UNIVERSITY OF ROCHESTER

LASER SAFETY PROGRAM FOR RESEARCH and TEACHING LABORATORIES

Environmental Health & Safety
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University of Rochester
Laser Safety Program for
Research and Teaching Laboratories

Table of Contents

Appendices

I. INTRODUCTION

The purpose of this program is to ensure the safe use of lasers in research and teaching laboratories. These lasers include those that operate at wavelengths between 180 nm and 1080 μm.

Designated personnel, both staff and students, shall be aware of the hazards lasers present, be provided with instructions on the safe use of lasers, follow recommendations for the proper use of lasers, and be included in the medical surveillance program, when required. To achieve this goal, the University recognizes the American National Standards Institute's (ANSI) "American National Standard for Safe Use of Lasers", ANSI Z136.1-2014, the ANSI "American National Standard for Safe Use of Lasers in Educational Institutions", ANSI Z136.5-2009, and New York State Department of Labor's Code Rule 50 https://www.labor.state.ny.us/workerprotection/safetyhealth/sh50.shtm .

Those using only Class 1, 2, or 3R (older lasers previously labeled as 3a or IIIa) lasers are exempt from many of the control measures of this program. Personnel in laboratories using Class 3B and 4 lasers shall follow the recommendations outlined in this program. Many hazards are associated with lasers. Lasers may cause eye injury from direct and reflected beams. High-power laser beams can burn exposed skin, ignite flammable materials, and aerosolize chemicals that can release hazardous fumes, gases, debris, or radiation. The equipment and optical apparatus required to produce the lasing action and control/direct the laser beam also introduce hazards associated with high-voltage electrical equipment, high-pressure gases, cryogenic materials, noise, radiation, and toxic gases. Also, lasers are often used with chemicals and biological materials. When any of these hazards are present, the appropriate controls need to be established to comply with the applicable federal or state regulations/codes.

The most common causes of laser accidents include:

- Unanticipated eye and skin exposures during alignment.
- Misaligned optics and misdirected beams.
- Eye protection not used or not available.
- Eye or skin injury of photochemical origin.
- Incorrect eyewear worn for the laser in use.
- Equipment malfunction.
- Intentional/unintentional exposure of unprotected personnel.
- Operators unfamiliar with laser equipment.
- Lack of protection for ancillary hazards.
- Improper restoration of equipment following service.
- Defeating safety interlocks.
- Failure to have or follow Standard Operation Procedures (SOPs).
- Improper methods of handling high voltage.
- Inhalation of laser-generated air contaminants and/or viewing laser-generated plasmas.
- Fires resulting from ignition of materials.

- Unanticipated exposure during usage.

(List compiled mostly from ANSI Z136.5-2009, Section 3.5)

Laser Pointers: There are some concerns for the use of laser pointers, even though they have proven to be useful for educators and for meetings. Because all laser pointers are easily moved to other locations, posting/labeling rooms where laser pointers might be used is impractical.

Generally, the hazards of laser pointers are limited to non-permanent retinal damage to the eye. The majority of the laser pointers are either Class 2 lasers with a maximum power output of less than 1 mW or Class 3R diode lasers in the 630-680 nm wavelength (red), with a maximum power output of between 1 and 5 mW. The laser pointers of concern that can present a significant potential for eye injury and may not be properly labeled are those imported from Russia or China. These lasers emit green beams operating at 532 nm and have emissions exceeding the maximum permissible exposure. One such laser has a filter in the cap, which, if removed, allows the laser to emit both 532 nm and 1064 nm beams, in excess of 15 mW, making it an even more hazardous Class 3B laser. The University community is asked to report inappropriate use of laser pointers to Environmental Health & Safety.

II. RESPONSIBILITIES

A. The Principal Investigator (PI) or Lab Supervisor is responsible for:

1. Providing immediate supervision of personnel using lasers in the laboratory.

2. Appointing a Laser Safety Officer (LSO) for the day-to-day safe operation of a Class 3B or 4 laser/laser system present in the laboratory. Although the PI or Lab Supervisor is ultimately responsible for safe operation of the laser(s), he/she can delegate the day to day operation of the laser(s) to the LSO. Some departments may elect to have a single LSO for their entire department.

3. Providing, implementing, and enforcing the safety recommendations and requirements in this program.

4. Determining those who are qualified/authorized to use lasers(s) in their locations and having these individuals participate in the University's web-based laser safety training program, or equivalent departmental training, as listed in Section III, and document the training.

5. Providing laser users with documented training in the Standard Operating Procedures for lasers in their locations and determining any training required for visitors (non-University personnel, contract personnel, or colleagues). Laser users must sign-off on SOP signature page to demonstrate it was read and understood.

6. Notifying EH&S and the LSO immediately of an exposure or incident involving any laser.

7. Determining the maximum output for any lab manufactured laser and to classify the laser as listed in Section IV and Appendix 6. These lasers must be registered with EH&S using the Laser Registration Form (Appendix 1).

8. Properly disposing or transferring lasers after they are no longer under their operation. Contact EH&S for requirements for either disposal or transferring of lasers.

9. Complying with University policies and programs; non-compliance will be reported to the appropriate dean for action.

B. Laser Safety Officers (LSOs) are responsible for:

1. Completing an inventory of Class 3B and 4 lasers in the laboratory. An Environmental Health & Safety (EH&S) Laser Registration Form, Appendix 1, or equivalent departmental form, is to be used to register all Class 3B and 4

lasers. A copy of the completed inventory is to be sent to EH&S

2. Conducting a Laser Safety Inspection for lasers in their department at least once per year. Appendix 2 provides the information required for the inspection. This form or an equivalent departmental form can be used. Records of the inspections are to be retained in the department. A copy of the inspection form is to be sent to EH&S.

3. Reporting problems of non-compliance with laser safety to EH&S.

4. Notifying EH&S immediately of an exposure, incident or near miss relating to a **Class 3B or 4** laser. Completion of the University Employee Incident or Near Miss Report is required.

5. Verifying that personnel using **Class 3B and Class 4** lasers participated in the University's EHS Laser Safety Training on MyPath or an equivalent departmental program initially and then once every 3 years.

6. Informing PIs to have their laser users participate in the Laser Medical Surveillance Program, as outlined in Section XII, if required by their department.

7. Determining the necessity of access controls (locked doors, laser curtains, etc.).

8. Determining the laser protective eyewear (laser rated goggles, laser rated safety glasses that have built in side shields) needed for **Class 3B & 4** lasers.

C. Laser Users are responsible for:

1. Signing and following SOPs while operating lasers.

2. Keeping the PI, or the LSO informed of any departures from established safety procedures.

3. Attending a session of the University's EHS Laser Safety training on MyPath or an equivalent departmental program. Retraining will be required for those individuals who are noted by the Laser Safety Officer, the PI or the Lab Supervisor as not following the SOPs.

4. Reporting any injury or near miss with a laser using the University's Employee Incident Reporting System.

5. Notifying the PI or lab supervisor of an exposure incident and seek medical assistance for injuries from the use of lasers.
   a. For eye exposures, seek assistance at the University's Flaum Eye Institute

(273-EYES, or 273-3937)

b. For other injuries, seek assistance at the University Health Service.

D. EH&S's Laser Safety Officer will be responsible for:

1. Auditing laser safety inspections to ensure that safety requirements are followed.

2. Providing assistance in evaluating and controlling hazards.

3. Informing the PI, the lab supervisor and/or the Laser Safety Officer for the laboratory of imminent health and safety concerns so immediate steps can be taken to correct the problem.

4. Periodically reviewing and updating the web-based Laser Safety Program.

5. Maintaining the laser inventory for Class 3B and 4 lasers at the University (excluding LLE).

6. Upon receipt of a laser registration, informing PI of the UR Laser Program and it's requirements.

7. Participating in accident investigations involving lasers.

8. Assisting laboratories in the coordination of medical assistance with University Health Service and the University's Flaum Eye Institute, when needed.

9. EH&S recognizes the Laser Safety Program at LLE as equal or superior to the EH&S program. All the listed responsibilities listed for EH&S's Laboratory Safety Unit are accomplished by LLE assigned staff.

E. University Health Service and the University's Flaum Eye Institute are responsible for:

1. Providing medical assistance for laser injuries.

2 Notifying the EH&S of the findings of an incident relating to a **Class 3B or 4** laser so a root cause analysis can be completed.

3. Assisting in the content of a Laser Medical Surveillance Program for those departments requesting such a program.

III. PERSONNEL TRAINING AND QUALIFICATION

A. All Laser Users

1. All staff and students operating lasers are required to attend the University's web-based Laser Safety Training or an equivalent departmental program. The training is to include general information on the classifications of lasers, fundamentals of laser operation, bioeffects of laser radiation, and control measures. A copy of the attendance sheet/quiz for each person participating in the training program is to be maintained in the lab or department of the laser users. The EHS Laser Safety Training on MyPath shall be taken upon initial assignment, and then at least once every 3 years for laser users.

2. The PI/Lab Supervisor, for a laboratory where a **Class 3B or 4** laser is used, shall provide site-specific training to his/her staff for these lasers. Such training can include review of SOPs as listed in III.B.2 and VI.A. Documentation of the training is to be maintained in the lab of the laser users.

3. The PI or Lab Supervisor must document those who he/she considers qualified and authorized to operate a laser. The PI determines the employee's or student's operational qualification from departmental training, technical training, or other acceptable learning experience. Individual departments can require additional qualifications through examination and annual refreshers.

B. Operation of a **Class 3B** or **Class 4** Laser

1. Those items listed in III.A shall be followed.

2. The PI shall review with the laser user the operating manual provided by the manufacturer for the laser equipment to be used, any specific Standard Operating Procedures (SOPs) or experiments to be conducted, and document this training by signing signature page of SOP.

3. PIs of **Class 3B and 4** lasers built in-house shall develop and maintain SOPs consistent with documents provided by the manufacturer of similar lasers.

IV. LASER CLASSIFICATIONS

Lasers and laser systems are grouped according to their capacity to produce injury. Specific controls are required for each group. Lasers manufactured after August 1, 1976 are classified and labeled by the manufacturer. Information on the label includes the laser class, the maximum output power, the pulse duration (if pulsed), and the laser medium or emitted wavelengths. The American National Standard for Safe Use of Lasers modified the classification of lasers in 2014 to:

A. **Class 1**: Low-power lasers and laser systems that cannot emit radiation levels greater than the Maximum Permissible Exposure (MPE). **Class 1** lasers and laser systems are incapable of causing eye damage. These lasers are exempt from control measures.

The maximum exposure duration for a Class 1 laser is assumed to be no more than 30,000 seconds except for infrared systems, with wavelengths greater than 0.7 um, where 100 seconds shall be used. This does NOT apply to service periods requiring access to Class 1 enclosures containing higher-class lasers.

B. **Class 1M:** These lasers and laser systems are considered incapable of producing hazardous exposures during normal use unless the beam is viewed with an optical instrument (collecting optics). These lasers are exempt from control measures other than to prevent potentially hazardous optically aided viewing.

The maximum exposure duration is assumed to be no more than 30,000 seconds except for infrared systems, with wavelengths greater than 0.7 um, where 100 seconds shall be used.

C. **Class 2**: These low-power lasers or laser systems operate in the visible spectrum (400-700 nm) and are incapable of causing eye damage because of the aversion response (0.25 seconds).

Previously rated Class 2 lasers that emit visible radiation less than 0.4 mW are now classified as Class 1.

D. **Class 2M:** These low-power lasers or laser systems operate in the visible spectrum (400-700 nm) and are incapable of causing eye damage because of the aversion response (0.25 seconds). However, Class 2M lasers are potentially hazardous if viewed with certain optical aids.

Previously listed Class 3A lasers for momentary viewing without optical aids are now classified as Class 2M.

E. **Class 3**: Medium power lasers and laser systems capable of causing eye

damage with short duration (<0.25 seconds) exposures to a direct or specular reflection viewing conditions, but is normally NOT a diffuse reflection or fire hazard. This class is subdivided into 3R and 3B lasers.

1. **Class 3R**: These lasers or laser systems may be hazardous under some direct and specular reflection viewing conditions if the eye is focused and stable, but the probability of an eye injury is small. These lasers do NOT pose a fire hazard or a diffuse-reflection hazard.
2. **Class 3B**: These medium-powered lasers or laser systems in the visible or invisible regions may be hazardous under intrabeam (direct) or specular (mirror-like) reflection viewing conditions, but is normally not a diffuse (scattered) or significant skin hazard except for higher power 3B lasers operating at certain wavelength region.

F. **Class 4**: These high-power lasers and laser systems are capable of causing acute hazards to the eye and skin with short-term duration (<0.25 seconds) exposures to direct, specular reflection, or diffuse reflection beams. Class 4 lasers and laser systems are also capable of igniting flammable and combustible materials even from diffuse reflection. These lasers may produce laser-generated air contaminants and hazardous plasma radiation.

G. It is the responsibility of the PI/Lab Supervisor who operates or supervises the operation of a "fabricated" laser to provide sufficient information to EH&S to verify the classification and labeling of the laser.

V. LASER HAZARDS

In addition to the hazards present from laser radiation, many chemicals and other physical hazards shall be controlled. Serious injuries resulting from the use of lasers are generally not from the beam; rather, they are due to electrical and other hazards that were overlooked.

A. Electrical Equipment and Systems

1. High risk of injury and fire exists in laser operations because of the presence of electrical power supplies. High-voltage capacitors require grounding to discharge the component prior to servicing of the laser or laser component. The frames, enclosures, and other accessible metal non-current carrying metallic parts of laser equipment shall be grounded.

2. High-pressure arc lamps, filament lamps, and capacitors in laser equipment can present an explosion hazard. These items shall be enclosed in housing which can withstand the maximum explosive pressure resulting from component disintegration.

3. The installation, operation, and maintenance of electrical equipment and systems shall conform to the standards stated in the National Electric Code (NEC). Research personnel are not permitted to install electrical wiring or outlets in labs, or to daisy chain power strips. For River Campus and Medical School locations, contact Facilities at x3-4567. For the Laboratory for Laser Energetics, contact x5-4575.

B. Ionizing and Non-ionizing Radiation

1. A laser operation may involve ionizing radiation that originates from the presence of radioactive materials or the use of electrical power in excess of 15 kV. Contact the EH&S Radiation Safety Office at x5-3781 for an evaluation of radioactive material hazards for these activities.

2. Microwave and radio frequency (RF) fields may be generated by laser systems or support equipment.

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C. Hazardous Materials

1. Only those hazardous materials that are needed for the operation of a laser should be brought into a laser laboratory. Consult the University's Chemical Hygiene Program for appropriate actions to take to prevent exposures to hazardous chemicals. All hazardous chemicals shall be properly labelled, used, stored, and controlled. Consult the Safety Data Sheets, the product label, and the EH&S Laboratory Safety Unit (x5-3241) for additional

information/assistance.

2. All hazardous chemicals shall be entered into the University's Chemical Inventory/SDS System (Chematix). Contact the Laboratory Safety Unit for details on this system. Chemicals at LLE are entered into a special chemical inventory system in use at LLE.

3. Do not allow laser beams and strong reflections to impinge on combustible materials, highly flammable materials/gases, or substances that decompose into toxic products under elevated temperatures, without providing adequate controls.

4. Laser Generated Air Contaminants (LGAC) may be generated when **Class 3B** and **Class 4** laser beams interact with matter. The primary control measure for LGAC shall be the use of engineering controls. Engineering controls requires general ventilation and may include local exhaust ventilation or isolation of the process. Local exhaust ventilation systems can include hoods, ducts, air cleaners, and fans. The design of a system shall be reviewed by EH&S before the new system is installed. Process isolation may include physical barriers, master-slave manipulators, or remote control apparatus. Respiratory protection shall be implemented as a means of protection only after the use of engineering controls. All use of respiratory protection shall comply with the University's Respiratory Protection Program. Contact the EH&S Occupational Safety Unit at x5-3241 for additional information.

D. Dyes and Solutions

1. Dye lasers normally use a lasing medium composed of a complex fluorescent organic dye dissolved in an organic solvent. These dyes vary greatly in toxicity, mutagenicity, and potential carcinogenicity. All dyes and dye solutions shall be treated as hazardous chemicals. Most solvents suitable for dye solutions are flammable and toxic by inhalation and/or skin absorption.

2. Obtain the Safety Data Sheet from the manufacturer/supplier or from EH&S for any dye or solvent used.

3. Use and store all dyes and solvents in accordance with the University's Chemical Hygiene Program.

4. Prepare/handle dye solutions in a chemical fume hood. Wear a lab coat, eye protection, and gloves. The Laboratory Safety Unit can assist in the selection of the required personal protective equipment.

5. Pressure-test dye laser components before using dye solutions. Pay particular attention to those connections that may allow material to escape containment.

Install spill pans (secondary containment) under pumps and reservoirs.

E. Compressed Gases

1. SOPs are to be developed when a laser application includes gases such as chlorine, fluorine, hydrogen chloride, or hydrogen fluoride. Any compressed gas, with a NFPA health hazard rating of **3 or 4 (or GHS rating of 1 or 2)**, either used or stored in a laser lab or other laboratory support location, is to be enclosed in an approved and operational ventilated gas cabinet. Contact the Laboratory Safety Unit to determine if any additional special exhaust system is required.

2. All gas cylinders are to be labeled. Different classes of gases are to be stored separately.

3. All compressed gas cylinders are to be stored upright and secured to the wall or bench with an approved chain or cylinder strap.

4. When gas cylinders are not in use or whenever the cylinders are transported, the protective caps shall be in place.

5. All personnel working in a laser lab using compressed gases shall complete training on gas safety annually. This training is provided in the EH&S's Lab Safety Training on MyPath or LLE's training courses.

F. Cryogenic Liquids

1. Cryogenic liquids, such as liquid nitrogen, are used occasionally to cool lasers and to cool sensors used as receivers of reflected or transmitted laser signals.

2. Insulated gloves, clothing without pockets or cuffs, and chemical splash goggles or face shields shall be worn when transporting or using cryogenic materials. Safety spectacles without side shields are inadequate.

3. Inert gas may reduce the oxygen level in a room causing unconsciousness or death. Use cryogenics only in well-ventilated areas.

4. State, local and federal regulators consider cryogenic liquids as compressed gases. General gas safety training, as listed in V.E.5 above, will provide the necessary training to use these materials properly.

VI. GENERAL LASER SAFETY REQUIREMENTS

A. Standard Operating Procedures (SOPs): The establishment of written Standard Operating Procedures and their use, especially in locations where the laser operators may have limited experience, can greatly reduce hazards to those in the location and minimize exposures. See Appendix 7 for a Laser SOP Template. SOPs and controls include:

1. Designation of a laser control area for all Class 3B and 4 lasers by the LSO. In lieu of calculations, the entire room can be designated the laser control area.

2. A laser control area having an accessible evacuation path for emergencies.

3. Step by step instructions for startup, shutdown, emergency shutdown, and alignment.

4. Specification for type of laser protective eyewear required including wavelength and OD.

5. Steps to take after an incident or near miss.

6. The use of partitions, curtains, beam stops or interlocks for separating one laser or laser system from others.

7. A thorough discussion of alignment procedures and possible hazards before carrying out an actual laser alignment. When alignment is done, the required PPE shall be utilized. When needed, a temporary laser controlled area shall be established. Alignment must be done with a low power visible beam unless additional controls are in place to minimize exposure potential to the beam.

8. Lasers shall be limited to the lowest output power needed for the demonstrations in classrooms or lecture halls. For Class 3B and 4 lasers, the written SOP shall specify the necessary controls required during the demonstration.

B. Eye Protection: The manufacturer's laser manual states the level of eye protection needed to protect personnel when using a particular laser. The PI/Lab Supervisor, LSO or designated representative is responsible for determining/verifying the need for laser eye protection for a particular laser(s). When required, eye protection will be provided by the PI or Lab Supervisor for staff and visitors to wear in the laser control area. Contact the Laboratory Safety Unit for assistance in the appropriate selection.

C. The minimum laser radiant energy or laser power level required for the application shall always be used.

D. Beam Control: To minimize direct eye exposure, the following precautions are to be followed:

1. Do not look directly into the laser beam or at a specular or diffuse reflection, regardless of its power.

2. Terminate the beam at the end of its useful path.

3. Locate the beam path at a point other than eye level when standing or when sitting at a desk.

4. Minimize specular reflections. Watches and jewelry should be removed, or need to be covered by using gloves and long sleeves to cover reflective items. Use non-reflective tools in laser area.

5. Securely mount the laser system on a stable platform to maintain the beam in a fixed position during operation and limit beam traverse during adjustments.

6. Confine primary beams and dangerous reflections to a defined laser radiation area.

7. Orient the laser so that the beam is not directed towards entry doors or aisles.

8. Clearly identify beam paths and ensure that they do not cross "populated" areas or traffic areas.

9. Enclose the beam path as much as feasible. When the beam path is not totally enclosed, locate the laser system so that the beam path will be outside the normal eye-level range. A beam path that exits from a controlled area shall be enclosed whenever the beam irradiance exceeds the MPE.

10. Class 4 beam enclosures must be fabricated from fire-resistant materials.

VII. ADDITIONAL CONTROLS FOR **CLASS 2** and 2M LASERS

A. Warning Signs: A sign is to be mounted at each entrance to the operating area that conforms to ANSI Z136.1 – 2014 (Figure 1a) or ANSI Z136.1 – 2007 (Figure 1a).

B. Warning Signs: Alternate signage that meets the IEC 60825-1 or ANSI Z535, the most recent edition, can be used for the signage for all classes of lasers.

C. If the laser has not been labeled by the manufacturer, attach a label on the laser with its classification and relevant warning information. Contact the Laboratory Safety Unit for assistance.

D. Refer to Section VIII and Appendices 3 & 4 for assistance on control measures for various classifications of lasers.

VIII. GENERAL CONTROLS FOR **CLASS 3** AND **CLASS 4** LASERS

A. PIs/supervisors are required to have the operating manuals available in the laboratory for **Class 3** and **Class 4** lasers. All users are to observe proper procedures for alignment, operation and maintenance of the laser.

B. Labels: A laser classification label shall be conspicuously affixed to the laser housing.

C. Warning Signs

1. For all **Class 3R** lasers and laser systems, each entrance shall be posted with a sign that conforms to ANSI Z136.1 – 2014 (Figure 1a) or ANSI Z136.1 – 2007 (Figure 1a).

2. For **Class 3B** laser and laser systems, each entrance shall be posted with a sign that conforms to ANSI Z136.1 – 2014 (Figure 1b) or ANSI Z136.1 – 2007 (Figure 1b).

3. For **Class 4** laser and laser systems, each entrance shall be posted with a sign that conforms to ANSI Z136.1 – 2014 (Figure 1b, 1c) or ANSI Z136.1 – 2007 (Figure 1b, 1c).

D. Controlled access in laser labs:

1. Laser controlled areas shall be established that have doors that lock (but non-lockable from the inside in case of an emergency), window coverings, and surfaces consisting of diffuse reflected material. The facility shall be a fully enclosed room or laboratory with floor-to-ceiling walls.

2. Access to the area during laser operation requires the permission of the authorized laser operator.

E. Key Control

1. A **Class 3B** laser should be provided with a master switch. This master switch shall be operated by a key or by a coded access.

2. A **Class 4** laser shall be provided with a master switch. This master switch shall be operated by a key or by a coded access.

F. Safety Interlocks

1. All protective enclosures/housings that surround commercial laser devices and high-voltage electrical sources shall also be protected with interlocks.

Interlocks shall be designed so that after they are actuated, the capacitor banks, shutters, or power supplies cannot be re-energized except by manually resetting the system.

2. If interlocks are not feasible, the PI/Lab Supervisor may consider the use of alarms or voice warnings. The Laboratory Safety Unit shall be consulted for these options.

G. Securely fasten all mirrors, prisms, beam stops, etc., in the beam path. Ensure that the laser is also securely fastened.

H. Circuit breakers shall be identified and labeled for each laser and accessible for emergency shutdown.

I. Beam Enclosure: The entire beam path of **Class 3B** and **Class 4** lasers, including the target area, should be surrounded by an enclosure, if practical. When total enclosures of the laser beam path is not practical, both the non-enclosed laser beam and any strong reflections shall be terminated at the end of the useful path. Such devices include backstops, shields, or beam traps.

J. Reflection Control: Materials that diffusely reflect laser radiation shall be used in place of specular reflective surfaces whenever possible. To minimize personnel exposure, specular reflecting surfaces that are needed for beam-path control shall be enclosed or shielded.

K. Invisible Beams: Ultraviolet (UV) and infrared (IR) lasers that emit invisible beams require additional controls. Shields shall be installed that will attenuate UV radiation to levels below the MPE for the wavelength being used. Hazardous concentrations of by-products formed by the reaction of intense UV radiation with materials in the area shall be controlled. IR beam enclosures and backstops shall be fabricated with IR-absorbent material. For **Class 4** lasers, the absorbent material shall also be fire-resistant.

L. Direct Viewing: Personnel shall never look directly into any laser beam unless such action is specifically approved by the LSO or the Laboratory Safety Unit. The primary beam and specular reflections of **Class 3B** and **Class 4** lasers are particularly hazardous. In those cases where it is necessary to directly view a beam from a **Class 3B** or **Class 4** laser, special provisions, such as filters, are mandatory.

M. Alignment: High-power laser optical systems shall never be aligned by direct beam viewing if the radiant exposure or irradiance exceeds the MPE. Appropriate alignment goggles, diffuse reflectors, image-retaining screens, exposed Polaroid film, and other devices that will minimize eye exposure are to be used to properly align a high-power laser. Also, where feasible, a visible low power laser should be used for alignment of a high power laser.

N. Optical Viewing Aids: Using optical systems such as cameras, microscopes, etc., to view laser beams may increase the eye hazard. All collecting optics shall incorporate suitable means (such as interlocks, filters, or attenuators) to prevent eye exposures above the MPE.

O. Unattended Equipment: When lasers are to be left unattended, de-energize the power supplies or capacitor banks or lock the door to prevent unauthorized entry or activation of the equipment. The operation of unattended lasers is only allowed when a specific SOP has been written and approved by the PI/Lab Supervisor.

P. Temporary Installations: Occasionally, it may be necessary to remove protective enclosures or override equipment interlocks or other safety devices for service adjustments, maintenance, special training exercises, etc. In these instances, a temporary controlled laser area shall be set up. Because the area will not have all the standard safety features, the SOP shall describe provisions for protecting personnel who could potentially be exposed. See Section IX.

IX. CONVERTING TO A CLASS 1 ENCLOSURE LASER

Any laser or laser system can be converted to a **Class 1** enclosed laser by including all the following controls in the laser system. These controls will effectively enclose the laser, thus preventing personnel contact with the emitted radiation while permitting unrestricted access into the area.

A. Protective Housing: House the laser system within a protective enclosure to prevent the escape of laser radiation above the MPE. The protective housing shall prevent personnel access to the laser system during normal operations. Personnel entering the enclosure to perform maintenance or adjustment tasks shall be made aware of the higher risks and comply with the control measures for the higher risk laser class.

B. Safety Interlocks: Commercial lasers should have installed safety interlocks whenever the protective enclosure can be opened, removed, or displaced. When activated, these interlocks shall prevent a beam with a radiant energy above the MPE from leaving the laser or laser system. Service adjustments or maintenance work performed on the laser system shall not render the interlocks inoperative or cause exposure levels outside the enclosure to exceed the MPE, unless the work is performed in a laser area with limited access and appropriate safeguards, supervision, and controls.

C. Fail-Safe Design: The protective enclosure and the laser system shall be designed and fabricated so that if a failure occurs, the system will continue to meet the requirements for a **Class 1** enclosed laser system.

D. Modifications to commercial laser systems shall be evaluated. Contact the Laboratory Safety Unit for a review of the evaluation. If the modifications decrease the safety controls, an SOP will be required.

E. Attenuated Viewing Windows: Use viewing windows containing a suitable filter material that will attenuate the transmitted laser radiation to the levels below the MPE under all conditions of operation.

F. Warnings Signs and Labels: Label the enclosure with "DANGER” [if a Class 3B or 4 inside] - ENCLOSED LASER" sign. Attach a label directly to the laser to give the laser classification in the absence of the enclosure. Make sure that the label can be seen immediately when the enclosure is opened.

X. PROTECTIVE EQUIPMENT

A. Eye Protection

1. Laser protective eye wear shall be worn whenever MPE levels may be exceeded. Information on the selection of laser protective eyewear for Class 3B or 4 lasers is available through ANSI Z136.1-2014 Section 4.4.4.2.

2. In general, eyewear provides protection over a narrow range of the laser spectrum. Eyewear designed for protection at one wavelength may afford little or no protection at another wavelength. Consult the laser manufacturer, a laser eyewear supplier/manufacturer, or the Laboratory Safety Unit for proper selection of protective eyewear.

3. Laser protective eyewear shall be approved by the American National Standards Institute (ANSI Z87.1-2010) and be clearly labeled with optical densities and wavelength for which protection is afforded. The use, storage, and limitations of protection afforded by personal protective equipment should be known. Consult the UofR's Personal Protective Equipment Plan for additional information. Eyewear shall be inspected every 6 months by the LSO for pitting and cracking of the attenuating material, for mechanical integrity, and light leaks in the frame. Records of the eyewear inspections are to be retained in the laser lab.

B. Skin protection

1. Protection for the skin may be afforded through the use of clothing to cover normally exposed skin areas.

2. Skin protection is recommended for repeated ultraviolet exposures from Excimer lasers. Such protection includes long sleeved shirts and gloves. UV rated creams are recommended for the face and ears.

3. Any type of glove or lab coat used for protection from a **Class 4** laser shall be made of flame retardant material.

XI. POSSIBLE EXPOSURES FROM LASERS

A. All exposures to laser light are to be maintained as far below the Maximum Permissible Exposure (MPE) as is practicable. The MPE is the level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. The criteria for MPE for the eye and skin are listed in ANSI Z136.1-2014. The MPE depends on several factors, including the wavelength, exposure duration, and whether the exposure is to the eye or skin. Refer to ANSI Z136.1-2014 Section 8 for information in determining the MPE for any specific situation.

1. Eye Exposures: The greatest risk in using lasers is eye damage from radiation that the laser emits. The eye tissue most at risk varies based on the wavelength of light the laser is utilizing.
    a. For lasers operating in the visible spectrum, if the eye intercepts the total beam, the radiance at the eye is the same regardless of the distance of the viewer from the source. This is because the exposure at the retina remains the same due to the eye's focusing properties.
    b. Acute exposure of the eye to lasers of certain wavelength and power can cause corneal and/or retinal burns. The cornea is sensitive to far-IR and UV wavelengths. The lens is sensitive to near IR and near UV wavelengths. The retina is sensitive to near IR and visible wavelengths. Invisible IR and UV laser beams are most likely to cause ocular exposures.
    c. Chronic exposure to excessive levels may cause corneal or lenticular opacities (cataracts) or retinal injury.

2. Skin Exposures
    a. Acute exposure to high levels of optical radiation may cause a rise in temperature of the skin and result in skin burns. Almost 100% of radiation between 4 and 40 μm is absorbed (CO_2 lasers emit at 10.1 μm).
    b. The skin exposure hazard for UV lasers is greater than for others. Chronic exposures to UV wavelengths (290-320 nm) may result in carcinogenesis.

B. Chemical Exposures: Some lasers require hazardous substances for their operation (i.e., chemical dye, Excimer lasers). Consult Section V.C-F for specific information relating to these materials.

C. Electrical shock: Most high-power lasers require high voltages that can be lethal. Observe the precautions listed in Section V.A.

D. Fire hazards: The solvents used in dye lasers may be flammable. High-voltage pulse or flash lamps may cause ignition. Flammable and combustible materials may be ignited by direct beams or specular reflections from high-power, continuous-wave (CW) infrared lasers.

XII. MEDICAL SURVEILLANCE

A. Pre-placement eye examinations are **NOT** required for using lasers. Departments and PIs/Lab Supervisors can elect to have their employees/students have pre-placement eye examinations for those using Class 3B and 4 lasers.

1. A baseline eye examination for those PIs/Lab Supervisors electing to have their laser users can include ocular history, Amsler Grid Test, macular function, and visual acuity (correctable to 20/20). All such examinations will be conducted without charge to the employee and will be conducted during work hours.

2. A laser eye examination can be scheduled by calling the University's Flaum Eye Institute at 273-3937and requesting a laser eye examination. These examinations are performed by and under the supervision of an ophthalmologist, optometrist, or a qualified physician.

3. Skin examinations are not required for pre-placement except for those individuals who will be working with ultraviolet lasers and have a history of photosensitivity. These examinations can be scheduled through UHS.

4. An examination is recommended, but not required, when an individual terminates his/her work with **Class 3B or 4** lasers. A department can be more restrictive and elect to have their employees using lasers undergo an exit laser eye exam when the employee terminates his/her work with lasers.

5. All records of medical examinations will be retained for at least 30 years by the University's Health Information Management System.

B. EXPOSURE INCIDENTS

1. If the incident causes an injury or could potentially have caused an injury, the person or persons need to inform their PI/Lab supervisor.

2. Any individual with a suspected eye injury should be referred to the UofR's Flaum Eye Institute (call 273-3937).

3. Injuries/exposures from chemicals and electrical operations or laser beam interactions to the skin should be seen by a UHS (call x5-1155).

4. Complete a University Employee Incident Report for any injuries. Access to the reporting system is available at http://www.safety.rochester.edu/SMH115.html . A near miss is reported using the same system choosing the Near Miss option.

5. The Laboratory Safety Unit will conduct or assist in an investigation to determine the root cause and assist the staff in establishing appropriate measures to prevent additional incidents.

APPENDIX 1
REGISTRATION FORM
For
RESEARCH LASERS

Directions:

Complete this registration form for each Class 3B and 4 research laser.

DEPARTMENT:		**PI/SUPERVISOR:**	
BULDING:		**LASER SAFETY OFFICER:**	
ROOM #:			

MANUFACTURER	
MODEL NO.	
SERIAL NO.	
HAZARD CLASS (1,1M, 2,2M, 3R, 3B, 4)	
YEAR MANUFACTURED	
TYPE (CW or PULSED)	
LASING MEDIUM	
MAXIMUM OUTPUT	
OPERATIONAL WAVELENGTH(s) [NM]	
PULSE WIDTH / REPETITION RATE	
BEAM DIVERGENCE	
EMERGENT BEAM DIAMETER	
ACTIVE/INACTIVE	
PROPERTY TAG NO.	
PURPOSE	
Laser Eyewear wavelength range and OD	
Is Beam fully enclosed, partially enclosed or open	

Name (print):_____ Signature: _____

Date:____/____/_____

Send a copy of the inventory form to:
Environmental Health and Safety, Box 278878, Fax #274-0001

APPENDIX 2
RESEARCH LASER SAFETY INSPECTION FORM

Complete this survey ***annually*** for each room where a Class 3B or 4 laser is in use.

BUILDING:		**PI/GROUP:**	
DEPARTMENT:		**ROOM #:**	
Laser		**Hazard Class**	
Serial #		**Property Tag No.**	

Answer the following questions with Y (yes), N (no) or NA (not applicable).
Those answers N (NO) indicate a problem that needs corrective action.

DOCUMENTATION

- Has the laser been registered with EH&S? ..... ____
- Has a written operating procedure been completed for the laser? ..... ____
- Have all laser operators had laser-specific training and signed-off on operating procedures? ____
- Have all laser operators taken EHS Laser Safety on MyPath within the past 3 years?…… ____
- Are all laser personnel authorized? ……... ____
- Have all laser operators been informed of emergency procedures? ……. ____
- Does the laser controlled area have an appropriate laser sign at each entrance?…….…… ____

PERSONAL PROTECTIVE EQUIPMENT (PPE)

- Do operators wear laser-eye goggles labelled for wavelength(s) of beam used?……... ____
- Are laser-eye goggles available for visitors? ……. ____
- Are laser-eye goggles inspected every 6 months for signs of pitting/cracking/damage?…. ____
- Are gloves available for lasers generating UV light? …..…… ____
- Is the needed PPE available for cryogenic liquids? …… ____
- Is PPE available for chemicals? …….. ____
- Are flame-resistant lab coats utilized for Class 4 lasers? …….. ____

ELECTRICAL/CHEMICAL SAFETY

- Are energized components enclosed? ……. ____
- Are interlocks checked at least annually? ……. ____
- Are Class 3B and 4 lasers equipped with a master switch with key control? …….. ____
- Is the area free of extension cords? ……. ____
- Are the chemicals stored properly according to hazard class? …… ____
- Is secondary containment used for dye lasers and associated equipment (pumps)? …….. ____
- Are compressed gas cylinders stored properly (upright, labeled, strapped)? …….. ____
- Are GHS health hazard 1/2 hazardous gases used in specially designed exhaust systems? ____
- Is a Class B:C fire extinguisher within 50’ of locations if flammable solvents are present? ____

BEAM PATHS

- Are beams terminated at the end of the useful path? …….. ____
- Is the beam height below eye level?..... ……..…… ____
- Is the laser oriented away from doors and aisles? ……..... ____
- Do personnel remove/cover jewelry when using lasers? ……..…… ____
- Are Class 4 beam enclosures fabricated from fire-resistant materials? ……..…. ____
- Are optical systems aligned using film/devices to minimize eye exposures? ……..… ____
- Are non-reflective tools used for work around laser (i.e. alignment)?..... _____
- Is the beam enclosed as much as possible to minimize exposure potential?..... _____
- Are beams aligned using low power visible beams?..... _____
  - If No, what other controls are in place to prevent exposure?_____

NAME (print): _____ Signature: _____

Please send a copy of completed form to Environmental Health & Safety, Box 278878 (or fax 274-0001)

APPENDIX 3
ENGINEERING CONTROL MEASURES FOR LASER CLASSES
(References cited for the control measure are from ANSI Z136.1-2014)

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 requited 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
▼ Shall if enclosed Class 3B or Class 4
NHZ Nominal Hazard Zone analysis required

APPENDIX 4
ADMINISTRATIVE & PROCEDURAL CONTROL
MEASURES FOR LASER CLASSES
(References cited for the control measure are from ANSI Z136.1-2014)

Administrative Control Measure	**CLASSIFICATION**						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.3.1)	-	-	-	-	-	●	X
Output Emission Limitation (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)	-	-	-	-	-	-	X
Laser in Navigable Airspace (4.4.3.6.2)	●	●	●	●	●	●	●
Alignment Procedures (4.4.3.6.2)	▼	X	X	X	X	X	X
Spectators (4.4.3.7)	-	○	-	○	-	●	X
Service Personnel (4.4.3.9)	LSO Determination						

LEGEND:
- X Shall
- ● Should
- ▼ 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 5
CONTROL MEASURES FOR LASER CLASSES
(References cited for the control measure are from ANSI Z136.1-2014)

	CLASSIFICATION						
	1	1M	2	2M	3R	3B	4
PPE: Laser Eye Protection (4.4.4.1)	-	-	-	-	-	X	X
PPE: Skin Protection (4.4.4.3)	-	-	-	-	-	●	●
Protective Clothing (4.4.4.1 and 4.4.4.3.1)	-	-	-	-	-	●	●
Laser Controlled Area Warning Signs (4.6)	-	-	-	-	-	X	X

APPENDIX 6
HAZARD CLASSIFICATION FOR CONTINUOUS WAVE LASERS
(From ANSI Z136.5-2009, Table 6)

Laser Type	**Wavelength (nm)**	**Power Range (W)**	**Maximum Hazard Class**
Helium-Cadmium (HeCd)	325	3.2×10^{-6} to 0.5	Class 3B
Argon (Ar)	351, 363	3.2×10^{-6} to 0.5	Class 3B
Argon (Ar)	488, 512	<0.001	Class 2
Helium-Neon (HeNe)	633	<0.001	Class 2
InGaAlP (diode)	670	<0.001	Class 2
Argon (Ar)	488, 514	0.001 to 0.005	Class 3R
Helium-Neon (HeNe)	633	0.001 to 0.005	Class 3R
InGaAlP (diode)	670	0.001 to 0.005	Class 3R
Argon (Ar)	488, 550	>0.5	Class 4
InGaAlP (diode)	670	>0.5	Class 4
Dye	400 to 550	>0.5	Class 4
GaAlAs (diode)	780	0.00018 to 0.5	Class 3B
InGaAs (diode)	900 to	0.004 to 0.5	Class 3B
Yb:Si Fiber	1020 to 1070	>0.5	Class 4
Nd:YAG	1064	0.00064 to 0.5	Class 3B
InGaAsP (diode)	1310	0.0044 to 0.5	Class 3B
Doubled Nd:YAG	532	>0.5	Class 4
Carbon Dioxide (CO_2)	10,600	>0.5	Class 4

APPENDIX 7:
Laser SOP Template

This outline is intended as guidance for preparing laser standard operating procedures (SOPs). The SOP should include all lasers in a given laser system, including alignment and pumping lasers. The SOP should be reviewed and revised as needed.

Enter Title Here

PI/Manager of space:
SOP written by:
Date:

Section 1: Overview

Describe the laser systems used in this application

A. Location of laser/laser systems (building, room)
B. Description of each laser:
    - Classification
    - Output characteristics
D. Purpose/application of laser system

Section 2: Risk Assessment Summary

Identify all hazards present and describe the risks they pose under operating conditions:

A. Laser beam(s)
B. Electrical
C. Chemical
D. Fire/explosion
E. UV light

Section 3: Controls

Describe controls used to mitigate the hazards

A. Engineering controls, e.g., interlocks, beam stops.
B. Administrative controls, e.g., signs, LSOP, etc.
C. Personnel Protective Equipment, e.g., laser eye protection (OD and wavelength range), gloves, flame-resistant lab coat.

Section 4: Operating Procedures

Provide a step-by-step description of the procedure and include:

A. Equipment preparation (start-up)
B. Operation
C. Normal Shutdown procedures
D. Special procedures:
    - Alignment-align with low power visible beam
    - Safety checks
    - Maintenance

Section 5: Emergency Response

A. Immediate actions
B. Emergency shut down of laser
C. Medical assistance
    1. If the incident causes an injury or could potentially have caused an injury, the person or persons need to inform their PI/Lab supervisor.

    2. Any individual with a suspected eye injury should be referred to the UofR's Flaum Eye Institute (call273-3937).

    3. Injuries/exposures from chemicals and electrical operations or laser beam interactions to the skin should be seen by a UHS (call x5-1155). After hours, go to the Emergency Department or urgent care.

    4. Complete a University Employee Incident Report for any injuries. Access to the reporting system is available at http://www.safety.rochester.edu/SMH115.html . A near miss is reported using the same system but choosing the Near Miss/Hazard option.

    5. The Laboratory Safety Unit will conduct or assist in an investigation to determine the root cause and assist the staff in establishing appropriate measures to prevent additional incidents.

D. Contact information
    Public Safety x13, or 275-3333
    UHS (University Health Service): 585-275-2662 (students); 585-275-4955 (employees)
    Flaum Eye Institute: 585-275-3937

Section 6: Additional Information

Provide any additional information and policies, e.g. regarding unattended operation, safety of building service workers or visitors, etc.

Section 7: User Training and Authorization

List training requirements for authorized users

1. *Complete EHS Laser Safety training on MyPath*
2. *Obtain laser specific training from PI or designee*

Training Documentation

Signing this document means that you have read and understand all aspects of this Standard Operating Procedure.

The supervisor is the person that acknowledges you took the training and understand the procedure. They can be a lab manager or researcher assigned by the PI to oversee this particular SOP.

Name (Printed)	Name (Signed)	Supervisor	Date