovea centralis. This process greatly amplifies the energy density and increases the potential for damage. Lesions may form on the retina as a result of local heating of the retina, subsequent to absorption of the light.

2. Corneal Damage--Infrared (Spectral Region 1400 nm to 1mm)

The cornea of the eye is opaque to infrared radiation. The energy in the beam is absorbed on the surface of the eye and damage results from heating of the cornea. Excessive infrared exposure causes a loss of transparency or produces a surface irregularity on the cornea.

3. Corneal Damage--Ultraviolet (Spectral Region 180-400nm)

The cornea of the eye is also opaque to ultraviolet radiation. As with infrared radiation, the energy of the beam is absorbed on the surface of the eye and corneal damage results. Excessive ultraviolet exposure results in photokeratitis (Welder’s Flash), photophobia, redness, tearing, conjunctival discharge, and stromal haze. There is a 6-12 hour latency period before symptoms of photochemical damage appear.

4. Other Ocular Damage

There are two transition zones between the corneal hazard and retinal hazard spectral regions. These are located at the bands separating UV and visible, and near infrared and infrared regions. In these regions, there may be both corneal and retinal damage. This wavelength can be focused by the eye but not perceived by it. Damage can thus be done to the retina in the same manner as visible light, even though the beam itself remains invisible.

5. Maximum Permissible Exposure (MPE)

On the basis of retinal damage thresholds and concentrations of light by the lens, maximum permissible exposure limits have been recommended by the American National Standards Institute (ANSI Z136.1-2000). The MPE values are set below known hazardous levels; however, the MPE values may be uncomfortable to view. Thus, it is good practice to maintain exposure levels as far below the MPE values as practical.

6. Protective Eyewear

ANSI Z136.1-2000 requires that properly selected protective eyewear be available and worn whenever hazardous conditions may result from laser radiation or laser related operations. The following criteria should be considered when selecting protective eyewear:

- The eye may be protected against laser radiation by the use of protective eyewear that attenuates the intensity of laser light while transmitting enough ambient light for safe visibility (luminous transmission).
• The ideal eyewear provides maximum attenuation of the laser light while transmitting the maximum amount of ambient light.
• No single lens material is useful for all wavelengths or for all radiation exposures. In choosing protective eyewear, careful consideration must be given to the operating parameters, MPEs, and wavelength.
• Persons working with lasers emitting in the visible region may be hesitant to wear protective eyewear during alignment procedures due to the inability to see the beam. Laser alignment goggles are available which provide acceptable protection during reduced power alignment procedures while allowing an outline of the beam to be seen.
• The laser manufacturer should be contacted regarding the recommended protective eyewear. Various laser protective eyewear vendors can also recommend the proper protective eyewear, based on the laser classification and operating parameters. The Laser Institute of America’s web site lists some laser safety vendors: www.laserinstitute.org.

7. Skin Exposure and Maximum Permissible Exposures

Acute exposure of the skin to large amounts of energy from the laser may cause burning. These burns are similar to thermal or radiant (sun) burns. The incident radiation is converted to heat which is not dissipated rapidly enough due to poor thermal conductivity of the tissue. The resulting local temperature rise causes denaturation of tissue protein. Injury of the skin depends on the wavelength of laser light, exposure time, and degree of skin pigmentation. The risk of developing skin cancer may increase with chronic exposure to ultraviolet radiation.
Appendix D - General Safety Procedures & Laser Classes

General laser safety guidelines:

- Do not work with or near a laser unless you have been authorized to do so.
- Do not enter a room where a laser is energized or where laser warning sign is illuminated, unless authorized.
- Before energizing a laser, verify that prescribed safety devices for the unit are being properly employed. These may include opaque shielding, non-reflecting and/or fire-resistant surfaces, goggles and/or face shields, door interlocks, and ventilation for toxic material.
- Make sure that a pulsed laser unit cannot be energized inadvertently. Discharge capacitors and turn off power before leaving the laser unit unattended.
- Don’t stare directly into the laser beam. Use appropriate eyewear during beam alignment and laser operation. Beam alignment procedures should be performed at lowest practical power levels.
- Control the access to the laser facility. This can be done by clearly designating trained personnel to have access to the laser room. Access can be controlled by locking the door and installing warning lights and signs on the outside door.
- Never leave the laser unattended when it is in operation.
- Remove any jewelry to avoid inadvertent reflections.

Laser Classification Summary:

The American National Standards Institute (ANSI) has established a laser hazard classification system in publication ANSI Z136.1-2000. Laser manufacturers are required to proper label their laser devices with the laser class.

<table>
<thead>
<tr>
<th>Laser Class</th>
<th>Hazard Description</th>
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<tbody>
<tr>
<td>Class 1</td>
<td>Cannot produce hazardous radiation</td>
</tr>
<tr>
<td>Class 2</td>
<td>Continuous intrabeam exposure can damage eye. Output power does not exceed 1 mW and eye protection is normally afforded by the natural blink reflex time (0.25 seconds). Direct viewing of class 2 laser radiation is prohibited.</td>
</tr>
<tr>
<td>Class 3a</td>
<td>The normal aversion response is generally sufficient to prevent injury from inadvertently viewing the laser output with unaided eye. CAUTION: the normal aversion response is not effective for invisible lasers, such as ultraviolet or infrared. Eye damage may occur if the beam is viewed with collecting optics. Output power is 1-5 mW.</td>
</tr>
<tr>
<td>Class 3b</td>
<td>Eye damage can occur from direct, momentary intrabeam exposure, or exposure to specular reflections. The normal aversion response will not protect the eye from injury. Output power is 5-500 mW.</td>
</tr>
<tr>
<td>Class 4</td>
<td>Eye and skin damage can occur from exposure to direct, momentary intrabeam, specular reflections, and diffuse reflections. Potential fire hazard.</td>
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Class 3b denotes lasers or laser systems that can produce a hazard if viewed directly for any period of time. This includes the viewing of specular reflections.

- Do not aim the laser at an individual’s eye. Permit only experienced personnel to operate the laser. Control spectators.
• Enclose as much of the beam path as possible. Even a transparent enclosure will prevent individuals from placing their head or reflecting objects within the beam path. Terminations should be used at the end of the useful paths of the direct beam and any secondary beams.

• Shutters, polarizers and optical filters should be placed at the laser exit port to reduce the beam power to the minimal useful level.

• A laser warning light is required outside of the laser use area, i.e., at all laser area entrances.

• Operate the laser only in a controlled access area (e.g., dedicated space) that can be secured.

• Place the laser beam path well above or well below the eye level of any sitting or standing observers whenever possible. The laser should be mounted securely to assure that the beam travels only along its intended path.

• Always use proper laser eye protection if a potential eye hazard exists for the direct beam or a specular reflection. A key switch should be installed to minimize tampering by unauthorized individuals.

• The beam or its specular reflection should never be directly viewed with optical instruments such as binoculars or telescopes without sufficient protective filters.

• Remove all unnecessary mirror-like surfaces from the vicinity of the laser beam path. Do not use reflective objects such as credit cards to check beam alignment.

Class 4 denotes lasers or laser systems that produce a hazard not only from direct or specular reflections, but may produce hazardous diffuse reflections. Such lasers may present significant skin and fire hazards as well. These high-power lasers are used in research laboratories and access to these laboratories must be controlled to permit only authorized personnel.

• All controls listed for Class 3b laser systems also apply to Class 4 lasers.

• These lasers should only be operated within a localized enclosure, or in a controlled workplace, or where the beam is directed into outer space. If a complete local enclosure is not possible, indoor laser operation should be in a light-tight room with interlocked entrances to assure that the laser cannot emit energy while a door is open.

• Appropriate eye protection is required for all individuals working within the controlled area.

• If the laser beam irradiance is sufficient to be a serious skin or fire hazard, a suitable shielding should be used between the laser beam and any personnel or flammable surfaces. Remote firing with video monitoring or other remote (safe) viewing techniques should be chosen when feasible.

• Outdoor high-power laser devices such as satellite laser transmission systems and laser radar should have positive stops on the azimuth and elevation traverse to assure that the beam cannot intercept occupied areas.

• Beam shutters, beam polarizers, and beam filters should always be used to limit use to authorized personnel only. The flashlamps in optical pump systems should be shielded to eliminate any direct viewing.

• Backstops should be diffusely reflecting and use fire resistant target materials where feasible. Safety enclosures should be used around microwelding and microdrilling work pieces to contain hazardous reflections from the work area. Microscopic viewing systems used to study the work piece should insure against hazardous levels of reflected laser radiation back through the optics.
Appendix E – Example Laser Caution & Danger Signs

Figure A: Sample warning sign for Class 2 and certain Class 3a lasers. Position 1 states precautionary or protective instructions. Position 2 describes the type of lasers, emitted wavelength, maximum output, and pulse duration if applicable. From ANSI Z136.1-1993 Figure 1a.

![Sample warning sign for Class 2 and certain Class 3a lasers.](image)

Figure B: Sample warning sign for certain Class 3a lasers and for Class 3b and Class 4 lasers. Position 1 states precautionary or protective instructions. Position 2 describes the type of lasers, emitted wavelength, maximum output, and pulse duration if applicable. From ANSI Z136.1-1993 Figure 1b.

![Sample warning sign for certain Class 3a lasers and for Class 3b and Class 4 lasers.](image)

Figure C: Sample Temporary Laser Controlled Area sign. This sign shall be posted outside a temporary controlled area for example, during periods of service. The area outside the temporary controlled area remains Class 1, while the area within is either Class 3b or Class 4. From ANSI Z136.1-1993, section 4.7.4.3 and Figure 1d.

![Sample Temporary Laser Controlled Area sign.](image)
Appendix F - Laser Eye Exams

- Laser eye exam requirements apply to all operators and users of Class 3b and 4 lasers. Contact the EH&S office (x2244) for the recommended laser eye exam facility.

- Pre-assignment Medical Exams

  The pre-assignment medical exam is conducted to establish a baseline against which ocular damage may be measured. The exam should meet applicable criteria from ANSI Z136.1-2000, including the specific laser radiation wavelength, ocular histories, visual acuity measurement and selected examination protocols.

  These examinations shall be performed by, or under the supervision of an ophthalmologist, according to ANSI Z136.1-2000. Records of these results shall be maintained in the individual’s medical file.

- Periodic & Termination Eye Examination

  Periodic and termination eye examinations are not required for laser workers.

- Incident-Related Eye Exams

  In the event of any accidental or suspected eye exposure to laser radiation, a thorough eye examination shall be conducted as specified in ANSI Z136.1-2000. Records of these results shall be maintained in the individual’s medical file.
# Appendix G – Examples Laser Safety Inspection Form

**Laser Supervisor:**

**Bldg. and Room:**

**Person(s) Interviewed:**

**Laser class/model:**

**Serial Number(s):**

## Laser Safety Checklist

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<th>Requirement</th>
<th>OK</th>
<th>NI</th>
<th>Recommendation/Comments</th>
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<tbody>
<tr>
<td>ANSI Signs/Labels</td>
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<tr>
<td>Shielding/Barriers</td>
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<tr>
<td>Control of Room Access</td>
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<tr>
<td>Warning Device when Energized</td>
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<tr>
<td>Interlock System</td>
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<td>Eye Protection</td>
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<tr>
<td>Room Illumination</td>
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<td>Reflective Surfaces in Room</td>
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<tr>
<td>Personnel Trained</td>
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<tr>
<td>Other Hazards (electrical, air contaminants, etc):</td>
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<tr>
<td>Written Standard Operating Procedure (SOP) for each Class 3b and Class 4 laser</td>
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<tr>
<td>All lasers registered with Mass DPH</td>
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<tr>
<td>Comments:</td>
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**Conducted By & Date:**

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**OK** = Adequate control or safeguard  
**NI** = Needs Improvement
Only authorized and trained users may operate the laser

Powering laser on (must be done ~30 minutes prior to use)
1. Make sure laser shutter is closed (set to “0”)
2. Make sure power strip is ON
3. Turn key on back of laser unit to power ON

Using laser
1. Turn on external laser sign (switch next to lab door)
2. Verify laser sign is illuminated
3. Shut and lock lab door
4. Pull the laser curtains to shield the doorway from the laser
5. Put on protective eye wear
6. Be aware of where exiting beam will hit
7. Open laser shutter (set to “1”)
8. If Mark II probe head is being used, open probe head shutter

NOTE: Laser shutter must be turned off when connecting or disconnecting the excitation fibers from the laser or the probe head.

Powering laser off
1. If Mark II probe head is being used, close probe head shutter
2. Close laser shutter (set to “0”)
3. Turn key on back of laser unit to power OFF
4. Remove protective eye wear, pull back curtains, turn off laser sign

Authorized Users:

Name: Name:
Signature: Signature:
Name: Name:
Signature: Signature: