Marine Biological Laboratory

THE UNIVERSITY OF CHICAGO

LASER SAFETY MANUAL

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TABLE OF CONTENTS

1 INTRODUCTION

The Marine Biological Laboratory (MBL) uses lasers and laser systems, which are an integral part of the academic and research environment. Lasers are extraordinary research tools that enable scientists to perform novel experiments and explore innovative applications that may lead to pioneering scientific discovery.

The LASER (**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation) produces an intense, highly directional beam of light. If lasers are used incorrectly or laser hazards are not effectively controlled, laser radiation can cause serious injury to the eye and skin. The MBL is committed to taking all reasonable control measures to protect faculty, staff, students, and the MBL Community from exposure to laser radiation hazards, and ensure compliance with all applicable federal, state and local laws and regulations.

1.1 Purpose

The MBL's Laser Safety Program provides guidance for the safe use of lasers and laser systems in research and teaching laboratories. The policies and procedures outlined in the Laser Safety Manual are based upon the ***American National Standards Institute (ANSI) Standard for Safe Use of Lasers (ANSI Z136.1-2014).***

All individuals installing, operating, using, maintaining, repairing, or servicing lasers or laser systems at the MBL are required to follow best practices in laser safety described in ANSI Z136.1-2014, and all applicable federal, state and local laws and regulations.

All Principal Investigators and Course Directors/faculty members working with Class 3B and Class 4 lasers or laser systems should keep a current copy of the Laser Safety Manual, and make it readily available to all Laser Users in their approved laser controlled area or laboratory.

1.2 Scope

The Laser Safety Program applies to all persons working with Class 3B or Class 4 lasers or laser systems in research and teaching laboratories at the MBL. They include Principal Investigators/Senior Scientists, Course Directors/faculty members, MBL Fellows, visiting scholars, interns, and students.

1.3 Laser Safety Manual Review

The Laser Safety Officer (LSO) shall review the Laser Safety Manual for effectiveness and update it, as needed. The LSO may also seek input from Authorized Laser Users, experienced laser users, or affiliated partners.

2 LASER SAFETY PROGRAM ORGANIZATION

The Laser Safety Program organization at the MBL consists of the Radiation Safety Committee (RSC), LSO, Principal Investigators or Course Directors (Authorized Laser Users), and Laser Operators (Users). The RSC is responsible for ensuring compliance with all applicable federal, state and local laws and regulations involving both ionizing and non-ionizing radiation, including safe use of laser radiation.

The RSC is responsible for providing oversight of the Laser Safety Program at the MBL. The Committee shall establish and maintain reasonable policies and procedures for the evaluation and control of laser hazards, including recommendations for appropriate laser safety training program and materials. The RSC shall review and approve or disapprove all applications for authorization to use Class 3B and Class 4 lasers or laser systems at MBL. The RSC has authority to suspend, restrict, or terminate the operation of a laser or laser system if it is judged that the laser hazard controls are inadequate.

The RSC membership includes the RSO and MBL scientists or faculty members who are knowledgeable in the use of ionizing and non-ionizing radiation sources. The Committee may seek advice from researchers or faculty members with expertise in laser technology or in laser hazard assessment.

The LSO is responsible for ensuring that the policies and guidelines established by the Committee are implemented. The LSO is also responsible for informing the Committee of any compliance issues at the MBL. The LSO is authorized to terminate any activity or process that presents an immediate danger to life or health.

3 ROLES AND RESPONSIBILITIES

3.1 Radiation Safety Committee

The key responsibilities of the RSC include:

- Maintain awareness of all new or revised federal, state and local regulations and ANSI standards on laser safety.
- Review and approval of the use of Class 3B and Class 4 lasers or laser systems for research and teaching purposes at the MBL.
- Establish and review institutional policies and procedures for the control of laser hazards in research and teaching laboratories to ensure compliance with applicable state and federal regulations.
- Review the annual audit reports of the Laser Safety Program conducted by the LSO, and recommend reasonable solutions to correct any deficiencies.
- Review any injuries, accidents, or incidents involving lasers or laser systems and recommend corrective actions to prevent recurrence.

3.2 Laser Safety Officer

The specific duties and responsibilities of the LSO include:

- Develop and coordinate implementation of the Laser Safety Program.
- Maintain inventory of all Class 3B and Class 4 lasers or laser systems.
- Register all Class 3B and Class 4 lasers or laser systems with the Massachusetts Department of Public Health, Radiation Control Program.
- Classify or verify classifications of lasers or lasers systems used at MBL.
- Provide Laser Safety Training for faculty, staff, and students working with Class 3B and Class 4 lasers or laser systems.
- Conduct hazard evaluations of work areas where Class 3B and Class 4 laser or laser system are installed.
- Conduct periodic safety inspections and annual audits of all laser laboratories and facilities.
- Provide and post ANSI-approved warning signs and labels at laser controlled areas.
- Recommend or approve PPE (e.g., laser protective eyewear, clothing, barriers, and screens).
- Review and approve Standard Operating Procedures (SOPs), Alignment Procedures, and other administrative control measures for Class 3B and Class 4 lasers.
- Liaise with the Massachusetts Department of Public Health, Radiation Control Program on matters relating to MBL's Laser Safety Program.
- Investigate laser accidents and incidents.
- Review and update the Laser Safety Manual, as appropriate.
- Maintain records required by applicable federal, state and local regulations.

3.3 Principal Investigator

The Principal Investigator (PI) has the ultimate responsibility for ensuring the safe use of lasers or laser systems within their research or teaching laboratory.

- Notifying the LSO when purchasing, acquiring, or disposing of Class 3B or Class 4 lasers or laser systems.
- Submit a **LASER REGISTRATION FORM (APPENDIX A)** to the LSO for each Class 3B and Class 4 laser or laser system.
- Notify the LSO of any acquisition, transfer, or disposal of Class 3B and Class 4 lasers or laser systems. A **LASER REGISTRATION FORM (APPENDIX A)** must be submitted to the LSO for each new or modified laser. In addition, a **LASER TRANSFER FORM (APPENDIX B)** must be submitted for each laser or laser system that is disposed.
- Provide Equipment-specific Laser Safety Training for each laser user (e.g., physical hazards, health hazards, and emergency procedures) (**APPENDIX C**).

- Develop and submit to the LSO for approval the current Standard Operating Procedures (SOPs) for each Class 3B and Class 4 laser or laser system using the **LASER SOP (APPENDIX D)** as a guide.
- Identify laser hazards present in the work area, implement appropriate hazard controls (e.g., ANSI-approved signs and labels), and correct any identified unsafe conditions (**APPENDIX E** and **APPENDIX F**).
- Identify all authorized personnel who are permitted to operate or maintain a Class 3B or Class 4 laser or laser system.
- Ensure that laser users have attended the Laser Safety Training provided by the LSO prior to operating a Class 3B or Class 4 laser or laser system.
- Provide required protective measures for laser radiation control (e.g., laser protective eyewear, barriers, curtains, etc.).
- Conduct annual self-inspection of lasers and laser use area using the Laser Safety Self-Inspection Checklist (**Appendix G**).
- Ensure that laser users follow established laser safety procedures.
- Notify the LSO in the event of an exposure incident.
- Keep copies of all current SOPs, training records, inspections, and accident or incident investigations.
- Keep a current copy of the Laser Safety Manual within the approved laser laboratory.

3.4 Laser Users

- Know the hazards, safety procedures, and control measures for laser use in the work area.
- Attend Laser Safety Training conducted by the LSO prior to using any Class 3B and Class 4 lasers or laser systems.
- Complete Equipment-specific Laser Safety Training offered by the PI/Laboratory Supervisor prior to operating a laser or laser system (**APPENDIX C**).
- Plan and conduct laser operations in accordance with established SOPs and good safety practices.
- Use laser safety controls to minimize exposure to laser radiation.
- Wear recommended PPE (e.g., laser protective eyewear).
- Report known or suspected laser accidents or incidents to the PI and LSO.

4 LASER ACQUISITION, TRANSFER, AND DISPOSAL

4.1 Laser Acquisition

The Principal Investigator (Authorized Laser User) must notify the LSO of all Class 3B or Class 4 lasers or laser systems by submitting a **LASER REGISTRATION FORM (APPENDIX A)** for each laser or laser system to the LSO. A new form must be submitted when significant changes are made to the original laser or laser system. The LSO will conduct a Hazard Evaluation of the laser work area and make appropriate recommendations.

4.2 Laser Registration

All Class 3B and Class 4 lasers or laser systems must be registered with the Laser Safety Officer. The PI/Laboratory Supervisor shall complete the **LASER REGISTRATION FORM** (**APPENDIX A**) for existing Class 3B and Class 4 lasers, including lasers transferred to the MBL from other institutions. If a Class 3B or Class 4 laser is fabricated in the laboratory, the PI shall send an updated **Laser Registration Form** describing the modifications made. The PI shall keep a copy of the **Laser Registration Form** in their laboratory.

Laser systems containing embedded Class 3B or Class 4 lasers are exempt when the manufacturer, according to CDRH requirements, establishes the laser systems' lower classification.

The Commonwealth of Massachusetts Regulations for the Control of Lasers requires that all Class 3B and Class 4 lasers or laser systems be registered with the Massachusetts Department of Public Health, Radiation Control Program (MRCP). The LSO shall coordinate formal registration of Class 3B and Class 4 lasers or laser systems with the MRCP. When new Class 3B or Class 4 lasers are acquired (via purchase, on loan, or borrowed), or when lasers are taken out of service or relocated, the LSO must be notified promptly.

4.3 Transfer of Lasers

The LSO must be notified when a Class 3B or Class 4 laser or laser system is transferred from the control of one PI to another PI within the MBL Campus. The new PI/Laboratory Supervisor must complete a Laser Registration Form (Appendix B).

The LSO must also be notified if a Class 3B or Class 4 laser or laser system is transferred off-MBL Campus. Some lasers use hazardous materials and may require decontamination prior to shipment. Contact the LSO for more information (508-289-7645 or safety@mbl.edu).

4.4 Disposal of Lasers

The LSO must be notified when a Class 3B or Class 4 laser or laser system is sold or disposed. All lasers must be disposed in accordance with applicable federal, state and local regulations. According to MRCP regulations, all lasers for disposal must be made inoperable.

For Class 3B and Class 4 lasers and laser systems:

- Contact the LSO to discuss laser decommissioning plans.
- Remove all means of activating the laser or laser system (electrically deactivated), or destroy the laser hardware (rendered inoperable).
- Review the manufacturer's laser manual for "**CAUTION!**" statements that list hazardous materials.
- Remove and properly dispose of all hazardous materials (e.g., mercury switches, batteries, oils, dyes, beryllium oxide) or other chemicals that are contained in the laser system.
- Properly dispose of any chemical, biological, or radioactive wastes generated from the laser activities.

4.5 Laser Hazard Evaluation

Class 3B and Class 4 lasers may present various hazards. The LSO shall visit the research or teaching laboratories where Class 3B and Class 4 lasers are used to assess the hazards of the particular laser or laser systems in use within the laboratory.

The following items shall be reviewed during the laser hazard evaluation:

- Brief review of general laser safety fundamentals.
- Evaluation of the lasers in use.
- Laser laboratory inspection.
- Review of personal protective equipment (PPE).
- Calculation of Maximum Permissible Exposure (MPE) levels for eye and skin.
- Calculation of Nominal Hazard Zone (NHZ) distances.

4.6 Laser Laboratory Safety Inspections

The LSO shall conduct periodic safety inspections of research and teaching laboratories working with Class 3B and Class 4 lasers or laser systems. The LSO will review the items specified in ANSI Z136.1-2014, including:

- Verification of Laser Safety Training and Equipment-Specific Laser Safety Training for all laser operators/users (Refer to **APPENDIX C**).
- Warning signage (Class 3B and Class 4 lasers) (Refer to **APPENDIX F**).
- Laser equipment labeling (e.g., class warning label, aperture, etc.).
- Laser safety equipment (barriers and curtains present are fire resistant).
- Appropriate and adequate protective eyewear.
- Laser Standard Operating Procedures (SOP) and Emergency Procedures (Refer to **APPENDIX D**).
- Laser laboratory setup (interlocks, device setup, Nominal Hazard Zone, barriers, etc.)(Refer to **APPENDIX E**).
- Laser inventory (e.g., new, transferred, or disposed lasers or laser systems).

- Non-beam hazards (e.g. high voltage, compressed gas cylinders, chemical exposure likelihood etc.).

5 LASER USER TRAINING AND REGISTRATION

The PI/Laboratory Supervisor is responsible for ensuring that faculty, staff, and students receive appropriate training on the laser hazards in their work area and that a record of the training is kept. Laser users must be re-trained whenever a new hazard is introduced into the work area. ***Only trained and registered laboratory workers are allowed to operate Class 3B and Class 4 lasers or laser systems***.

5.1 Laser Safety Training

All individuals working with Class 3B or Class 4 lasers or laser systems must complete the initial Laser Safety Training prior to using lasers. The Laser Safety Training is conducted by the LSO and covers the following topics:

- Fundamentals of laser operations (e.g., physical principles, construction, etc.).
- Biological effects of laser radiation on the eye and skin.
- Beam related hazards: significance of spectacular and diffuse laser reflections.
- Classification of lasers and laser systems.
- Control measures and personal protective equipment (e.g., laser eyewear).
- Non-beam hazards (e.g., fire hazards, chemical exposure).
- Overall responsibilities of management and employee.
- Emergency procedures.

5.2 Equipment-Specific Laser Safety Training

Laser operators and users must be provided with laboratory-specific safety training regarding the procedures and equipment used in the laser laboratory. All operators or users of Class 3B and Class 4 lasers or laser systems must obtain Equipment-specific Laser Safety Training for all the lasers they plan to use **(APPENDIX C)**. This hands-on training must be provided by the PI/Laboratory Supervisor or an experienced laser user.

Equipment-specific training for Class 3B and Class 4 laser users must include a thorough review of hazards associated with each laser that a person may operate. The following items should be included in the training:

- Review of the Standard Operating Procedures (SOP) for each laser system.
- Laser safety equipment and personal protective equipment (PPE).
- Selection and use of laser protective eyewear.

- Laser Controlled Area (LCA), Nominal Hazard Zones (NHZ), warning signs, and labels.
- Beam and Non-Beam Hazards.
- Turning ON/OFF the laser device.
- Emergency stop or deactivation procedure.
- Alignment protocols.
- Accident reporting procedures.
- Evaluation of prospective laser user's competence in laser operation and safety procedures.

The PI/Laboratory Supervisor must retain records of equipment-specific laser operator training for review by the LSO during laser safety audits and by the MRCP inspectors during periodic inspections.

5.3 Annual Refresher Laser Safety Training

Refresher Laser Safety Training shall be provided annually. The training includes a review by the laser user of the Laser SOP and Emergency Operation Procedures for each laser or laser system. Laser users may fulfill this requirement by attending one of the Laser Safety Training sessions conducted by the LSO.

Changes to an existing laser system that would lead to additional laser hazards may require an updated laser SOP and additional Equipment-Specific Laser Safety Training. The PI/Laboratory Supervisor should contact the LSO to assess if additional training is required.

6 LASER CLASSIFICATION

Lasers are categorized into several classes depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin, or potential for causing fires from direct exposure to the beam or from diffuse reflections. The American National Standards Institute (ANSI) classifies lasers and laser systems into seven classes (ANSI Z136.1-2014).

Commercially produced lasers are classified according to the U.S. Food and Drug Administration (FDA) Center for Devices and Radiological Health (CDRH) Federal Standard (FLPPS, 21 CFR 1040.11). The FLPPS requires that laser product manufacturers and modifiers of laser products must certify that their product conforms to the requirements of the FLPPS.

Certified laser products are easily identified by the certification label that must be affixed to the product. Principal Investigators and other individuals who purchase lasers and laser systems must ensure that the devices are certified in according to the requirements of the FLPPS. Removal of protective housing or system modification can increase a laser's classification. Contact the LSO for review prior to servicing or system modification.

Lasers and laser systems that are fabricated in-house and are used by the individual(s) who designed and constructed the device are not subject to the requirements of the FLPPS. They must be classified according to the recommendations of the ANSI Z136.1-2014 Standard to ensure appropriate control measures are implemented.

6.1 Class 1 Laser System

- Considered incapable of producing exposure conditions during normal operation unless the beam is viewed with an optical instrument such as a telescope.
- Exempt from any control measures other than to prevent potentially hazardous optically aided viewing, and is exempt from other forms of surveillance.

6.2 Class 2 Laser System

- Emits radiation in the visible portion of the spectrum (400 nm to 700 nm).
- Eye protection is normally afforded by the aversion response.

6.3 Class 2M Laser System

- Emits in the visible portion of the spectrum (400 nm to 700 nm).
- Eye protection is normally afforded by the aversion response for unaided viewing.
- Class 2 M laser is potentially hazardous if viewed with certain optical aids.

6.4 Class 3 Laser System (medium power):

Class 3 lasers may be hazardous under direct and specular reflection viewing conditions. It is usually not a diffuse reflection or fire hazard.

There are two subclasses:

- **Class 3R laser system** is potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable. The probability of an actual injury is small. The laser will not post either fire hazard or diffuse-reflection hazard.
- **Class 3B laser system** may be hazardous under direct and specular reflection viewing conditions. It is normally not a diffuse reflection or fire hazard.

6.5 Class 4 laser system (high power)

- Is a hazard to the eye or skin from the direct beam.
- May pose a diffuse reflection or fire hazard.
- May also produce laser generated air contaminants (LGAC) and hazardous plasma radiation.

7 BEAM HAZARDS

When laser radiation is incident upon the body, the body tissues absorb some of the laser radiation. If the radiant exposure is high enough, this can cause injury. The parts of the body that are at greatest risk of injury from laser radiation are the eyes and the skin. The amount of laser radiation absorbed will depend on wavelength, tissue type, beam power, size of the irradiated area, and exposure duration. 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.

7.1 Eye Hazards

The eye is extremely susceptible to injury if exposed to the beams from lasers. The human eye is designed to transmit, focus, and detect light. Eye injuries occur at lower power levels than for the skin.

Laser irradiation of the eye may cause damage to the cornea, the lens, or the retina. The type of injury depends on the intensity of light, its wavelength, and the exposed tissue. Lasers cause biological damage by depositing heat energy in a small area (i.e., thermal effects) or photochemical processes. Acute exposure to laser radiation may result in corneal or retinal burns. Cataract formation or retinal damage may result from chronic exposure to laser light. Retinal damage is a major concern from exposure to wavelengths in the visible and near infrared region.

7.1.1 Retinal Damage

Visible (400 nm to 760 nm) and infrared A (760 nm to 1400 nm) wavelengths penetrate through the cornea and are focused on a small area of the retina and the fovea centralis. The focusing process greatly amplifies the energy density and increases the potential for damage.

7.1.2 Lens Damage

Wavelengths in the ultraviolet A (UV-A) spectral region (315 nm to 400 nm) are mainly absorbed in the lens of the eye. Photochemical or thermal damage to the lens of the eye disrupts the exact relationship between the tissue layers of the lens. This may result in areas of increased light scatter (i.e., cataract).

Under normal conditions, the lens will begin to harden with age. Exposure to UV-A accelerates this process and may lead to presbyopia (the loss of the ability of the lens to accommodate or focus).

7.2 Skin Hazards

Acute exposure to high levels of laser radiation in the infrared region may cause skin burns. Erythema (reddening of the skin), skin cancer, or accelerated aging may result from chronic exposure to ultraviolet light. The extent and type of damage depends on the amount of energy deposited and the wavelength of the light. Unlike injury to the eye, acute damage to the skin is usually reversible. Shielding the beam and reflections or covering the skin with opaque materials may reduce laser radiation effects on the skin.

There are various types of beam exposures that are not limited to intra-beam viewing. For high powered lasers, specular or diffuse reflections may be damaging.

Table 7.1: Summary of the biological effects to the eyes and skin at various wavelengths.

SPECTRRAL REGION	WAVELENGTH	EYE	SKIN
Ultraviolet C	200 nm – 280 nm	Photo keratitis	Erythema (sunburn) Skin Cancer Accelerated skin aging
Ultraviolet B	280 nm – 315 nm	Cornea Photo keratitis	Increased pigmentation
Ultraviolet A	315 nm – 400 nm	Photochemical cataract	Pigment darkening Skin burn
Visible light	400 nm – 780 nm	Photochemical and thermal retinal injury	Pigment darkening Photosensitive reactions Skin burn
Infrared A	780 nm – 1.4 µm	Cataract and retinal burn	Skin burn
Infrared B	1.4 µm – 3.0 µm	Corneal burn Aqueous flare Cataract	Skin burn
Infrared C	3.0 µm – 1000 µm	Corneal burn	Skin burn

8 NON-BEAM HAZARDS

8.1 Electrical Hazards

Electrical hazards pose the most significant risk and are the major cause of injury among non-beam hazards. Most lasers have high electrical voltages inside. An electrical shock hazard can occur from contact with exposed electrical power, device control, and power supply conductors operating at potentials of 50 V or more. Individuals involved in such uses must be trained in electrical safety and in proper Lockout/Tagout procedures.

- Class 3B and Class 4 lasers should have a separate circuit and local cut-off switch (breaker) for the circuit.
- High voltage sources and terminals must be enclosed unless the work area is restricted to qualified persons only.
- Capacitors must be equipped with bleeder resistors, discharge devices, or automatic shorting devices.
- Label and post electrical high voltage hazards and switches. Clearly identify the main switches to cut-off power.
- Before working on a laser, de-energize the equipment. Lock out and tag out the disconnect switches so that power is not reconnected while you are working on the laser.
- Have at least two persons in an area while working on high-energy power systems.

8.2 Laser-Generated Air Contaminants

Laser-Generated Air Contaminants (LGACs) may be generated when certain Class 3B and Class 4 lasers beams interact with matter. Characteristics of the contaminants depend upon the target material, cover gas, and beam irradiance. The LSO will evaluate the potential occupation exposure to LGAC and ensure appropriate control measures are implemented.

8.3 Collateral and Plasma Radiation

Collateral and plasma radiation refers to radiation produced by system components other than the primary laser beam. The LSO may perform an evaluation and recommend appropriate controls, if necessary.

- **Radiation (Ionizing Radiation):** May be produced from electrical components of laser systems greater than 15 kV and from laser-metal induced plasmas.
- **Ultraviolet (UV) and Visible Radiation:** May be generated from laser discharge tubes and pump lamps. Can cause skin and eye damage.
- **Radiofrequencies (RF):** Some lasers contain RF excited components.

- **Plasma Radiation:** Created during certain processes, and may contain hazardous UV and blue light emissions.

8.4 Explosion Hazards

Lasers and subsidiary equipment may present explosion hazards. High-pressure arc lamps, filament lamps, and capacitor banks in laser equipment must be enclosed in housings that can withstand the maximum explosive pressure resulting if the component disintegrates. The laser target and elements of the optical train may also shatter during laser operation and should be enclosed in a suitable protective housing. Capacitors may explode if they are subjected to voltages higher than their rating. They must be effectively shielded and equipped with current-limiting devices. High-energy capacitors should be enclosed in 1/8 inch thick steel cabinets.

8.5 Fire Hazards

Class 4 laser beams represent a fire hazard and under certain circumstances, Class 3 lasers can initiate fires. Use flame retardant materials whenever applicable with all laser applications.

- Lasers and laser facilities should be constructed and operated to eliminate or reduce any fire hazard.
- Laser laboratories should contain an appropriate fire extinguisher.
- A non-combustible material (e.g., brick) should terminate laser beams.
- Combustible solvents or substances should be stored in proper containers and shielded from the laser beam or electrical sparks.
- Excessive combustible materials should be removed in order to minimize fire hazards.

8.6 Compressed Gases

Many hazardous gases (e.g., chlorine, fluorine, hydrogen chloride, and hydrogen fluoride) are used in lasers. A standard operating procedure (SOP) should be developed for the safe handling of compressed gases. Gas cylinders must be attached to a cart or secured by a chain or strap. Incompatible gases (e.g., toxics, corrosives, flammables, and oxidizers) must be stored separately. Contact the EHS at x7424 or safety@mbl.edu for more details regarding Chemical Hygiene Plan.

8.7 Noise

Noise levels in laser laboratories can exceed safe limits because of high voltage capacitor discharges. *If you have difficulty hearing or understanding a "normal"* *tone of voice at a distance of about three feet, noise levels are probably exceeding safe levels and you should be using hearing protection.*

The LSO may perform a noise survey to determine whether noise levels exceed recommended exposure limits. Hearing protection may be required.

8.8 Laser Dyes and Solutions

Laser dyes are complex fluorescent organic compounds that when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. These dyes are frequently changed and special care must be taken when handling, preparing solutions, and operating dye lasers. A Safety Data Sheet (SDS) for dye compounds must be made readily available to all personnel using lasers.

The PI/Laboratory Supervisor must ensure that all individuals who work with laser dyes and solvents receive appropriate chemical safety training. The training should cover hazardous material handling, storage, and hazardous waste disposal. For additional information, refer to the MBL Chemical Hygiene Plan.

8.9 Hazardous Chemicals and Waste Disposal

Dye lasers use fluorescent organic dyes to obtain tunable beams. The dyes may be toxicity and are often dissolved in hazardous solvents. Review the Safety Data Sheet (SDS) for the dye and solvent before handling these chemicals. A chemical fume hood may be required.

Some laser optical components are made of hazardous materials, such as calcium telluride, zinc telluride, cadmium oxide, and beryllium. If irradiance limits are exceeded these compounds may decompose.

Dispose of all hazardous wastes in accordance with the relevant guidelines outlined in the Chemical Hygiene Plan. Contact the EHS Manager at x7424 or safety@mbl.edu for assistance.

9 CONTROL MEASURES FOR LASER HAZARDS

Control measures are used to minimize the possibility of eye and skin exposures to laser radiation hazards. The recommended control measures shall apply to normal operating conditions, alignments, maintenance, and service.

Control measures include engineering controls, administrative controls, and personal protective equipment (PPE). Engineering controls should be considered as the first choice. Administrative controls should be used whenever engineering controls are neither feasible nor appropriate.

Principal Investigators using lasers shall provide and maintain the appropriate control measures (e.g., protective eyewear, beam stops, barriers, beam housing, etc.), as recommended in ANSI Z136.1-2014.

9.1 Warning Signs and Labels

A laser controlled area, in which access is restricted for the purpose of protection from laser radiation, must be conspicuously posted with laser warning signs. All warning signs and labels must comply with ANSI Z 136.1-2014 and the FDA/CDRH Standards. The warning sign must have certain prescribed wording at specific locations depending on the class and type of laser; these signs should be obtained from LSO. Refer to **APPENDIX F** for samples of laser controlled area warning signs.

- **WARNING**: Must be used with all signs and labels associated with all Class 3R lasers and laser systems that exceed the appropriate MPE for irradiance, all Class 3B lasers, and most Class 4 laser systems.
- **DANGER**: Must be used with all signs and labels associated with a Class 4 laser or laser system with high power (multi-kW) or pulse energy.
- **CAUTION**: Must be used with all signs and labels associated with Class 2 and 2M lasers and laser systems, and all Class 3R lasers and laser systems that do not exceed the appropriate MPE for irradiance.
- **NOTICE:** Must be used on signs posted outside a temporary laser controlled area. The area within the temporary controlled area must also have appropriate signs posted (**WARNING** or **DANGER** sign for Class 3B or Class 4 lasers).

9.2 Labeling of Protective Equipment

1. **Labeling of Protective Eyewear**

   All eyewear must be clearly labeled with the optical density and wavelength. Color-coding or other distinctive identification is recommended in multi-laser environments.

2. **Labeling of Laser Protective Windows and Collecting Optic Filters**

   All laser protective windows must be labeled with the optical density and wavelength(s) for which protection is afforded. They should be labeled with the threshold limit and exposure time for which the limit applies, and the conditions under which protection if afforded.

3. **Labeling of Laser Protective Barriers**

All laser protective barriers must be labeled with the barrier threshold limit and exposure time for which the limit applies, and beam exposure conditions under which protection is afforded.

9.3 Engineering Controls

The engineering control measures required for Class 3B and Class 4 lasers are listed below. Where specific engineering controls are infeasible they may be replaced with specific administrative and procedural controls and personal protective equipment (PPE) with prior review by the LSO. Alternative controls and PPE requirements must be documented in a written SOP.

Table 9.1: Engineering controls for Class 3B and Class 4 laser systems.

ENGINEERING CONTROLS	Class 3B Laser	Class 4 Laser
Engineering controls Protective Housing. For active laser work with housing off, contact LSO for hazard evaluation and appropriate controls.	✓	✓
Engineering controls Interlocks on Protective Housing	✓	✓
Service Access Panels Interlocked or tool required and appropriate warning label on the panel	✓	✓
Key Control	+	✓
Remote Interlock Connector	+	✓
Beam stop or Attenuator	+	✓
Laser Activation Warning System	+	✓
Emission Delay		✓
Remote Firing and Monitoring		✓
Panic Button		✓
Viewing windows, diffuse display screens, or collecting optics (lenses, microscopes, etc.) are controlled with interlocks, filters, or attenuators to maintain laser radiation at the viewing position at or below the applicable MPE.		✓
Enclosed Beam Path	+	+

Key:

✓ Required
+ Recommended

9.4 Administrative and Procedural Controls

1. Standard Operating Procedures

The PI should develop written SOPs for Class 3B and Class 4 lasers and laser systems (**APPENDIX D**).

2. Authorized Personnel

The PI/Laboratory Supervisor must identify authorized personnel who are authorized to operate, maintain, or service Class 3B or Class 4 lasers or laser systems.

3. Alignment Procedures

Alignment of Class 3B and Class 4 laser optical systems (e.g., mirrors, lenses, beam deflectors, etc.) shall be performed while ensuring that the primary beam, or a specular or diffuse reflections, does not expose the eye to a level above the applicable Maximum Permissible Exposure (MPE). A copy of the Alignment Procedures must be maintained in the laboratory.

9.5 Personal Protective Equipment

Flame-resistant laboratory coats and gloves may be used to prevent an acute exposure to the skin and subsequent burns. Loose fitting clothing and long, loose hair are hazards in a laser laboratory. Jewelry and watches should never be worn when working with lasers to minimize the likelihood of beam reflections or electrocution.

9.6 Eye Protection

All personnel who work in areas where there is a possibility of being exposed to a hazardous level of laser radiation are required to wear approved laser eyewear. The ANSI Z136.1-2014 requires that protective eyewear be available and worn whenever hazardous conditions may result from laser radiation or laser related operations.

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

Eye protection is generally not designed to withstand the direct hit of a high-powered Class 4 beam. Pulsed lasers can have extremely high peak powers and cause instant eyewear failure. Users must take all possible precautions to avoid and prevent direct beam exposures.

9.7 Skin Protection

The potential for skin injury from the use of high power lasers can present a potential hazard. For laser systems using an open beam, skin protection may be necessary. Covering exposed skin using laboratory coats, gloves, and an UV face shield will protect against UV scattered radiation. Adequate skin protection may be required for certain applications using high power laser systems.

When UV scatter cannot be reduced by shielding, other forms of skin protection must be used. Chemical face shields can block all scattered mid to far UV while laboratory coats and gloves can reduce exposure to the rest of the body.

10 CLASS-BASED LASER CONTROLS

10.1 Class 1, 2, and 3R Laser Systems

When used as intended Class 1, Class 2 and Class 3R lasers or laser systems are generally low hazard devices. The following safety control requirements still apply:

- The PI/Lab Supervisor is responsible for ensuring safety training on proper use of the specific laser or laser system.
- Exposure to laser radiation must be kept below the Maximum Permissible Exposure (MPE) under all conditions of operation or maintenance.
- The lasers or laser systems must have the appropriate warning labels and signs with appropriate cautionary statement.
- Removal of protective housing or system alteration can increase a laser's classification. Contact the LSO for review prior to servicing or system modification.
- Use of Class 3R laser with telescopes, microscopes, or alignment devices should be reviewed by the LSO prior to operation.

10.2 Class 3B Laser Control Area

- Ensure the laser users have completed the required Laser Safety Training and are authorized to operate the lasers.
- Never aim the laser beam at an individual's eye, or intentionally direct the laser beam at another person.
- Must be controlled to permit lasers and laser systems to be operated only by authorized personnel.
- Must be posted with the appropriate warning sign(s) (Appendix D).

- Must be under the direct supervision of an individual knowledgeable in laser safety.
- All area or entryway safety controls must be designed to allow rapid exit by laser personnel and entry to the laser controlled area under emergency conditions.
- Operate the laser only in a controlled area (e.g. in a closed room with covered or filtered windows and controlled access).
- Use terminations at the end of the direct and any secondary beam paths.
- Must have all windows, doorways, open portals, etc. either covered or restricted to reduce the transmitted laser radiation to levels at or below the applicable ocular MPE.
- Place the laser beam path above or below the eye level of any sitting or standing observers, whenever possible.
- Always use proper laser eye protections if a potential eye hazard exists for the direct beam or a specular reflection;
- Install a key switch to minimize tampering by unauthorized individuals.
- Never view the beam or its specular reflection with optical instruments such as binoculars or telescopes.
- Must have only diffusely reflecting materials in or near the beam path where possible.
- Remove all unnecessary mirror-like surfaces from the vicinity of the laser beam path; and
- Do not use reflective or partially reflective objects (e.g., credit cards and glossy objects) to check beam alignment.
- Must have appropriate personal protective equipment readily available (i.e., eye protection).

10.3 Class 4 Laser Control Areas

Class 4 Laser Control Areas must incorporate all Class 3B control measures, plus the following:

- Control area interlocks or alternate controls to preclude the entry of unprotected personnel while Class 4 laser radiation is present in the control area. The interlock system may be designed to preclude entry while the laser is operating or to terminate laser operation when the door is opened without deliberate overriding of the interlock by a trained laser user; OR
- Blocking barrier, screen, curtains, etc. must be used to block, screen, or attenuate the laser radiation levels so that the MPE is not exceeded at the entry point.
- At the entryway there must be a visible or audible signal indicating that the laser is energized and operating at Class 4 levels. A lighted laser warning sign or flashing light (visible through protective eyewear) is acceptable entryway warning light alternatives.

- Personnel trained on entryway procedures and adequate personal protective equipment provided upon entry.

11 SPECIAL CONSIDERATIONS

11.1 Service of Embedded Class 3B or Class 4 Lasers

Access to Class 3B or Class 4 lasers or laser systems enclosed within a protective housing or protected area enclosure is limited to properly trained individuals and by specific engineering and administrative controls. Contact the LSO for more information (x7645 or safety@mbl.edu).

11.2 Laser Alignment Guidelines

- Exclude unnecessary personnel from the laser area during alignment.
- Use low-power visible lasers for path simulation of higher power visible or invisible lasers whenever possible.
- Wear laser protective eyewear during alignment. Use special alignment eyewear when circumstances (e.g. wavelength, power, etc.) permit their use.
- When aligning invisible (e.g. UV, IR) beams, use beam display devices such as image converter viewers or phosphor cards to locate beams.
- Perform alignment tasks using high-power lasers at the lowest possible power level.
- Use a shutter or beam block to terminate high-power beams at their source except when actually needed during the alignment process.
- Use a laser rated beam block to terminate high-power beams downstream of the optics being aligned.
- Use beam blocks and/or laser protective barriers in conditions where alignment beams could stray into areas with uninvolved personnel.
- Place beam blocks behind optics (e.g., turning mirrors) to terminate beams that might miss mirrors during alignment.
- Locate and block all stray reflections before proceeding to the next optical component or section.
- Be sure all beams and reflections are properly terminated before high-power operation.
- Post appropriate area warning signs during alignment procedures where lasers are normally Class 1 (enclosed).
- Only those who have received laser safety training should do alignments.

12 MEDICAL EVALUATIONS

Baseline and termination eye examinations are optional for Class 3B and Class 4 laser use, based on ANSI Z136.1-2014 recommendations. Eye examinations are required for incidents or for cause conditions. The MBL strongly encourages baseline eye examinations for all faculty, staff, and students working with open beam Class 4 lasers or laser systems. In the event of any accidental or suspected eye exposure to laser radiation, personnel must seek immediate medical attention for a thorough eye examination by the ophthalmologist.

13 LASER INCIDENTS AND EMERGENCY PROCEDURES

13.1 Reporting Laser Incidents

In the event that a laser user suspects they have been exposed to excessive levels of laser radiation:

- Inform the PI/Lab Supervisor of incident immediately.
- Notify the Laser Safety Officer (x7645 from MBL Campus phone or 508-289-7645 from cell phone) or safety@mbl.edu to report the incident.
- Seek medical attention for an eye exam.
- Complete an Accident or Injury Report Form and submit it to the HR Department within 48 hours.

13.2 Accident Investigation

Upon notification of an accident or incident, the LSO, EH&S Manager and the Human Resource Department will conduct an accident/incident investigation, as follows:

- The team interviews injured workers and witnesses.
- The team evaluates the workplace for factors associated with the accident or laser exposure.
- The team determines the possible causes of the accident or exposure.
- The PI/Laboratory Supervisor takes corrective action to prevent the accident or exposure from recurring.
- The PI/Laboratory Supervisor records the findings and corrective actions taken.

13.3 Emergency Procedures

In the event of an emergency involving lasers or laser systems:

- Shut down the laser or laser system immediately and remove the interlock key.
- If possible, alert everyone to exit the laboratory.

- In case of exposure or suspected exposure to laser radiation, seek immediate medical attention.
- In the event of fire or life-threatening injuries, call 911 or MBL Campus Security (7-911).
- Inform the PI/Laboratory Supervisor promptly following the incident; and
- Notify the Laser Safety Officer (x7645 from MBL Campus phone or 508-289-7645 from cell phone) or safety@mbl.edu to report the incident.

14 REFERENCES

1. Commonwealth of Massachusetts Department of Public Health, ***Regulations for the Control of Lasers*** (**105 CMR 121.000**), "*To Control the Radiation Hazards Of Lasers, Laser Systems and Optical Fiber Communication Systems Utilizing Laser Diode or Light Emitting Diode Sources*".
2. ***American National Standard for Safe Use of Lasers (ANSI Z136.1-2014)***. The Laser Institute of America, Orlando, Florida, 2014.
3. ***American National Standard for Safe Use of Lasers in Research, Development, or Testing (ANSI Z136.8-2012)***. Laser Institute of America, Orlando, Florida 2012.
4. ***CLSO's Best Practices in Laser Safety***, First Edition. Laser Institute of America, Orlando, Florida, 2008.
5. ***Laser Safety Guide***, Twelfth Edition. Benjamin Rockwell (Editor). Laser Institute of America, Orlando, Florida, 2015.

15 APPENDICES

APPENDIX A

LASER REGISTRATION FORM

PRINCIPAL INVESTIGATOR/DEPARTMENT INFORMATION		
Principal Investigator:		Email:
Department/Center/Division:		Phone:
LASER SYSTEM LOCATION	Building:	Room #:

LASER REGISTRATION INFORMATION

Type of Registration:

NEW laser or laser system acquisition or installation.

ALTERATION of an existing laser or laser system.

(a) ***Alterations*** *include any change(s) that substantially increases or decreases the number of sources, source strength, output, or wavelengths produced.*

(b) Relocation or movement of lasers or laser systems from one workspace to another is regarded as an alteration.

LASER OR LASER SYSTEM DESCRIPTION			
Manufacturer	Model Number	Serial Number	Acquisition Date
Laser Class	Class 1 with a Class 4 inside	Class 3B	Class 4
Optical Characteristics	Wavelength(s) (nm)	Beam Diameter (mm)	Divergence (mR)
Type	CW	Single Pulsed	Multiple Pulsed
Pulse Rate (Hz):	Pulse Duration (s)	Maximum Energy or Power:	
Intended Use:	☐ Research ☐ Demonstration **Other (specify)**		
Laser Service	**DONE IN-HOUSE**	**CONTRACTED OUT**	
Principal Investigator Signature:			**Date:**

LASER SAFETY OFFICER (LSO) USE ONLY		
MRCP Laser Reference	**Date of Registration**	**Date of Disposal**
NAME OF LSO:		
SIGNATURE:		**DATE:**

APPENDIX B

LASER TRANSFER FORM

PLEASE COMPLETE AND SEND THIS SOP to the Laser Safety Officer (LSO) at safety@mbl.edu.

SECTION 1: CURRENT OWNER INFORMATION			
Principal Investigator:			Email:
Department:			Phone:
Building where laser is currently located:			Room #:
Intended Date of Transfer:			
SECTION 2: LASER IDENTIFICATION INFORMATION			
Manufacturer		Model Number	Serial Number
Laser Type (e.g., HeNe, Argon):			
Classification:	Class 1 with a Class 4 inside	Class 3B	Class 4
Type	CW	Single Pulsed	Repetitively Pulsed
SECTION 3: NEW LASER LOCATION			
Building where laser is currently located:			Room Number
If laser is moving to another Department or leaving MBL completely, please explain:			
Principal Investigator:			
Signature:			**Date:**

LASER SAFETY OFFICER (LSO) USE ONLY		
New MBL Laser ID Number	**Date Reviewed**	**Date of Transfer**
Comments:		
Laser Safety Officer		
Signature:		**Date:**

APPENDIX C

EQUIPMENT-SPECIFIC LASER TRAINING FORM

SECTION 1: TRAINING INFORMATION	
Principal Investigator:	
Department / Center / Division:	
Laboratory Supervisor:	
Laser User / Trainee:	
Date of Training:	

SECTION 2: REQUIRED TRAINING	
TOPICS	**INITIALS**
✓ Laser Area, Nominal Hazard Zones, Signs and Warning Labels	
✓ Laser safety equipment and Personal Protective Equipment (PPE)	
✓ Beam and Non-Beam Hazards	
✓ Turning ON the laser or laser system	
✓ Turning OFF the laser or laser system	
✓ Emergency Stop or Deactivation Procedure	
✓ Alignment Protocols	
✓ Standard Operating Procedures	
✓ Accident/Incident Reporting	
✓ **Other Topics Discussed** (*please specify*):	

SECTION 3: CERTIFICATION & SIGNATURE

(a) I have read and understood the contents of the Laser SOP. I am aware of the occupational hazards and risks associated with the specific lasers or laser systems that I will be working with.

(b) I have received on-site hands-on training on the safe use of the specific laser systems. I have been given the opportunity to ask questions regarding their use.

(c) I agree to comply with the safe work practices outlined in this training session, the applicable Laser SOP, and the MBL's Laser Safety Manual.

(d) I agree to wear the recommended Personal Protective Equipment (PPE) when using the specific lasers or laser systems.

Laser User's Signature:	***Date:***
PI / Supervisor Signature:	***Date:***

APPENDIX D

LASER STANDARD OPERATING PROCEDURES (SOP)

PLEASE COMPLETE AND SEND THIS SOP to the Laser Safety Officer (LSO) at safety@mbl.edu. The LSO will review the SOP and send the approved copy to the Principal Investigator / Laboratory Supervisor or designee.

1. LASER LOCATION

Department/Center/Division	Building	Room Number

2. LASER SAFETY CONTACTS

Principal Investigator/Course Director:	Ph.:
Laboratory Supervisor/Course Assistant:	Ph.:
Laser Safety Officer (LSO): **Simon Muchohi**	(508)-289-7645
MBL Campus Security:	x7911
Fire/Medical Emergency	Dial 911

3. LASER SYSTEM DESCRIPTION

Manufacturer	Model	Serial Number	
Laser Type (Nd: YAG, etc.): OTHER:			
Laser Classification: Class 1 with a Class 4 inside Class 3B Class 4			
Wavelength (nm):			
Beam Diameter (mm):		Beam Divergence (mrad):	
Describe how the laser will be used:			
Mode of Operation (Select One): Continuous Wave (CW) Pulsed Q-Switch			
Enter Mode-Related Parameters (Energy, Power, Time)			
Mode	**Parameter**	**Value**	**Units**
CW	Average Power		Watts (W)
Pulsed/Q-Switch	Joules per Pulse		Joules (J)
Pulsed	Pulse Repetitive frequency		Kilohertz (kHz)
Q-Switch	Pulse Width		Nanosecond (ns)

4. OPERATING AND SAFETY PROCEDURES

- Remove jewelry that might reflect beams.
- Obtain appropriate eyewear. Be certain it is of appropriate OD for the wavelength(s) in use.
- Turn on outside warning light.
- Inspect optical setup for recent changes/and or foreign objects.
- Verify that all personnel in lab are wearing approved eyewear.
- Issue a verbal warning prior to starting laser.
- Insert key into laser controller.
- Proceed as per User Manual to obtain laser output.

A. Startup Procedures (REQUIRED) (including manufacturer's recommended steps and the point at which laser protective eyewear must be worn):

B. Operating Procedures (*power settings, Q-switch mode, pulse rate, etc.*):

C. Special Procedures (*beam alignment, safety tests, maintenance tests, etc.*):
Beam Alignment (**REQUIRED**) (*Attach laser system's specific alignment procedure OR provide modified alignment procedure*).

Safety Tests (Interlock test, etc.):

Maintenance:

D. Shutdown Procedures:

5. CONTROL MEASURES

LASER OR LASER SYSTEM CONTROLS		
CHECK IF VALID	**CONTROL**	**COMMENTS**
	Entryway (door) interlocks or controls	
	Laser enclosure interlocks	
	Emergency stop/panic button	
	Master switch (operated by key or code)	
	Laser secured to base	
	Beam stops/beam attenuators	
	Warning signs	
	Reference to equipment manual	
	Appropriate/sufficient eyewear available	
	Other:	

SPECIFIC HAZARDS AND CONTROLS *Check all that apply and provide control measures that will be implemented.*		
CHECK IF VALID	**HAZARD**	**CONTROL MEASURES IMPLEMENTED**
	Unenclosed beam or access to direct or scattered light	
	Laser at eye level of person sitting or standing	
	Ultraviolet radiation or blue light exposure	
	Reflective material in beam path	
	Chemical (e.g., dyes, solvents, etc.); attach SDS	
	Fumes or vapors	
	Electrical (e.g., high voltage, large current, etc.)	
	Capacitors	
	Compressed gases or cryogenic liquids	
	Fire or ignition sources	
	Trip hazard	
	Other:	

6. PERSONNEL PROTECTIVE EQUIPMENT

A. Eyewear

LASER EYEWEAR					
For This Laser….			…Wear This Eyewear		
Serial No.	Type	Wavelength (nm)	Wavelength attenuated (nm)	Optical Density (OD)	Manufacturer / Model
Example	Nd:YAG	1064, 532	1064, 532	5+	UVEX

B. Other protective equipment required within the Nominal Hazard Zone.

ITEM	LOCATION	USAGE	CONDITION

APPENDIX E

CONTROL MEASURES FOR DIFFERENT CLASSES OF LASERS (ANSI Z136.1–2014)

Table 10a. Control Measures for the Seven Laser Classes

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.4.2.1)	X	X	X	X	X	X	X
Without Protective Housing (4.4.2.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.4.2.1.3)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.4.2.1.4)	∇	∇	∇	∇	∇	X	X
Key Control (4.4.2.2)	—	—	—	—	—	•	•
Viewing Windows, Display Screens and Diffuse Display Screens (4.4.2.3)	Ensure viewing limited < MPE						
Collecting Optics (4.4.2.6)	X	X	X	X	X	X	X
Fully Open Beam Path (4.4.2.7.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.4.2.7.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.4.2.7.3)	Further controls not required if 4.4.2.1 and 4.4.2.1.3 fulfilled						
Area Warning Device (4.4.2.8)	—	—	—	—	—	•	X
Laser Radiation Emission Warning (4.4.2.9)	—	—	—	—	—	•	X
Class 4 Laser Controlled Area (4.4.2.10 and 4.4.3.5)	—	—	—	—	—	—	X
Entryway Controls (4.4.2.10.3)	—	—	—	—	—	—	X
Protective Barriers and Curtains (4.4.2.5)	—	—	—	—	—	•	•

LEGEND:
- X Shall
- • Should
- — No requirement
- ∇ Shall if enclosed Class 3B or Class 4
- NHZ Nominal Hazard Zone analysis required

APPENDIX E

CONTROL MEASURES FOR DIFFERENT CLASSES OF LASERS (ANSI Z136.1–2014)

Table 10b. Control Measures for the Seven Laser Classes (cont.)

Administrative (and Procedural) Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.3.1)	—	—	—	—	—	•	X
Output Emission Limitations (4.4.3.2)	—	—	—	—	LSO Determination		
Education and Training (4.4.3.3)	—	•	•	•	•	X	X
Authorized Personnel (4.4.3.4)	—	—	—	—	—	X	X
Indoor Laser Controlled Area (4.4.3.5)	—	◦	—	◦	—	X NHZ	X NHZ
Class 4 Laser Controlled Area (4.4.2.9 and 4.4.3.5)	—	—	—	—	—	—	X
Temporary Laser Controlled Area (4.4.3.5)	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	—	—
Controlled Operation (4.4.3.5.2.1)	—	—	—	—	—	—	•
Outdoor Control Measures (4.4.3.6)	X	◦ NHZ	X NHZ	◦ NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.4.3.6.2)	•	•	•	•	•	•	•
Alignment Procedures (4.4.3.8)	∇	X	X	X	X	X	X
Spectators (4.4.3.7)	—	◦	—	◦	—	•	X
Service Personnel (4.4.3.9)	LSO Determination						

LEGEND:
- X Shall
- • Should
- — No requirement
- ∇ Shall if enclosed Class 3B or Class 4
- MPE Shall if MPE is exceeded
- NHZ Nominal Hazard Zone analysis required
- ◦ May apply with use of optical aids

APPENDIX F

LASER WARNING SIGNS

Figure 1. Sample warning sign for Class 2, Class 2M, and Class 3R lasers. From ANSI Z36.1-2014 (Figure 1a).

Figure 2. Sample warning sign for certain Class 3R, Class 3B, and Class 4 Laser Controlled Areas. Adapted from ANSI Z36.1-2014 (Figure 1b).

Figure 3. Sample warning sign for Class 4 Laser Controlled Area. Adapted from ANSI Z36.1-2014 (Figure 1c).

Figure 4. Sample warning sign for Class 4 Laser Controlled Area. Adapted from ANSI Z36.1-2014 (Figure 1c).

Figure 5. Sample Temporary Laser Controlled Area (LCA) sign, which is posted outside a temporary LCA (e.g., during service period). The area outside the temporary LCA remains Class 1, while the area within LCA is either Class 3B or Class 4. Adapted from ANSI Z36.1-2014 (Section 4.6.2.3).

APPENDIX G

LASER SAFETY SELF-INSPECTION CHECKLIST

The Principal Investigator (PI) or Laboratory Supervisor is responsible for ensuring that laser self-inspections are conducted annually and that completed checklists, including any corrective actions taken, are maintained on file in the laser laboratory.

Principal Investigator:	Email:
Laboratory Supervisor:	Email:
Department/Center/Division/Course:	Phone:
Building:	Room #:

	YES	NO
Administrative and Procedural Controls		
Are all authorized users and training dates listed in the SOP?		
Have all commercially produced Class 3B and Class 4 lasers been registered with the LSO?		
Have all lasers fabricated or modified on MBL Campus been registered with the LSO?		
Written Standard Operating Procedures (SOP) and maintenance and alignment procedures are available and kept with laser equipment?		
Personal Protective Equipment (PPE)		
Goggles appropriate for the laser used are available and used?		
Appropriate goggles are available for visitors?		
Are viewing cards for non-visible beam available?		
Class 3B and Class 4 laser controlled area signs are posted to indicate that the use of eyewear is required to operate the devices?		
Beam Hazard Controls		
Protective housing intact and interlocks tested or alternative controls reviewed by LSO and described in SOP?		
Access to laser controlled to prevent persons being accidentally exposed to the laser beams by posting or controlling the entrance?		
Laser controlled areas posted and laser equipment are labeled with ANSI-approved warning signs and labels?		
Are windows and ports, which could allow a laser beam to stray into uncontrolled areas covered or protected during laser operation.		
Beam stops present at end of all beam paths?		
Barriers or screens are non-combustible)		
No exposed wiring or electrical circuits)		

	YES	NO
Is an inspection covering the items listed below performed prior to each operation?		
(a) Protective eyewear is appropriate for laser operation and is clean/ free of damage?		
(b) All beams traced and dumped?		
(c) Mirror backs covered?		
(d) Beam path enclosed where possible?		
(e) Optical bench free of unnecessary reflective items?		
(f) If beam crosses walkway, are there posted barriers, is a rope or chain placed across path during operation?		

LIST ANY OTHER SAFETY DEFICIENCIES FOUND:
LIST CORRECTIVE ACTIONS TAKEN FOR ANY IDENTIFIED DEFICIENCIES:

INSPECTED BY: ____

SIGNATURE: _____________________________________ **DATE:** ________

APPENDIX H

*LIST OF LASER PROTECTIVE EYEWEAR MANUFACTURERS AND VENDORS

COMPANY	CONTACT INFORMATION
Laser Institute of America	13501 Ingenuity Drive, Suite 128 Orlando, FL 32826 (800) 345-2737; (407) 380-1553 Fax: (407) 380-5588 https://www.lia.org/
Coherent Inc.	5100 Patrick Henry Drive Santa Clara, CA 95054 Phone: (800) 227-8840 https://www.cohr.com/
Sperian Protection Americas Inc.	900 Douglas Pike Smithfield, RI 02917 Phone: (813) 412-8666 Fax: (401) 233-7641 http://www.sperianprotection.com
Kentek Corp.	32 Broadway Street Pittsfield, NH 03263 (800) 432-2323;(603) 223-4900 Fax: (603) 435-7441 http://www.kenteklaserstore.com
Rockwell Laser Industries	7754 Camargo Road Cincinnati, OH 45243 Phone: (513) 272-9900 Fax: (513) 272-9901 https://www.rli.com/
U.S. Laser Corp.	825 Windham Ct. N. PO Box 609 Wyckoff, NJ 07481 (201) 848-9200 www.uslasercorp.com
NoIR Laser Shields	Noir Medical Technologies 6155 Pontiac Trail South Lyon, MI 48178 (800) 521-9746; (734) 769-5565 Fax: (734) 769-1708 http://noirlaser.com
Laservision USA	595 Phalen Boulevard Saint Paul, MN 55130 Phone: (888) 966-8730 Fax: (651) 357-1830 www.lasersafety.com www.laservision-usa.com

**Inclusion in this list does not imply endorsement of the manufacturer or vendor by MBL.*

APPENDIX I

GLOSSARY OF TERMS

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 laser hazard class.

Aperture: An opening through which radiation can pass.

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

Average power: The total energy in an exposure or emission divided by exposure or emission duration.

Aversion response: Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. In the ANSI Z136.1 Standard, the aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 s or less.

Beam Diameter: The diameter of a portion of the beam that contains 86% of the output power.

Beam: A collection of light rays that may be parallel, divergent, or convergent.

Coherent: A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous function.

Continuous wave (CW): The output of a laser, which is operated in a continuous rather than pulsed mode. In this standard, a laser operating with a continuous output for a period > 0.25 seconds 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 layer of the human eye that covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

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.

Diffuse reflection: Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Divergence: The angle at which the laser beam spreads in the far field; the bending of rays away from each other, as by a concave lens or convex mirror; measured in milliradians (mrad). Sometimes this is also referred to as beam spread.

Duty factor: The product of the pulse duration and the pulse repetition rate.

Electromagnetic radiation (Spectrum): Includes radio waves; X-rays; gamma rays; and infrared, ultraviolet, and visible light. The flow of energy consisting of electric and magnetic fields lying transverse to the direction of propagation. X-ray, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, or photon energy.

Embedded laser: An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

Enclosed laser: A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place.

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

Erythema: Redness of the skin due to congestion of the capillaries.

Extended source: An extended source of radiation that can be resolved into a geometrical image in contrast with a point source of radiation, which cannot be resolved into a geometrical image. A light source whose diameter subtends a relatively large angle from an observer.

Failsafe 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.

Hertz (Hz): The unit that expresses the frequency of a periodic oscillation in cycles per second. The term also describes the number of repetitive pulses occurring per second.

Infrared radiation (IR): Invisible electromagnetic radiation with wavelengths that lie within the range 0.7 µm to 1 mm.

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

Ionizing radiation: Electromagnetic radiation having sufficiently large amount of photon energy to directly ionize atomic or molecular systems with a single quantum event. Contrasts with non-ionizing radiation of lasers.

Irradiance (E): The power emitted per unit area upon a surface; expressed in watts per square centimeter (W/cm^2). Sometimes referred to as power density.

Joule (J): A unit of energy. 1 Joule = 1 watt second (Ws).

Laser: An acronym for Light Amplification by Stimulated Emission of Radiation. A laser is a cavity, with mirrors at the ends, filled with material such as crystal, glass, liquid, gas, or dye. A device that produces an intense beam of light with the unique properties of coherency, collimation, and monochromaticity.

Laser Pointer: A laser or laser system designed or used to specify a discrete point or location, such as those lasers used in classroom lectures or for the aiming of firearms. These products are usually Class 1, Class 2, or Class 3R.

Laser system: An assembly of electrical, mechanical, and optical components that includes a laser.

Limiting aperture: The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation and classification.

Maximum Permissible Exposure (MPE): The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

Nominal Hazard Zone (NHZ): A zone that describes 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.

Nominal Ocular Hazard Distance (NOHD): The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure does not exceed the applicable MPE.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include maintenance or service as defined in this section.

Optical density (OD): A logarithmic expression for the attenuation of the irradiation produced by an attenuating medium, such as an eye protection filter.

Photosensitizers: Substances that increase the sensitivity of a material to irradiation by electromagnetic energy.

Point source: Ideally, a source with infinitesimal dimensions. Practically, a source of radiation whose dimensions are small compared with the viewing distance. For the purpose of this standard, a point source leads to intrabeam viewing condition.

Power: The rate at which energy is emitted, transferred, or received. Unit: watts (Joules per second).

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

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.

Pulse Repetition Frequency (PRF) or Rate: The number of pulses produced per second by a laser.

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 (~10-250 ns) intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Q-Switched laser: A laser that emits short (<30 ns), high-power pulses by means of a Q-switch.

Radian (rad): A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1radian=57.3 degrees; 2n radians=360 degrees.

Radiance (L): Radiant flux or power output per unit solid angle per unit area expressed in watts per centimeter squared per steradian ($W \cdot cm^{-2} \cdot sr^{-1}$).

Radiant energy (Q): Energy emitted, transferred, or received in the form of radiation. Unit: joules (J).

Radiant exposure (H): Surface density of the radiant energy received. It is used to express exposure to pulsed laser radiation in units of joules per centimeter squared ($J \cdot cm^{-2}$).

Radiant flux (W): Power emitted, transferred, or received in the form of radiation. Unit: watts (W). Syn: radiant power.

Repetitive pulsed laser: A laser with multiple pulses of radiant energy occurring in sequence with a pulse repetition frequency greater than or equal to 1 Hz.

Source: A laser or a laser-illuminated reflecting surface.

Specular reflection: A mirror-like reflection.

Transmittance: The ratio of total transmitted radiant energy to the incident radiant energy, or the fraction of light that passes through a medium.

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

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 400nm to 700nm.

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 are in phase.