

ENVIRONMENTAL HEALTH AND SAFETY

LASER SAFETY

PROGRAM DESCRIPTION

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# Purpose

Laser Safety is the responsibility of all individuals at The Pennsylvania State University (the University) including faculty, staff, students, researchers, and visitors. The use of lasers at Penn State requires compliance to federal and state guidelines and university policies, which are important for the safety and protection of all individuals at the University.

The Rules and Procedures in this document have been adopted by The Pennsylvania State University to provide for the safe use of lasers at the University. They are distributed to help inform workers at the University about how to meet the requirements of federal and state guidelines and University requirements. It is the intent of the University that these Rules and Procedures allow as much freedom as possible for experimenters while assuring that injury and exposure of personnel to nonionizing radiation be minimalized.

This document contains requirements that cover the possession, use, and transfer of all class 3B and 4 lasers, and class 1 lasers with embedded 3B or 4 lasers on Penn State controlled property by Penn State personnel or others and by Penn State personnel in the field. It is also a resource and guide for all other laser classes and should be referenced by anyone working with lasers, regardless of class.

# Introduction

Lasers are capable of causing injuries to the eyes and skin. Class 3B lasers are capable of causing eye injuries from direct beam and specular reflection exposure. Class 4 lasers are capable of causing eye and skin injuries from the direct beam, specular and diffuse reflections, igniting flammable materials, and generating hazardous air contaminants.

Although lower classes of lasers (Class 1, 1M, 2, 2M, and 3A or 3R) are not subject to this manual and policy, their use is subject to other applicable requirements of the American National Standard Institute (ANSI). Users of lasers must ensure safe use. Please consult with the Laser Safety Officer (LSO) if additional information is needed.

This Manual is not intended to be a fully comprehensive reference but is to ensure the safe use of lasers at the University. To achieve this goal, Penn State has referenced applicable regulations and the most recent ANSI for Safe Use of Lasers, ANSI Z136.1, which is recognized as the best practice standard for laser safety and widely used by regulatory agencies including the Food and Drug Administration (FDA) and Occupational Safety and Health Administration (OSHA). Additional hazards associated with lasers such as high voltage, high pressure, noise, radiation, and toxic gases due to laser operations are also mentioned in this manual. Further advice concerning hazards associated with specific lasers and/or the development of new and unfamiliar procedures should be obtained through consultation with the LSO or Environmental Health & Safety (EHS).

# Scope and Applicability

These Rules and Procedures cover the possession, use, and transfer of all class 3B and 4 lasers, and class 1 lasers with embedded 3B or 4 lasers on Penn State controlled property by Penn State personnel or others and by Penn State personnel in the field. This includes the non-University Park campuses, but not the Milton S. Hershey Medical Center or the College of Medicine located at the Hershey campus. The medical center and the College of Medicine are covered by rules which are administered by entities separate from Penn State.

Penn State institutions that require special access, such as the Applied Research Laboratory (ARL), to which EHS and the LSO have escorted access only, shall follow the requirements outlined in this manual. However, these institutions may appoint their own LSO who can ensure users within their institution follow applicable regulations and guidelines. This designee may deal with day-to-day laser safety issues and special exemptions on their own but must inform the University LSO of any decisions made that are different than any policies outlined in this document. Any changes agreed upon by the designated ARL LSO and the LSO will be recorded and kept on file with EHS records. Penn State’s LSO has the same responsibilities over ARL lasers as outlined in section 5 and ARL has the same recordkeeping requirements and evaluation standards as outlined in section 7.

These Rules and Procedures are intended for use by everyone who works with lasers covered by these Rules. An electronic copy is available on the Penn State [EHS Website](https://ehs.psu.edu/laser-safety/overview) and can be downloaded there for your reference.

Where existing or future federal, state, or local regulations are found to be different from the requirements contained in this manual, those legally accepted regulations shall supersede this document.

# Terms and Definitions

## Acronyms and Abbreviations

AEL: Accessible Emission Limit

ANSI: American National Standards Institute

AU: Authorized User

CW: Continuous Wave

EHS: Environmental Health and Safety

FLPPS: Federal Laser Product Performance Standard

Hz: Hertz

IAW: In Accordance With

IR: Infrared

J: Joule

LCA: Laser Controlled Area

LEP: Laser Eye Protection

LGAC: Laser Generated Airborne Contaminants

LSO: Laser Safety Officer

MPE: Maximum Permissible Exposure

MDS: Material Data Sheet

NHZ: Nominal Hazard Zone

NOHD: Nominal Ocular Hazard Distance

OD: Optical Density

PI: Principal Investigator

PPE: Personal Protective Equipment

SOP: Standard Operating Procedure

UV: Ultraviolet

VLT: Visible Light Transmission

W: Watt

## Definitions

The definitions listed below are given in a pragmatic as opposed to a detailed manner. They are defined to reflect their use in this document and at Penn State. They are in no way intended to reflect dictionary definitions or their use in any other field or location.

**Accessible Emission Limit**: The maximum accessible laser emission level permitted within a certain laser class.

**Accessible laser radiation**: The laser radiation emitted from a certain laser under a certain set-up and conditions to be compared with the AEL to determine the laser’s hazard class.

**Administrative control measures**: Control measures incorporating administrative or procedural means [e.g., training, signage, SOPs] to mitigate potential hazards.

**Authorized Personnel**: Individuals approved by lab management or PI to operate, maintain, service, or install laser equipment.

**Authorized User**: Individual who is the principal user of the laser and directly in charge of control measures. Can also be Principal Investigator.

**Aversion Response**: Closure of the eyelid or movement of the eye or head in response to a noxious or bright light situation. For the purposes of this document, the aversion response is considered to be 0.25seconds or less from exposure to a bright, visible, laser source.

**Collateral radiation**: Any electromagnetic radiation, except for laser radiation, emitted by a laser system.

**Collecting optics**: Optical instruments, including lenses and telescopes, that have magnification and would cause an increase in power density of the laser beam. Prescription glasses are not considered collecting optics.

**Continuous Wave**: A laser having a continuous output for a period of 0.25 seconds or greater.

**Control Measure**: A means to mitigate potential hazard associated with the use of lasers. Control measures can be engineering, administrative, or PPE.

**Diffuse Reflection**: The reflection of a laser beam off of a non-reflective surface or medium which causes the energy to scatter in a random distribution.

**Embedded Laser**: A laser with a higher classification than the system it is enclosed in due to engineering controls limiting the access to laser emission.

**Enclosed Laser**: A laser contained within a protective housing of itself or another laser system. Removal of this protective housing would provide additional access to laser radiation than intended and may cause an increase of hazard class or exposure above MPE.

**Energy**: Characterizes the output of pulsed lasers and is expressed in units of Joules

**Engineering control measures**: Physical control measures designed or incorporated into the laser system or application. [e.g., interlocks, shutters, barriers]

**Infrared**: For the purpose of this document, the region of the electromagnetic spectrum between 700 nanometers and 1 millimeter.

**Intrabeam viewing**: The viewing condition in which the eye is exposed to all or part of the laser beam before the beam has been reflected or diffused.

**Irradiance**: Power incident per unit area upon a surface, expressed in Watts per square centimeter.

**Joule**: A unit of energy. 1J = 1W/s

**Laser barrier**: A device used to block or attenuate direct or diffuse laser radiation. Laser barriers are often used to establish the boundary of a laser control area

**Laser Control Area**: The laser use area where the occupancy and activity of those within in controlled and supervised. Usually, the barrier in which only authorized laser personnel can enter. This area may be defined by walls, barriers, or other means. Within this area a potentially hazardous laser exposure may occur. Can be a different area than the NHZ. The entrances to the LCA are where the Warning signs shall be posted.

**Maintenance**: Performance of those adjustments or procedures, which are carried out by the user(s) to ensure the intended performance of the product. Maintenance does not include *operation* or *service* as defined in this section.

**Maximum Permissible Exposure (MPE):** The level of laser radiation in which an unprotected person may be exposed to without any adverse biological effects to the eyes or skin. Exposures above this level can result in injuries to the eyes or skin. All control measures are designed to keep any exposure under the MPE.

**Nominal Hazard Zone (NHZ):** The physical space in which the level of direct, reflected, or scattered radiation may exceed the MPE. Exposure levels beyond this space will be below the MPE.

**Nominal Ocular Hazard Distance (NOHD):** The distance along the axis of an unobstructed laser beam in which a direct exposure would not result in laser radiation levels above the MPE. Exposure before this distance would result in laser radiation levels above the MPE. Only a factor of concern for lasers used outdoors or within a first-floor lab with windows.

**Operation:** The performance of the laser or laser system over the full range of its intended functions. Also referred to as *Normal Operation*. Operation does not include *maintenance* or *service* as defined in this section

**Optical Density (OD):** The transmittance factor of a pair of LEP given as a whole number between 1-10. Every pair of LEP is required to be labeled with the OD it affords for each wavelength it protects from.

**Personal Protective Equipment:** Personal safety protective device used to mitigate hazards associated with laser use.

**Principal Investigator:** Owner of the lab or area where lasers are used or owner of the laser or laser system. Can be both. See Authorized User.

**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 laser is emitted is not considered part of the protective housing. The protective housing also limits access to other energy emissions and electrical hazards associated with the components and terminals. The protective housing may also enclose optics or an entire workstation.

**Pulsed laser:** A laser that delivers its energy in the form of a single pulse or train of pulses.

**Q-switch**: A device for producing a very short, intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium. These are usually added after-market and can make a laser much more hazardous.

**Radiant Exposure**: Surface density of the radiant energy received, expressed in units of Joules per unit area.

**Reflection**: Deviation of radiation following incidence on a surface

**Retina**: the sensory tissue that receives the incident image formed by the cornea and lens of the human eye.

**Retinal hazard region**: Optical radiation with wavelengths between 400 and 1400nm, where the principal hazard is to the retina.

**Secured enclosure**: An enclosure to which casual access in impeded by appropriate means.

**Service**: The performance of procedures, typically defined as repair, to bring the laser or laser system back to full and normal operation status. Usually done by a professional or representative of the manufacturer. Service does not include *maintenance* or *operation* as defined in this section.

**Shall**: The word *shall* is to be understood as mandatory.

**Should**: The word *should* is to be understood as advisory.

**Specular reflection**: A mirror-like reflection.

**Standard Operating Procedure** **(SOP):** Formal written description of the safety and administrative procedures to be followed performing a specific task.

**Transmission:** Passage of radiation through a medium.

**Transmittance:** the ratio of transmitted power (energy) to incident power (energy).

**Ultraviolet radiation:** Electromagnetic radiation with wavelengths between 180 and 400 nm.

**Visible Luminous Transmission:** The amount of visible light passing through a filter, weighted for the response of the human eye, expressed as a percentage. This percentage value is given for each pair of LEP. This value should not be lower than 25% for LEP used at Penn State.

**Visible radiation (light):** The term used to describe the electromagnetic radiation that can be detected by the human eye. For purposes of this document, this term describes light that falls in the wavelength range of 400 to 700 nm.

**Watt:** Unit of power. Equivalent to 1 Joule per second.

**Wavelength:** The distance in the line of a sinusoidal wave from any one point to the next point in phase. E.g., peak to peak.

# Roles and Responsibilities

## Individual Roles and Responsibilities

### Laser Safety Officer

The University LSO is a designated staff member who has the knowledge and authority to apply appropriate laser radiation protection rules, standards, and practices. The LSO is named and specifically authorized to perform duties specified in this document and the American National Standards Institute (ANSI) Z136.1. The Laser Safety Officer (LSO) is responsible for ensuring the safe use of lasers at all Penn State locations, except the Milton S. Hershey Medical Center or the College of Medicine located at the Hershey campus.

The LSO is responsible for managing the laser safety program; identifying laser safety problems; initiating, recommending, or providing corrective actions; verifying implementation of corrective actions; and ensuring compliance with all applicable regulations.

The LSO also has the following duties and responsibilities:

* Specify whether any changes in control measures are required following any service or maintenance of lasers that may affect the output power or operating characteristics, or whenever deliberate modifications are made that could change the laser class and affect the output power or operating characteristics.
* Inspect and ensure the proper use of protective eyewear and other safety measures during audits.
* Ensure compliance with the laser requirements and with any engineering or operational controls required by the University, ANSI, and other applicable regulations.
* In situations where engineering controls may not be adequate, the LSO must specify alternate controls to obtain equivalent laser safety protection.
* Within 24 hours of discovery of an injury, report to the appropriate department or entity each injury involving any lasers at the University.
* Developing a laser safety program description and policies and revising them when necessary.

The LSO, or any other EHS employee working in conjunction with the LSO, is also responsible for:

* Conducting safety audits of Class 3B or 4 laser laboratories and inventories of class 1 system and inactive lasers at a scheduled interval (see Section 7).
* Aiding in evaluating and controlling laser hazards.
* Maintaining records of all Class 3B or 4 laser operations including inventory.
* Reviewing Standard Operating Procedures (SOP) for authorized lasers
* Participating in accident/incident investigations involving lasers.
* Immediately stopping imminent hazards and/or escalating non-compliance IAW EHS program.

The staff of EHS has the authority to enter any laboratory to carry out inspections to determine compliance with regulations or a user's authorization to use lasers.

### Principal Investigators, Authorized Users, or Supervisors of Laser Laboratories

Principal Investigators (PI), Authorized Users (AU), or Laboratory supervisors register and receive approval from the LSO for authorization to use class 3B and 4 lasers and laser systems. The supervisor is usually a member of the University faculty or staff (including emeritus members). He or she is responsible for all activities making use of lasers and for the actions of all personnel working under his or her authorization. The responsibilities of the PI, AU, or supervisor include, but are not limited to, the following:

* Ensuring compliance with the University’s approved laser safety program description regarding Class 3B and 4 lasers and laser systems.
* Ensuring the health and safety of everyone whose work he or she controls.
* Ensuring that all persons using lasers under his or her authorization complete all laser safety training and annual non-laser retraining required by EHS.
* Ensuring that all persons using lasers under his or her authorization have access to appropriate laser safety eyewear that is regularly inspected, cleaned, and maintained.
* Developing SOPs for the laboratory, obtaining approval of the SOP from the LSO, and updating the SOP if any aspect of the laser set-up changes.
* Ensure all laser users sign an SOP Acknowledgement Form if the SOP has been updated and keep this form on file with the SOP. (Initial SOP review signatures are collected on the Laser Specific Training Document discussed in Section 7).
* Ensuring that all lasers in the laboratory are properly classified and labeled.
* Registering all Class 3B and 4 lasers and laser systems with the Radiation Safety Office.
* Ensure all users have specific laser safety training for the laser(s) including operating and alignment procedures.
* Notify EHS immediately in the event of any laser related injury.
* Maintaining a current record of the lasers in their possession.
* Directing all purchases, transfers, and shipments of lasers to EHS for processing and approval.
* Notify LSO of status, ownership, or location change of lasers in their possession prior to terminating employment at the University.
* The LSO expects that all supervisors authorized to use or store lasers will promptly respond to annual EHS requests for an itemized inventory of the supervisor’s lasers and certify the results of such inventory in a timely manner. (See section 7)

The affected work unit(s) at the budget executive/administrative level, may vary depending on the breadth and depth to which a program has impact. Broad differences may be expected from such organizations as: OPP, ARL, ABS, Police Services, Regional Campuses, OVPR, and Academic Units.

### Laser Users

Each individual user, including each supervisor, is ultimately responsible for the safe use of the radiation sources to which he or she has access. Each individual shall:

* Follow laboratory SOPs and work safely.
* Sign the SOP Acknowledgement Form when the SOP is updated
* Read, be familiar with, and comply with these Rules and Procedures applicable to his or her work.
* Be familiar with the nature of his or her area's lasers and the extent of their potential risk.
* Wear appropriate laser safety PPE
* Prevent unauthorized persons from accessing lasers in his or her area.
* Notify the Authorized User (AU), Principal Investigator (PI) or supervisor in the event of an exposure incident as well as any other injuries.
* Follow the steps outlined in 7.1.1 and 7.1.3 for incident/accident and exposure response and guidance.
* Completing laser safety training.

## Key Interfaces

This section describes the significant and notable interfaces for this program.

### Internal EHS Interfaces

N/A

### Other Penn State University Interfaces

N/A

## Third Party Responsibilities

### Third Party Laser Users (e.g., Contractors, Visiting Researchers, Concert/Show Organizers)

Third party laser users who are brining non-university-owned lasers to Penn State shall follow any requirements outlined in section 14 of this document.

Third party laser users who are visiting Penn State and using university-owned lasers shall have the responsibilities outlined in section 5.1.3.

### Other Third Party (for example, Students, Visitors, Temporary Employees)

Any other third party who may find themselves involved with laser usage or sharing space with active lasers shall obey any laser warning signage or lab-specific requirements for that laser or laser system.

Any third party who will be using lasers at Penn State (even temporarily) shall follow the requirements outlined in section 5.1.3.

## Medical Surveillance

Any individual who has been, or suspects they have been, exposed to laser radiation shall report and document this accident through the appropriate channels. Refer to [SY-04](https://policies.psu.edu/policies/sy04) for accident reporting and investigation.

You shall seek medical attention through the Occupational Medicine Employee Health Surveillance program even if no injury is immediately apparent. For eye exposure to a laser, an eye exam is needed to check for macular function, visual acuity, color vision, and any past eye history. Some eye injuries caused by a laser may not be immediately perceptible to the injured individual, and so it is critical to get an eye exam from Occupational Medicine even if no side-effects of exposure are immediately felt. If a laser injury, exposure, or potential exposure occurs, Occupational Medicine must be consulted. The default period of consultation is 90 days, which may be modified only at the discretion of a physician.

The accident shall also be reported to your immediate supervisor.

## Raising Safety Concerns

All persons working with lasers who have concerns about their personal safety, the safety of the general public, or the safety of the environment should promptly report the matter to their supervisor. If the supervisor is unable to answer the person’s concerns to his or her satisfaction, he or she is encouraged to contact EHS to report the situation. If the person raising the concern is not satisfied with the action(s) taken by EHS, the person is free to contact the LSO, the EHS Research manager, the EHS Assistant Director, or the EHS Director with his or her concerns. In any case, the person raising the concern may not be retaliated against in any way by his or her supervisor, EHS, or the University. Such retaliation is contrary to maintaining a safety-conscious environment.

If you have any concerns about safety, workplace issues, compliance, or retaliation you shall call the Penn State Ethics Hotline at 1-800-560-1637 or report the issue [online](https://secure.ethicspoint.com/domain/en/report_custom.asp?clientid=55078). Please visit [this website](https://universityethics.psu.edu/penn-state-hotline) for more details on reporting misconduct.

# Resources, References, and Source Information

## Requirement and Program Design Inputs

This document contains all necessary guidelines for owning and operating a laser at Penn State. It shall be considered the standard to follow for all laser safety needs and guidance.

Penn State’s laser safety program is based on the recommendations provided in ANSI Z136.1. This document and program use the standard as a guide for running an effective laser safety program. However, if a laser user or laser lab is within full compliance of the current ANSI laser standard, they shall be considered in full compliance of Penn State’s Laser Safety Program.

### Regulations (Federal, State, Local)

#### OSHA 1926 Subparts D and E

OSHA 1926 Subparts D and E outline the requirements for laser use in construction. See Section 14 for more details on laser usage in construction at Penn State.

### Codes and Standards

#### ANSI Z-136.1 – 2014

The ANSI Z-136.1 standard from 2014, American National Standard for Safe Use of Lasers, is the document that Penn State’s laser safety program is based on. Z-136.1 provides guidance on laser classification, laser control measures, and laser safety program creation.

ANSI’s standard is considered a recommendation for best practices for laser use. While only being a recommendation, it is still widely regarded as a thorough guide to all aspects of a comprehensive laser safety program.

Any new versions of Z-136.1 will trigger a re-visit of Penn State’s laser safety program to determine if any new changes are warranted based on the newest recommendations.

Any lab or user following older versions of ANSI Z-136.1 will still be considered in full compliance with Penn State’s laser safety program so long as there has been no change within their lab since the current standard has taken effect. Examples of changes that would no longer allow adherence to older versions of ANSI are: addition of a laser, relocation of laser lab, SOP update, change in laser set-up, change or update of control measures.

## Contextual and Supporting References

None.

## Other Resources

Other documents supporting Penn State’s laser safety program and providing guidance can be found on the EHS website and linked throughout this document.

# Programmatic Information and Requirements

# EHS Laser Safety Program Information

## Incident and Emergency Planning and Response

**In case of a life-threatening emergency, call 911.** These could include, but are not limited to: Fire, explosions, serious injuries, and any other incident/accident which poses immediate threat to life or the environment.

If an incident/accident that does not pose a life-threatening injury occurs call Environmental Health and Safety (EHS) at (814) 865-6391 during normal business hours (M-F, 8am-5pm) or University Police (814) 863-1111 during all other times or holidays. After hours University Police can direct any call to the appropriate EHS staff member.

If the incident/accident involves the suspicion or knowledge of a laser exposure take the following actions immediately:

* **Call 911 if there is a life-threatening injury**
* Turn off the equipment and secure it to prevent use by other individuals (See LOTO procedures)
* Do not change the equipment’s configuration. The details from the exact set-up are critical in determining the extent of exposure
* Contact EHS at the numbers listed above and below.
* Visit Occupational Medicine

Emergency Telephone Numbers and Contact Information

Environmental Health and Safety 814-864-6391

Laser Safety Officer 814-865-1216

Radiation Safety Officer 814-863-3939

Radiation Protection Office 814-865-6391

**Radiation Safety Office Emergency 814-777-0215**

**PSU Public Safety (Emergency) 814-863-1111**

**Police, File, and Ambulance Emergencies 911**

### EHS Incident Reporting and Response

If an accident or incident occurs as a result of the laser beam or non-beam hazard, but no injury or property damage occurs, the user shall still inform the PI and EHS or the LSO of the event. Instances such as: a stray beam striking laser safety goggles or almost hitting an individual, an interlock or safety feature hasn’t been functioning during normal operation, the beam ignites a material that is quickly extinguished, a spill of dye or toxic material, or a temporary failure of ventilation are all examples of what could be considered a “near miss”.

These near misses shall be reported to the PI and the LSO so a strategy can be formed to avoid these incidents in the future. Attempting to fix these issues without informing the LSO can lead to the dangerous situation repeating and an individual being severely injured.

If a laser user reports unsafe working conditions or near misses to the PI or LSO, no retaliatory action can be taken against them. If a user feels that their PI is not taking their safety concerns or warnings seriously, they should covey them to the LSO or EHS. If they then feel that their contact in EHS or the LSO is ignoring their concerns, it should be brought to the Vice President of Research’s attention. Always report unsafe work conditions to avoid potential future accidents or incidents. See Section 5.5.

#### Emergency Spill Reporting and Response Procedures

N/A

### Emergency Rescue Procedures

N/A

### Facility Evacuation or Lockdown Procedures

N/A

### Specific Laser Emergency Procedures

If exposure to a laser beam has occurred and an injury has resulted, call 911 for a life-threatening injury or EHS for anything else. It is important to resolve the injury before reporting the accident to EHS. Once the injury is treated you shall call EHS or the LSO to report the incident. If exposure, or expected exposure, to a laser beam has occurred, and no injury is immediately apparent, follow the steps outlined in 7.1.1 to report the incident/accident.

If the laser beam or laser system has caused a non-beam accident or injury, such as fire, explosion, toxic chemical exposure, electrical shock, cryogenic burn, or any other type of injury not related to laser exposure call 911 first if emergency attention is needed. Follow the steps outlined in 7.1.1. If the issue does not warrant emergency services, call EHS first. For more information on non-beam hazards and specific EHS program information, see section 9 for non-beam hazards and 7.1.1 for EHS specific reporting and response.

## Training Requirements

Only trained personnel are permitted to use lasers. Each PI, AU, or lab supervisor is responsible for assuring that he or she and all those working under his or her authorization have received sufficient training necessary to safety use lasers. A list of all trained personnel and their certificates shall be kept by the laboratory supervisor and updated as new users join or leave the group.

At a minimum, all faculty, staff, students, and visitors operating Class 3B and Class 4 lasers are required to complete the Laser Fundamentals and Safety Training prior to working with lasers or provide applicable training certificate or proof of training to EHS. Before operating a Class 3B or 4 laser, faculty, staff, students, and visitors shall:

### Review the Laser Safety Program Description (this document)

### Review the SOP for the specific laser to be used. Most laser equipment is provided with instructions for safe operation by the manufacturer; however, at Penn State, a standalone SOP for each laser in use is required for all Class 3B and 4 lasers.

### Approved SOPs for all active Class 3B and 4 lasers shall be available for review during laboratory and laser equipment audits. These SOPs shall be maintained with the laser equipment for reference by the operator and maintenance or service personnel. Contact the LSO for a standardized SOP Laser Template or outline. All instructions for required items within the SOP can be found in the Template or Outline. These documents can be found on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-resources).

### Receive training from the PI, AU, or laboratory supervisor covering safe operation of the specific laser(s) to be used, administrative procedures, alignment procedures and other applicable SOPs.

### Sign the Laser Specific Training Documentation form found on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-resources) indicating any faculty, staff, students, or guests who operate class 3B or 4 lasers have completed the tasks above for the specific laser. This document must be signed and dated by the user and updated anytime a new user is authorized to use the laser. This document must be available for review during audits and should be maintained with the training certificates.

### Training Requirements

Training for this program is a combination of Initial Training and Periodic Training, each of which is described below.

#### Initial Training

#### General Laser Safety Training

On-line training is currently available through the [Penn State *Learning Resource Network/ Cornerstone/ Skillsoft*](https://lrn.psu.edu/) modules. Training includes the on-line module, plus a quiz that requires a 70% or higher to pass.

Once the training is completed, a copy of the certificate must be kept on record within the lab.

#### Laser Cutter Safety Training

If the laser user will only be using an enclosed and interlocked laser cutter or 3D printer with an enclosed class 3B or 4 laser, they may take the Laser Cutter Safety Training in lieu of the General Laser Safety Training.

The on-line training for laser cutter safety is not yet currently available on the Learning Resource Network platform. Please reach out to the LSO for a copy of the training and quiz.

Once the training is completed, please send the name and quiz score of the individual to the LSO so a certificate can be generated.

A copy of the certificate must be kept on record within the lab.

#### Hands-On/Practical Training

Each affected employee or student shall be trained by their Supervisor, Safety Officer, or company representative in pertinent use of job-specific engineering controls, work practice controls, housekeeping measures, and specifics of individual lasers.

This training shall be documented with a signature on the Laser Specific Training Documentation form found on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-program-forms) and kept with the other laser records.

#### Periodic Training

Periodic training is not an EHS requirement for laser use at Penn State University. However, PIs, Lab Supervisors, or Building Safety Managers may require periodic training for their own lab/building. If this is the case, it shall be indicated in the SOP.

The Fundamentals of Laser Safety training shall be taken again if:

* Employee(s) or student(s) demonstrate lack of knowledge (e.g., improper use of controls, disregard for best safe practices, or after a near miss occurs) as deemed by the LSO, PI, AU, or Lab Supervisor
* The laser user has left Penn State’s instruction or employ for any amount of time and has now returned. [e.g., a student trained with lasers who graduated and was hired on as an employee months or years later]

A user does not need to re-take the Fundamentals of Laser Safety training if they switch laser labs or if they take an extended break from laser use but are still under Penn State employ/instruction for the entire duration of the break. A user shall retake the Fundamentals of Laser Safety training in these two scenarios if their PI or Lab Supervisor requires it.

### Training Proficiency

PIs, Lab Supervisors, Facility Coordinators, Department Safety Officers, or Laboratory Safety Officers may also require additional trainings beyond what is required above before using lasers at Penn State. These additional requirements shall be followed if they exist within the specific lab, building, or department.

### Training Exceptions, Allowances, and Equivalencies (OPTIONAL)

None.

## Documentation & Recordkeeping

All laser users shall keep their laser documentation in a readily accessible location for audits or general use. This location could either be a physical binder within the lab or a folder on a shared drive or computer. The following documentation shall be available and kept within the binder or folder: SOPs for all lasers, training records for all laser users, and laser specific training documentation for all lasers. The following documents shall be available and should be kept within the binder or folder: laser manuals and laser service and maintenance records. The following documents should be available and should be kept in the binder or folder if available: laser purchase and receipt records and laser lab self-audit forms.

Note: “shall” designates that an item is required and “should” designates an item is recommended.

### Documents that Constitute this Program

|  |  |  |
| --- | --- | --- |
| **Table 1. Summary of Program-Specific Implementing Documents** | | |
| **EHS Document ID** | **EHS Tier** | **Document Title** |
| EHS-0079at1 | 1 | Laser Registration Form |
| EHS-0072 | 2 | Laser Eye Protection Guide |
|  | 1 | Laser Warning Sign Template |
| EHS-0075 | 1 | Laser SOP Template |
| EHS-0073 | 1 | Laser SOP Outline |
| EHS-0071 | 2 | Laser Registration and Implementation Procedures |
| EHS-0074 | 2 | Laser Cutter Safety |
|  | 2 | Laser Alignment Procedures |
|  | 1 | Administrative Control Measures |
|  | 1 | Engineering Control Measures |
|  | 1 | Laser Audit Form |
| EHS-0079at2 | 1 | SOP Acknowledgement Form |
| EHS-0079at3 | 1 | Laser Specific Training Documentation Form |

### Customer Record Retention Requirements

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 2. Summary of Customer Record Retention Requirements** | | | |
| **Records Series  (Types of Documents)** | **Record Description** | **Records Series Description** | **Retention Period** |
| Standard Operating Procedure | SOP for Laser or laser system | Specific set of operating instructions and safety protocols designed by PI for each laser in their possession | Life of Equipment |
| Environmental Health and Safety Inspections and Audits – Except Process Safety Management (PSM) | Laser Safety Audit | Audit done by the LSO or other qualified personnel on an annual basis for every active lab | End of calendar year which in which audit was completed + 7 years |
| Annual and semi-annual self-audits and inspections - records completed by the work unit that show compliance with EHS programs | Self-Audit Form | Optional Self-Audit form to be completed at PI’s discretion and as a guide for full lab compliance | End of Calendar Year +1 year |

### NOTE: Consult the Office of Records Management, General Records Retention Schedule (EHS Records Retention Schedule), [here](https://policy.psu.edu/general-retention-schedule#EHS) , for additional detail on Record Retention requirements.

### Additional Documented Information (SDS, etc.)

Any communication between an Authorized User and the LSO regarding specific exemptions given to any aspect of the laser lab or agreed upon control measures that are not mentioned in this document shall be maintained by the LSO within the EHS recordkeeping system and considered for future updates to this document to be listed in section 13. See 7.4.2.2

### Additional Document and Recordkeeping Requirements

The SOP Acknowledgement Form on the last page of the SOP template shall be updated and maintained as the SOP is updated (Appendix 1). If any changes are made to the specific SOP that is form is attached to, all users who operate this equipment shall sign and date this form to indicate that they are aware of all changes made to the SOP. The user shall keep this form attached to the back of their SOP for as long as that version of the SOP is valid. If a new version is drafted, all users shall sign a blank copy of this form and replace the previously signed copy. On an annual basis, the LSO will require the PI, AU, or Lab Supervisor to sign the bottom of this form to confirm that no changes have been made to the SOP in the last calendar year. The LSO will keep this version of the document on file.

In addition to the records mentioned above, the PI or Authorized User of the laser lab is also required to maintain records of all maintenance, modification, and service records for the laser or laser system.

## Minimum Program Inspections, Self-Audits, and Evaluations

The inspections, self-audits, and evaluations in this section represent minimum planned frequencies for these activities. Additional, more frequent inspections, audits, or evaluations may occur as needed to address regulatory changes, regulatory requests, observed trends, corrective actions, or other EHS concerns.

### Minimum Inspections

#### Minimum Periodic Inspections

N/A

#### Work Unit Inspection

N/A

#### Minimum EHS Inspections

N/A

### Minimum Audits

Labs with active class 3B or 4 lasers shall be audited in person by the LSO or other qualified EHS individual on a yearly basis but not to exceed 16 months between audits. The audit will confirm the PI’s laser inventory, ensure all the proper control measures are in place and functioning as intended, and check all required documentation.

Inactive class 3B or 4 lasers or class 1 laser systems with embedded class 3B or 4 lasers need only be inventoried on a yearly basis. No in person audit is required in these cases. The yearly inventory can be accomplished in-person or by sending pictures of the laser’s identifying information and location to the LSO or other qualified EHS individual.

Laser PIs shall make a reasonable effort to work with the auditor in scheduling in-person audits or inventory checks. If multiple attempts have been made to schedule an audit with no success, the LSO may visit the lab unannounced in order to complete the inventory within the required timeframe of one year. If all registered lasers could not be located during an unannounced visit, or lasers could not be tested, the lab will be in non-compliance until a full audit can be completed.

Any issues discovered during the audit will be shared with the PI and kept on record with the LSO. Depending on the severity of issues, they may be corrected at the time of the audit, or an audit follow-up may need to be scheduled. Any issues found within the lab are assessed for risk and corresponding corrective actions are taken accordingly. If another qualified EHS individual is conducting the audit and finds an issue, the LSO shall be contacted to determine necessary actions.

### Minimum Program Self-Audits and Evaluations

#### Self-Audits

Self-Inspection forms are available to all laser users on the EHS website. These forms should be completed on a yearly basis by the Authorized User or PI to confirm they are following the Penn State Laser Safety Program. These forms do not need to be turned into the Radiation Protection Office or shown to the LSO or other qualified EHS personnel at the time of the audit. They are recommended to be used as a guide to prepare for an in-person audit.

#### Evaluations

An evaluation shall be completed by the LSO and is a more specific visit than an audit. An evaluation of a laser lab or specific laser set-up may be warranted under multiple circumstances. For example:

* The laser user has questions about control measure implementation.
* The laser user is setting up their laser lab for the first time.
* The laser user has an existing laser lab but is adding a new laser that has different control measures and requirements than their previous laser(s).
* The LSO is following up on concerns from a previous audit.

An evaluation may be requested by a laser user or required by the LSO depending on the circumstances. Evaluations are not reoccurring and are not required unless specifically requested by the LSO. The LSO may request an evaluation for any reason.

An evaluation may take the place of the yearly audit, and reset the compliance calendar, if all lasers in a lab space and all necessary control measures for those lasers are checked at the time of the evaluation.

### 

## Program Metrics

A laser lab that is following the requirements of this document shall be considered in compliance. This includes having EHS or LSO lead audits completed on a yearly basis if the lab uses any active class 3B or 4 lasers or having inventories completed if they have inactive lasers or class 1 systems.

### Non-Compliance

A laser lab will be considered in a state of Non-compliance if:

* An in-person audit was not completed within a 16-month period following the previous audit, evaluation, or installation of the laser. If scheduling difficulties occurred between lab personnel and EHS staff or LSO, then this time may be extended.
  + It is the LSO or EHS personnel’s responsibility to initiate the process of scheduling an audit and keep track of the audit schedule. If no one form EHS or the LSO has reached out to the lab to initiate an audit, the lab will not be considered in a state of non-compliance if more than 16 months has elapsed since the previous audit, evaluation, or installation.
* The LSO deems that safety control measures are not sufficient to protect users from laser hazards.
* The LSO deems that safety procedures outlined in the SOP are not being followed and a harmful exposure could result.
* A pattern of administrative control measure infractions, not necessarily direct hazard related, continue to manifest over a long period of time.
  + For example: document up-keep, outdated signage, unregistered lasers
* An administrative control measure infraction, not necessarily direct hazard related, continues to persist through multiple audits, evaluations, or verbal/written suggestions and is not corrected.
  + For example: document up-keep, outdated signage, unregistered lasers

The LSO shall determine if a lab or laser is in non-compliance for laser safety reasons. When the LSO has determined the lab or laser to be in a state of non-compliance, they may not use their laser(s) until the issue is resolved. A state of non-compliance can be attached to only one laser and not the entire lab. For example: if the lab has multiple lasers, but only one of them has an issue with its control measures, they may continue to use the other lasers in their lab.

If a laser user or laser lab continues to use their laser(s) while in a state of non-compliance, the EHS Escalation Program may be followed.

## Exceptions, Special Considerations, and Management of Change

### Exceptions and Special Considerations

The LSO may grant exceptions or special considerations to requirements or recommendations in this document based on special circumstances. These exceptions shall be recorded and kept on record within EHS. Exemptions may only be granted for tangible reasons that can be recorded and documented and will not change based on personnel in the lab. For example, control measure exemptions cannot be granted based solely on the user’s prior knowledge and experience with lasers. Only items such as laser set-ups, unique controls, and room design may factor into exemptions.

The LSO may also require items that are stricter than this document outlines. Stricter requirements shall only be used for special circumstances where the laser user or laser lab has created multiple dangerous situations in the past and it is of the LSO’s opinion that the lab needs more safety controls until it can be proven that they are no longer required.

These extra requirements might also be required if the laser or laser system utilizes new technology or methods that doesn’t fit into previous LSO or user experience, or ANSI does not cover.

These specific stricter requirements shall also be recorded and kept on file within EHS.

### Management of Change

Exceptions and special considerations will be recorded in section 13 as periodic updates to this document are made. If multiple similar exceptions or special considerations are made, changes to the main sections of this document will be considered. The items listed in the table in section 13 will be removed if changes made based on the exceptions are added to the body of this document.

# Hazard Identification, Assessment, and Control

## Hazard Identification

Lasers present multiple types of hazards including beam hazards and non-beam hazards. Both hazards need to be identified and controlled within the Laser Controlled Area (LCA). Hazard Assessment

Describe the processes, assessment tools, forms, job aids and methods used to conduct hazard assessments, outputs, and management of hazard assessment outputs.

### Beam hazards

Laser beam hazards are those that arise from exposure to a direct or reflected laser beam. These hazards are limited to eye and skin injuries, the severity and type of which correspond to the wavelength and intensity of the laser beam itself. Most of the control measures listed in this section for the purpose of reducing the risk of exposure to laser beam hazards.

#### Laser Effects on Eyes

The eyes are the most susceptible organ to laser damage in the human body. It only takes a small amount of the right laser energy to permanently damage an eye or cause blindness.

Different parts of the eye are affected by different wavelengths. Light wavelengths between 180-400nm and 1400nm-1mm are all absorbed by the cornea and lens of the eye. This interaction can either case acute thermal damage, such as burns or photokeratitis, or acute damage to the lens in the form of cataracts. This damage is usually not permanent at lower energies and can be reversed through the natural healing process or surgery.

Light wavelengths of 400-1400nm are focused by the lens onto the retina at up to 100,000x intensity. Injuries to the retina are usually acute in nature and are permanent. It is for this reason that the wavelengths between 400-1400nm have the lowest MPE values and are often considered the most dangerous.

The wavelengths of 400-70nm are within the laser-defined visible light spectrum, meaning that it can be seen by the human eye and therefore avoided. This light will also cause a natural aversion response by the eye to bright stimuli. However, the wavelengths 700-1400 are in the IR range and cannot be seen by the human eye. That makes this wavelength range particularly dangerous because it cannot be avoided and there is not a natural aversion response when it strikes the eye, but it is still focused on the retina by the lens.

### Non-Beam hazards

Non-beam hazards are those that arise form equipment or processes periphery to the laser itself. These can include cooling systems, electrical components, laser-target interactions, and the components used to produce the laser beam. The hazards that arise by the presence of the laser system can include most general lab hazards. These are described in more detail in section 11. EHS shall be contacted for the best methods to control non-beam hazards.

## Hazard Classification

### Laser Classification

Any laser or laser system produced or manufactured in the United States is required by the FDA to be classified into one of the following hazard classes IAW the Federal Laser Product Performance Standard (FLPPS). Lasers produced/manufactured in other countries may not have a required standard used to classify their lasers according to ANSI or FLPPS standards.

It is extremely important to be aware that a laser manufactured outside of the United States might be mis-classified or unclassified. In this case, a hazard analysis shall be performed by the LSO or knowledgeable PI to determine the hazard classification and appropriate control measures. If the laser is mis-classified or unclassified an appropriate label with its appropriate classification shall be added.

If a laser is “home-made” on university property, it is also subject to a hazard classification IAW ANSI Z136.1 and FLPPS. An appropriate label shall be added to the laser once hazard classification is complete.

#### Class 1 lasers

The following describes class 1 lasers as defined by ANSI Z136.1.

* Considered incapable of producing damaging radiation levels during operation
* Exempt from any control measures or other forms of surveillance
* Previously Class 2A under FLPPS
* Often incorporated into consumer and office equipment
* Can be both visible and invisible laser radiation
* The power ceiling for this class of laser is calculated from the Accessible Emission Limit (AEL)

#### Class 1M (Magnification) lasers

The following describes class 1M lasers as defined by ANSI Z136.1.

* Considered incapable of producing damaging radiation levels during operation unless the beam is viewed through collecting optics.
* Exempt from any control measures other than preventing potentially hazardous optically aided viewing and is exempt from other forms of surveillance.

#### Class 2 lasers

The following describes class 2 lasers as defined by ANSI Z136.1.

* Safe for accidental viewing
* Produce levels of radiation that could cause eye damage after any direct, long-term exposure
* Hazardous only if viewer overcomes the natural aversion response and has a direct exposure of greater than 0.25 seconds
* The natural aversion response is considered adequate protection from class 2 lasers
* Exempt from control measures and other forms of surveillance
* Visible light only
* Maximum CW limit is 1 milliwatt

#### Class 2M lasers

The following describes class 2M lasers as defined by ANSI Z136.1.

* Safe for accidental viewing
* Optically aided viewing with collecting options would produce hazards greater than class 2 lasers
* Exempt from any control measures other than preventing potentially hazardous optically aided viewing and is exempted from other forms of surveillance.

#### Class 3R lasers

The following describes class 3R lasers as defined by ANSI Z136.1.

* Previously referred to as class 3A in older standards. Some lasers may still have the 3A label
* “R” stands for Reduced requirements
* Potentially hazardous under direct and specular reflection viewing conditions but is not a diffuse reflection or fire hazard.
* Incapable of causing severe or permanent injury from accidental exposure. Severe injury is possible if aversion response is overcome.
* Exempt from any control measures or other forms of surveillance
* Power levels between 1 and 5 milliwatts for visible and invisible lasers. Also includes invisible lasers under 1 milliwatt and above class 1 levels.

#### Class 3B lasers

The following describes class 3B lasers as defined by ANSI Z136.1.

* Produces radiation levels powerful enough to injure human eye tissue with a short or accidental exposure to a direct or specularly reflected beam.
* Does not produce hazardous diffuse reflections under normal use
* Not usually capable of causing serious skin injuries
* Requires multiple control measures and multiple forms of surveillance
* Power levels between 5 and 500 milliwatts
* Visible or invisible laser light

#### Class 4 lasers

The following describes class 4 lasers as defined by ANSI Z136.1.

* Produces radiation levels powerful enough to permanently injure eye tissue with a short or accidental exposure to a direct, specularly reflected, or diffusely reflected beam. Is also a skin and fire hazard for direct, specularly reflected, and diffusely reflected beams.
* Can produce Laser Generated Airborne Contaminants (LGAC) and hazardous plasma radiation
* Requires all 3B control measures and forms of surveillance in addition to ones specific to class 4
* Power levels over 500 milliwatts

## Hazard Assessment

Classification and assessment of a laser or laser system shall be based on the maximum power available for its intended use. The LSO is responsible for making the distinction and classification based on the specific circumstances of the laser set-up. Therefore, a laser classified a certain hazard level by FLPPS can be considered a lower/higher hazard based on the LSO’s distinction of the laser in its specific use.

The LSO can use multiple aspects of the laser or laser system to evaluate the total hazard and classification. These include, but are not limited to, the laser’s capability of injuring personnel, the environment in which the laser is used (including accessibility of the beam path), the level of training of the personnel who use the laser, and the accessible level of laser radiation during operation.

The LSO must also consider multiwavelength lasers, repetitive-pulsed lasers, and Q-switched lasers in their hazard designation.

The Penn State laser safety program is mainly for safety guidance for research and educational activities involving lasers and especially for Class 3B and 4 lasers. The fundamental objective is to ensure potential exposures are at or below the laser specific Maximum Permissible Exposure (MPE).

Lasers can be operated in 3 modes. Normal operations are those that the laser set-up is specifically designed for. Maintenance operations are periodic operations that keep the laser running as intended. Service operations are when major repairs are needed to the laser to return it to normal function. For the purpose of this document, normal operations are to be performed by PIs and laser users who have completed general and specific laser safety training. Maintenance activities must be performed by the AU or designated laser users specified on the SOP. Service functions must never be performed by the AU or laser users unless they are qualified and certified to perform such functions and can demonstrate qualifications and certifications through documentation.

Control measures used to prevent exposure to laser radiation above MPE are outlined below.

## Hazard Control Measures

No one who operates lasers at Penn State shall be exposed to laser radiation levels above the applicable MPE under any foreseeable conditions of operation. Therefore, control measures shall be devised to reduce the possibility of exposure to the eyes or skin commensurate to the hazard classification. These control measures also include protecting users form non-beam hazards that may arise from the operation of a laser. Non-beam hazards and their control measures are detailed in a later section.

For all uses of a laser or laser system, the minimum laser radiation necessary for the intended use shall be used.

In most cases the required control measures are determined by only the hazard classification. Class 3B and 4 lasers have certain control measures. However, specific cases will require additional information about the laser and laser set-up for control measures to be determined.

Class 3B lasers require the approval of appropriate control measures by the LSO to reduce the risk of eye exposure from a direct or specularly reflected beam. In rare cases control measures may be required to prevent a fire hazard.

Class 4 lasers require the approval of appropriate control measures by the LSO to reduce the risk of eye and skin exposure from a direct, specularly reflected, or diffusely reflected beam. Control measures are required to prevent a fire hazard and may be required to mitigate Laser Generated Airborne Contaminates (LGAC).

Control measures are divided into 3 groups: Engineering controls, Administrative controls, and PPE. A control hierarchy should be followed when selecting control measures. Engineering controls being the first line of defense, followed by administrative and PPE.

### Engineering Controls

Engineering controls are physical means used to protect from laser radiation. They are considered the first line of defense for laser safety and should be used before administrative controls and PPE when applicable.

#### Protective Housing

Protective housing is normally included with the laser itself and is the means to enclosing and limiting access to radiant energy emissions, electrical hazards, and other hazards associated with the laser’s internal components.

A protective housing shall be required for all classes of lasers and laser systems. Protective housing for class 3B and 4 lasers that can be easily removed during operation and maintenance shall be interlocked and labeled. If the housing is not interlocked, it shall be mechanically secured and labeled so that it may not be opened without the use of a tool.

The interlocks shall be designed to prevent exposure above MPE levels if the protective housing is removed during normal operation or maintenance. Labels on protective housing shall be created IAW with 8.4.2.7 of this document. If a protective housing does not meet these requirements, it shall be considered a barrier or curtain.

If a class 3B or 4 laser is operated without a protective housing, the LSO shall conduct a hazard analysis to ensure that other adequate engineering control measures are in place.

#### Key Control

Class 3B and 4 lasers should be controlled by a master switch. This master switch shall be able to terminate the beam and/or system shutoff and shall be operated by a key or password control. The system shall not be able to be operated without the physical key or knowledge of the password.

If the laser controlled area is accessible to non-authorized personnel, the physical key shall be kept in a location known only to authorized users or the password shall be only known to authorized users. If the laser controlled area is only accessible to authorized personnel, the key/password is not required to be hidden.

All energy sources associated with class 3B or 4 lasers shall be designed to permit Lock Out/Tag Out procedures required by EHS. See Section 11.2.

#### Facility Window Protection

Facility windows that are located within, or at the boundary of, the NHZ of a class 3B or 4 Laser Controlled Area shall be equipped with an appropriate blocking barrier, filter, or screen that will reduce any stray laser radiation to levels below the MPE on the other side of the window.

Blocking material shall be selected to withstand a direct or diffusely scattered beam for the amount of exposure time for the specific application of the laser.

#### Laser Protective Barriers and Curtains

A blocking barrier, screen or curtain should be used at the entryway to the Laser Control Area to prevent any laser radiation above the MPE from exiting. A blocking barrier, screen, or curtain can also act as the barrier of the Laser Control Area if the hazard analysis done by the LSO deems it sufficient. If the laser barrier, screen, or curtain does not extend fully to the floor or ceiling, a hazard analysis shall be done to ensure it still provides sufficient protection outside of the Laser Control Area.

Barrier, screen, and curtain material shall be selected to withstand a direct or diffusely scattered beam for the amount of exposure time for the specific application of the laser. All laser barriers, screens, and curtains shall be labeled with the beam exposure conditions under which protection is afforded.

#### Beam Paths

Beam paths can be classified into 4 categories: Fully open, limited open, class 1 conditions, and enclosed.

Fully open beam paths for class 3B and 4 lasers shall have a full hazard analysis done by the LSO. Control measures shall be what this document and the LSO require.

Limited open beam paths for class 3B or 4 lasers exist when most of the beam path is covered, but the section that is open is large enough for someone to place some portion of their body into the beam path. A full hazard analysis shall be performed by the LSO to determine any area where laser radiation could be above the MPE

Class 1 condition beam paths for class 3B and 4 lasers exist when all, but a very small section of the beam is enclosed. The NHZ is too small for anyone to put a body-part into the beam path, but it is feasible that a reflective surface could be placed into the beam path and cause a hazardous reflection. This scenario most often occurs with confocal microscopes. The control measures for the hazard class of the laser shall be followed, but a hazard analysis is not needed.

Enclosed beam paths occur when none of the laser beam is accessible, and no location exists where laser radiation levels are above the MPE. No control measures are required, and the laser can be considered a class 1 laser system. The requirements for class 1 laser systems are discussed in 8.5.

#### Area Warning Device

A class 3B laser control area should, and a class 4 laser control area shall have an area warning device that is visible prior to entering the area. The purpose of this warning devise is to inform persons outside of the control area that the laser within is emitting, or about to emit, accessible laser radiation.

It is understood that it is not always feasible or affordable to install an area warning device onto an already existing lab space. Therefore, it is entirely acceptable to use any form of lighting or signage that will accomplish the purpose of warning personnel outside of the LCA that the laser is in operation. For example, a battery powered bike or closet light may be placed on the exterior of the lab to act as an area warning device so long as there is appropriate signage to inform personnel of its purpose.

Any device used as an area warning device shall only be activated when the laser is on and be deactivated when the laser is off.

#### Emission Warning Device

Within a laser control area, and audible or visible laser emission warning device shall be used for class 3B and 4 control areas. This device is to ensure that persons within the laser control area are aware that the laser is emitting, or about to emit, accessible laser radiation.

This device requirement is normally accomplished by a power indicator light on the laser system itself or its control panel. If such a light does not exist, but the laser system has an obvious and distinctive sound that arises from auxiliary equipment that is required to power the laser [e.g., the hum from a vacuum pump or fan], this requirement will be considered fulfilled.

If an indicator light on the laser is used to fulfill this requirement, that light shall be a different wavelength than the laser itself and LEP shall be chosen to ensure that this light is visible while wearing the LEP. See section 8.4.3.1 for guidance on selecting LEP.

#### Entryway Controls

Class 4 laser areas shall incorporate entryway controls. These controls can either be Non-Defeatable, Defeatable, or Procedural and shall be followed in a hierarchy in the order listed.

Non-Defeatable entryway controls are engineering controls built into the entryway for the purpose of reducing laser levels to below the MPE in the event of an unexpected entry into the Laser Control Area. These controls can include safety latches or area interlocks such as electrical switches, pressure plates, or infrared detectors that cannot be defeated by any personnel outside of the lab area.

Defeatable entryway controls serve the same purpose as Non-Defeatable and are the same technology but can be defeated from outside of the lab space to allow for entry without hampering laser activities. Defeatable entryway controls are used instead of Non-Defeatable in circumstances where the laser should not be shut off during operation. This includes instances where the laser is being used for medical purposes, or the laser system would be damaged by a sudden change in power. It shall be clearly evident that there is no laser radiation hazard at the point of entry if Defeatable controls are to be used over Non-Defeatable.

If both Non-Defeatable and Defeatable entryway controls are impossible or impractical, Procedural entryway controls may be used. If procedural entryway controls are used, the following shall apply:

* All authorized personnel with access to the Laser Control Area shall be adequately trained on the hazards within the LCA
* PPE shall be provided upon or prior to entry
* A blocking barrier (this can include a door, curtain, screen, or any physical barrier that prevents exposure above the MPE for anyone entering when the laser is in operation) shall be used, or it shall be proven an exposure above MPE cannot occur at the entryway.
* There shall be an area warning device (see 8.4.1.6) indicating that the laser is energized and operating at class 4 levels.

### Administrative Controls

Administrative controls are methods or instructions that specify rules, work practices, or both, in order to mitigate the potential hazards of laser use. Unless otherwise specified, all administrative controls shall apply to only class 3B and 4 lasers or laser systems.

Administrative controls are preferred to PPE when possible. Engineering controls and PPE may require administrative (or procedural) application.

#### Standard Operating Procedures

Standard Operating Procedures (SOPs) shall be written for each registered laser at Penn State. This includes class 1 systems embedded with class 3B and 4 lasers. Lasers that are part of a larger system (such as a confocal microscope) may have their SOP included within the SOP of the system they are a part of. For any new lasers being registered at PSU the PI or Authorized User shall send the SOP to the LSO for review before putting the new laser into operation. The written SOPs shall be maintained with the system for easy reference by the operation or service personnel.

The SOP shall include the following:

* The room design and layout including the position of the laser and any accessible entrances. This design shall be in the form of a “bird’s-eye” view of the lab space containing the laser.
* Start-up and shut-down procedures for the laser and ancillary systems
* General laser specific safety requirements.
* Any equipment-specific LOTO procedures.
* Safety measures for the control of any non-beam hazards within the lab.
* PPE requirements such as Laser Eye Protection and skin protection. Instructions on when and how to appropriately use shall also be included.
* Emergency procedures in case of a laser accident. Information such as emergency shut-down procedures and phone numbers of the PI and LSO shall be included in this section.

A template and outline of the SOP format can be found at the [EHS laser webpage](https://ehs.psu.edu/laser-safety/laser-safety-resources).

#### Training

Education and training shall be provided for any personnel who operate or perform maintenance or service on class 3B, class 4, or class 1 systems with embedded class 3B or 4 lasers. See section 7.2 for specific training requirements.

#### Authorization

Class 3B or Class 4 lasers shall be operated, maintained, or serviced only by authorized personnel. Class 1 laser systems with embedded class 3B or 4 lasers shall be operated by authorized personnel if the procedure would offer access to laser radiation levels above that of class 3R.

#### Indoor Laser Control Areas

A laser hazard analysis shall be conducted by the LSO or authorized personnel for all class 3B and 4 lasers and for any system containing embedded class 3B and 4 lasers. If that analysis determines that the maximum level of accessible laser radiation is that of class 3B or 4, a Laser Controlled Area shall be established, and adequate control measures shall be adopted.

The following administrative control measures shall be implemented for class 3B and 4 laser areas:

* Lasers and laser systems are only to be operated by personnel trained in laser safety and specific use of laser or laser system
* The LCA is posted with the proper warning sign on every accessible entrance
* The laser is operated so the beam path is well defined
* Require appropriate Laser Eye Protection (see 8.4.3.1)

In addition to the above, the following administrative control measures should be implemented for class 3B areas and shall be implemented for class 4 areas:

* Laser use is under the direct supervision of someone knowledgeable in laser safety
* A hazardous beam is terminated with a beam stop of appropriate material
  + This beam stop shall be rated for the irradiance of the laser beam and be made of flame-retardant material
* Material that is not a part of the aligning optics within the beam path is diffusely reflective.
* The laser is secured in place.
* Any exposed beam path is above or below eye level in a sitting or standing position. (Within a confidence interval)
* Require all windows, doors, or portals to be covered or restricted to prevent transmitted laser radiation above the MPE outside of the LCA.
* Disabling of the laser when not in use if the area is accessible by unauthorized personnel.
  + This can include having the laser system password protected or removing the key to the power supply.

If the laser or laser system is to be used outdoors the LSO shall be contacted for specific instructions, hazard analysis, and control measures.

#### Alignment

Any alignment of class 3B or 4 laser beams or optical systems (mirrors, lenses, deflectors) shall be done to ensure no exposure above the MPE occurs. Written alignment procedures shall be included within the SOP for class 3B and class 4 lasers.

Alignment SOPs shall be created for class 1 lasers systems with embedded class 3B or 4 lasers where alignment procedures would allow access to the laser beams. These need to be sent to the LSO for approval and kept near the laser system.

The use of lower powered lasers (such as class 1, 2, and 3A) to simulate the path of the higher powered laser for alignment is highly recommended.

Alignments shall only be performed if the following actions/precautions are taken:

* The personnel performing the alignment has received general laser safety training and specific training on the laser
* All unnecessary personnel are excluded from the area
* Proper LEP is worn
* Higher powered lasers are set to their lowest possible level or use co-aligned guide beams for alignment if available
* If the laser is a class 1 system with an embedded class 3B or 4 laser, a temporary laser control area needs to be created. See 8.5.3
* Shutters or beam blocks are used to block the source of the laser except for when actually needed
* Place blocks or stops behind optics being aligned in-case of a miss during optic alignment
* Ensure all beams are properly terminated before returning the laser to high power

#### Laser Warning Signs

Class 3B and 4 laser areas shall be posted with a laser warning sign on each accessible entrance. If an entrance is blocked by physical means and cannot be accessed even with a key, no signage is required.

Class 3R areas or areas with laser systems containing an embedded class 3B or 4 laser should be posted with a laser waring sign on all accessible entrances. If an entrance is blocked by physical means and cannot be accessed even with a key, no signage is required.

Laser warning signs shall be created in accordance with (IAW) the template provided on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-resources). If a lab is posted with a previous version of the laser safety warning sign from an ANSI Z136.1 version prior to the 2014 version, it is considered to be in compliance unless any changes were made to the laser inventory after January 31st, 2014.

A laser warning sign that is posted on a class 3R area or an area with laser systems containing an embedded class 3B or 4 laser shall include the signal word CAUTION in black letters on a yellow background.

A laser warning sign that is posted on a 3B laser controlled area or a class 4 laser controlled area, where laser exposure could result in serious injury, shall contain the signal word WARNING in black letters on an orange background.

A laser warning sign that is posted on a class 4 laser controlled area, where laser exposure will result in grave injury or death if laser control measures have failed, shall contain the signal word DANGER in white letters on a red background. This type of sign is usually reserved for multi-watt CW lasers or open beam pulsed lasers.

NOTE: The distinction between using the signal word “WARNING” versus “DANGER” for a class 4 laser controlled area is not explicitly defined. If there is trouble distinguishing the line between the situations, default to the “DANGER” signal word.

Follow the instructions laser waring sign template linked above to fill out the rest of the required information on the sign.

See Appendix B for examples.

#### Laser Warning Labels

Lasers and laser systems that are manufactured within the United States are required to be classified and labeled IAW the FLPPS standard. These lasers should already arrive correctly labeled and classified. Lasers manufactured in countries that follow the IEC standard are also labeled and classified by the manufacturer IAW IEC standards.

Lasers labeled and classified IAW FLPPS and IEC are considered appropriate by ANSI standards.

If a laser was manufactured in a country that does not follow FLPPS or IEC, or was “home-made”, then that laser shall be classified and labeled IAW ANSI before being used by the end user. This classification can be done by authorized personnel or the LSO.

A label created IAW ANSI standards shall include:

* A signal word. “CAUTION” for class 2, 3R, and 3B and “DANGER” for class 4
* Class of the laser or laser system
* Emitted wavelength, maximum power, and pulse information (if applicable)
* A precautionary statement for users. These are:
  + For class 2 lasers “Laser Radiation – Do Not Stare into Beam”
  + For class 3R and 3B lasers and laser systems “Laser Radiation – Avoid Direct Eye Exposure to Beam”
  + For class 4 lasers and laser systems “Avoid Eye exposure to Direct or Scattered Radiation; Avoid Skin Exposure to Direct Radiation”
* Either a Sunburst warning symbol (see Appendix 1) or color coded to match the laser hazard. Black font on a yellow background for “CAUTION” and black font with red symbol and signal word on a white background for “DANGER”.

See Appendix B for examples.

#### Controlled Operation

Whenever possible, class 4 lasers should be controlled and monitored at a position as far as possible from the emission point.

### Personal Protective Equipment

When other control measures are not applicable or practicable, Personal Protective Equipment shall be used to protect against laser radiation.

Laser eye protection shall be used within the Nominal Hazard Zones of class 3B and 4 lasers. Exemptions can be made for this rule if the NHZ is so small that a person’s eyes could not be put in the direct path of the beam and reflective material is not used within the beam path. Also, if the laser’s beam path is fully enclosed LEP is not needed.

#### Laser Eye Protection

LEP shall be administratively required within the NHZ of a class 3B or 4 laser or laser system. Their use shall be enforced when engineering and administrative controls are not practicable. An exemption can be given for the use of LEP if the LSO determines there is no danger of exceeding the MPE.

LEP is not required for class 2 or 3R lasers unless conditions are required where intentional direct exposure >0.25 seconds is required.

LEP can include goggles, face shields, spectacles, or prescription eyewear with a special coating to reduce the potential ocular exposure to below MPE levels. However, LEP is not meant to protect the wearer from a constant, intentional exposure. It is specifically designed to withstand diffusely scattered beams or a short direct exposure. Most LEP is designed to withstand a maximum exposure of 10 seconds before failing. LEP shall be used in a manner so that the damage threshold will not be exceeded even in a worst-case scenario.

Use the guide found on the [EHS Website](https://ehs.psu.edu/laser-safety/laser-safety-requirements-guidelines) to assist with selecting the correct pair of LEP.

#### Skin Protection

Skin protection is always best achieved through engineering controls. However, if that is not possible, PPE is the next best line of defense if one needs to be in the NHZ. Usually just long clothes (long sleeves and pants) or a lab coat will provide sufficient protection from scattered laser radiation. Gloves are also recommended if the user’s hands will be near the beam.

For higher power class 4 lasers, regular clothes, lab coats, or gloves may not afford proper protection. For this it is recommended that tightly-woven and flame-retardant fabrics are used to protect the user’s body and specialized gloves (like welder’s gloves) are used to protect the hands.

If the laser radiation is within the UV range, special care shall be taken to ensure no skin exposure over the MPE is received. Exposure to UV radiation shall be minimized by using special shields or protective clothing.

Contact the LSO with any skin protection questions.

## Class 1 laser systems with embedded 3B and 4 lasers

Class 1 laser systems with embedded class 3B or 4 lasers are safe for use without any additional control measures. They ensure laser radiation levels from the powerful lasers contained within stay within class 1 limits for any personnel within the laser area.

### Requirements

Requirements for class 1 laser systems embedded with class 3B or 4 lasers are different than the lasers they contain. They are exempt from most requirements unless protective housings are removed or interlocks are defeated.

Lasers that fall under this category still need to be registered with the RPO upon receipt and before first use.

Users of these lasers shall complete the general laser safety training and laser specific training given by the authorized user before first use of the instrument.

### Exemptions

Class 1 laser systems with embedded class 3B and 4 lasers are exempt from requirements in 8.4.2.4 and the need for a laser control area warning sign is recommended, not required. If laser area warning signs are used, they shall follow the requirements outlined in 8.4.2.6.

However, if the interlocks are defeated or the housing is removed from the laser, these exemptions no longer apply. See 8.5.3 for information on temporary laser control areas.

Yearly audits are not required for class 1 laser systems, but yearly inventory shall still be completed.

### Temporary Laser Control Areas

Temporary laser control area shall be created when interlocks or protective housings are removed from laser systems that are normally classified as class 1 systems but contain embedded class 3B or 4 lasers and no control measures exist within the area.

Temporary laser control areas shall follow all of the applicable requirements listed in section 8.4.2.4 for the entirety of the time that the protections are removed.

In addition, they shall be posted with a temporary laser control area sign. This sign shall have all of the necessary information for the laser contained within the housing or interlock. However, this sign shall have the signal word “NOTICE” along with blue coloring. The sign shall describe the exact type of newly form laser area. For example: “Temporary Class 4 Laser Control Area”. This sign shall be posted on each accessible entrance for the entirety of the time that the protective housings or interlocks are removed.

Please see Appendix B for an example of the sign layout and see the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-resources) for guidance on creating the sign.

# Laser Procurement Procedures

When a new class 3B, class 4, or class 1 laser system with an embedded class 3B or 4 laser is purchased at Penn State, the PI, AU or Lab Manager shall inform the LSO of this purchase.

Lasers purchased through the SIMBA purchasing system will automatically notify the LSO that a laser was purchased, but will not include the information of the PI, AU, or Lab Manager who is purchasing the laser. To ensure the LSO is aware of the laser purchase by your lab, the purchaser shall notify the LSO in a timely manner and before being turned on for the first time.

Lasers purchased through other means (e.g., online with a personal credit card, from another researcher at another institution) shall be reported to the LSO before arrival to PSU. Lasers not purchased through a US or European manufacturer often have missing or incorrect labels and need to be corrected to comply with Penn State and federal standards. It is important that the LSO is notified of these purchases to correct any issues before the laser is put into use.

# Initial Laser Use and Registration Procedures

## New laser procurement and registration without existing lasers

If a lab, PI, or Authorized User wishes to acquire a laser or laser system with a power of class 3B or greater or contains an embedded 3B or 4 laser, and does not already have an existing registered laser, they will need to complete the following steps before the laser can be officially used for the first time. A full detailed, downloadable guide can also be found on the EHS website.

* Inform the LSO or RPO of your laser purchase
  + SIMBA will automatically notify the RPO of any laser purchase, but it is highly recommended to also personally notify the LSO or RPO
* Register the new laser
  + Complete the registration form. The registration form can be found on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-program-forms).
  + Fill out the form completely and for each laser being purchased.
  + Send a copy to the LSO and keep an accessible copy for records.
  + This can be completed before the laser arrives.
* Ensure all users are trained
  + Anyone who will use the laser must complete the General Laser Safety Training course on the LRN as well as get specific training on the laser before their first use.
  + Refer to 7.2 for detailed training instructions.
* Create an SOP for the laser
  + A template can be found on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-resources).
  + An SOP shall be created for each laser. It is also acceptable if each laser has its own section within the same SOP document.
  + Send the completed SOP to the LSO for review.
* Obtain proper LEP for the lab before the laser is out into service.
  + Refer to 8.4.3.1 for LEP requirements.
* Ensure all proper control measures are in place for the laser lab
  + Refer to Section 8.0 for laser hazards and control measures. Contact the LSO if any assistance is needed in choosing appropriate control measures.
  + The laser may be operated for testing at lower powers before the control measures are fully completed. Control measures must be in place before full, normal operation of the laser occurs.
* Contact the LSO for an initial lab evaluation once all previous steps are completed.

## New laser procurement and registration with existing permit

If a lab, PI, or Authorized User wishes to acquire a laser or laser system with a power of class 3B or greater or contains an embedded 3B or 4 laser, and has an existing laser permit, they will need to follow the following steps before the laser can be officially used for the first time.

* Inform the LSO or RPO of your laser purchase
  + SIMBA will automatically notify the RPO of any laser purchase, but it is highly recommended to also personally notify the LSO or RPO
* Register the new laser
  + Complete the registration form. The registration form can be found on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-program-forms).
  + Only fill out the laser information section on the form.
  + Send a copy to the LSO and keep a printed copy for records.
* Ensure all users are trained on the specific laser or laser system
  + Anyone who will use the new laser must complete specific training on the laser before using it.
  + Refer to 7.2 for detailed training instructions.
* Create an SOP for the laser
  + A template can be found on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-resources).
  + An SOP shall be created for each laser. It is also acceptable if each laser has its own section within the same SOP document.
  + Send the completed SOP to the LSO for review.
* Ensure all proper control measures are added to the lab if the new laser or laser system is a different classification than the existing one(s).
  + Refer to Section 8.0 for laser hazards and control measures. Contact the LSO if any assistance is needed in choosing appropriate control measures.
  + The laser may be operated for testing at lower powers before the control measures are fully completed. Appropriate control measures must be in place before full, normal operation of the laser occurs.

# Non-Beam Hazards

## Types of non-beam hazards

Non-beam hazards (NBH) are all hazards arising from the presence of a laser system excluding direct exposure to the beam itself. These include secondary hazards from the beam, hazards from the equipment peripheral to the laser, and hazards from compounds that are necessary to the laser or periphery system’s function. NBH can occur when material is exposed to the beam, when materials used to generate the beam are released, or when individuals within the laser interact with components of the laser system. Because some NBH are life threatening, more control measures than are required in section 8.0 may be required for that laser control area. Please contact EHS for assistance with controlling any NBH that may arise from laser use.

All SOPs written for lasers shall include and address and NBH associated with the laser or laser system.

Non-beam hazards are separated into four categories: Physical, Chemical, Biological, and Human.

### Physical Non-Beam Hazards

#### Electrical Hazards

Electrical equipment presents multiple potential hazards including:

* Electric Shock – An electric shock hazard may occur from contact with energized electrical conductors contained in a laser’s control system, power supply, or other internal components. These exposures can occur during set-up/installation, service, or maintenance where protective housings may be removed. Electric shock occurrence and severity is difficult to predict, so it is important to protect against all accidental contact with electrical systems. This can be accomplished with barrier systems, grounding frames, enclosures, or other metallic parts, and appropriate Lock-Out-Tag-Out (LOTO) procedures.
* Resistive Heating – Resistive heating is the heating of a conductor due to the flow of electric current increasing with increasing resistance. If left unchecked, this can cause excessive heat build-up which can damage system parts. Touching one of these parts can also result in a burn. Normally the manufacturer provides sufficient cooling for normal operations. However, parts of the laser system should still be checked regularly for excessive heating and wear.
* Electrical Spark Ignition – Equipment malfunctions can lead to electrical fires. Electrical sparks can lead to the ignition of flammable vapors or flammable materials in the vicinity of the laser system. Fire extinguishers shall be located near areas where class 4 lasers are in use.
  + Ensure the fire extinguisher in use is appropriate for the type of fire that can be caused or use on the equipment in the area. See the Fire Prevention and Protection section of the [EHS Webpage](https://ehs.psu.edu/fire-prevention-and-protection/overview) for more guidance.
* Arc Flash – A fault in and electrical part can cause an arc. An arc flash can include intense radiant energy, high air temperatures, high-pressure waves, and shrapnel from the part or housing. Causes of arc flash are from human error or equipment malfunction.

There are multiple electrical-related potential safety hazards that can be found in laser use areas. They should be addressed immediately if discovered. These include: Uncovered or improperly insulated terminals, hidden “power-on” warnings or lights, lack of appropriate training, failure to discharge capacitors, improperly grounded laser equipment, non-adherence to OSHA standards, and excessive wires on the floor.

Safety requirements for electrical equipment are imposed by OSHA. It is important to follow these requirements as well as any requirements required by Penn State OPP or EHS. LOTO procedures and requirements are important for preventing electrical hazards. See [SY-35](https://policy.psu.edu/policies/SY35) for LOTO guidance and see the Energized Electrical Safety section of the [EHS Webpage](https://ehs.psu.edu/energized-electrical-safety/overview) for more guidance.

#### Non-Laser Radiation (NLR)

Operating a laser system or the interaction of laser radiation on targets can produce various forms of radiation. In some cases, the additional levels of NLR require extra control measures. Causes of NLR include collateral radiation and Laser-Target Interaction Radiation (LTIR)

Collateral radiation is any radiation (excluding laser radiation) is emitted from the laser or laser system. Examples include radiofrequency emissions, flashlamp light, and X-Rays emitted by high power components. Collateral radiation is rarely a safety concern but may require additional control measures to comply with regulations of the specific radiation type.

Laser-Target Interaction Radiation (LTIR) is non-laser radiation emitted by a material as a result of it being exposed to a laser beam. Examples include plasma generated form high powered lasers interacting with fine particulates or UV radiation from lasers welding materials. The LTIR emission depends on the laser irradiance and the material of the target.

NLR control measures and hazards are determined by the wavelength given off. The types are as follows:

* Ionizing radiation – X-Rays may be generated by the electrical components of laser systems, such as high voltage vacuum tubes (over 15kV), or from plasmas that result from laser beams with peak irradiance over 1016 Wcm-2. Laser-related ionizing radiation shall be controlled IAW applicable federal, state, and University ionizing radiation regulations. See the Radiation Protection section of [the EHS webpage](https://ehs.psu.edu/radiation-protection) for information on ionizing radiation.
* Optical Radiation – Collateral UV radiation from charge tubes or pump lasers, and plasma emissions created during laser-target interactions can cause enough UV and blue light to pose a long-term ocular hazard risk if proper PPE is not worn. Certain intensity UV light can also cause photokerititis. Any laser-related UV sources shall be properly shielded so that exposure levels are kept below limits specified by regulation.
* Microwave, radio, low frequency, and static EM fields – Power supplies and other electrical equipment associated with lasers are capable of generating EM fields. IEEE standards shall be followed if certain EM fields can be created by the laser or laser system.

Contact the Radiation Protection Office for guidance on NLR.

#### Fire Hazards

Class 4 laser beams present a fire hazard. If laser beams over 500mW strike anything directly or diffusely they may start a fire if that material is flammable. The highest risk of this occurring is when an enclosure of a class 4 laser is not designed to withstand 10W/cm2 or 0.5W of direct beam exposure.

The material used to terminate a class 4 laser beam shall be made of non-flammable material and be created to withstand the irradiance of the laser beam.

Class 4 laser enclosures shall be made of flame-retardant material. If the potential of direct exposure to the laser beam exists, the material blocking a class 4 laser from exiting the work area shall be rated to withstand the irradiance of the laser beam. Any user who purchases commercially available laser barriers shall obtain the fire prevention information from the manufacturer.

Fire Suppression

* Portable fire extinguishers shall be provided, or located within reasonable reach, to extinguish a fire occurring within the laser equipment or caused by the laser beam.
* The selection, placement, and maintenance of portable fire extinguishers shall be in accordance with NFPA 10.
* The LSO, or appropriate EHS individual, shall determine the need for an alternative extinguishers and suppression methods necessary for the specific laser installation(s).
* Training shall be provided on the use of fire suppression systems and equipment
* Materials adjacent to a class 4 laser that can be an ignition hazard shall be evaluated for their fire properties.

#### Explosion Hazards

High-pressure arc lamps, filament lamps, and capacitor banks all present an explosive hazard. They shall be enclosed in a protective housing that can withstand the maximum explosive pressure from the component failing. Any laser target that can shatter or explode form laser exposure shall be enclosed or protected to prevent injury to operators or observers.

#### Mechanical Hazards

Some lasers have mechanical moving parts, such as those attached to a robotic arm. These present multiple hazards, including laser-beam hazards. Robotic mechanisms or arms can malfunction and punch holes in protective housing, damage the laser system, or direct the laser towards operators. These are in addition to crushing hazards presented by mechanical parts.

Robots typically have a fixed working envelope but attaching a laser to them may extend its NHZ. This could add direct or reflected beam concerns at unexpected locations.

Control measures can include extra interlocks, light curtains, or non-rigid barriers.

#### Noise Hazards

Noise levels from certain lasers or laser systems may be of a high enough intensity that control measures are needed. See the Hearing Conservation section of the [EHS Webpage](https://ehs.psu.edu/hearing-conservation/overview) for more guidance.

### Chemical Non-Beam Hazards

#### LGAC

Laser Generated Airborne Contaminants (LGAC) may be generated when class 3B or 4 lasers interact with a certain material. The type and quantity of LGAC released depend on the target material and beam irradiance. EHS shall be contacted to ensure proper control measures and protection are present for potential LGAC exposure.

Generally, if class 4 lasers are used for materials processing, there shall be air filtration measures in place for potential LGAC. This includes all class 4 laser cutters. Class 4 laser cutters shall have a ventilation system or be solely operated within a hood.

#### Compressed Gas

Compressed gas cylinders present hazards from damage to the valve mechanism or puncture damage to the cylinder as well as hazards from the gas itself. Any compressed gas cylinder shall always be secured to the wall or benchtop to prevent it falling over.

Hazardous gasses, such as fluorine, hydrogen chloride, and hydrogen fluoride, are used in some laser applications. All hazardous gases shall be properly secured and contained in the proper cabinet with proper sensors and alarms IAW EHS policies. Contact EHS for assistance with compressed gas control measures. [See SY-25](https://policy.psu.edu/policies/sy25) for more details.

#### Cryogens

Cryogens are often used as a part of the coolant system for higher powered lasers. Proper PPE must be worn while handling or transferring cryogens. This includes insulated gloves, a lab coat, and a face shield. Only transfer cryogens in a well-ventilated area. See the Refrigerant Management section of the [EHS Webpage](https://ehs.psu.edu/Refrigerant-Management/overview) for more guidance.

#### Dyes and Solvents

Some lasers use dyes and solvents to tune their wavelength. They are fluorescent compounds that can form a lasing medium. Certain dyes are highly toxic and carcinogenic.

The dyes in these tunable lasers frequently needs changed, so the utmost care shall be taken when handling these chemicals. An MSDS or SDS shall be available for any individual changing the dye in these lasers.

### Biological Non-Beam Hazards

#### LGAC

Biological LGAC may be created when the laser beam interacts with tissue. This becomes a hazard when the tissue contains bacteria and viral organisms that survive the irradiation and become airborne. Ensure proper ventilation is used if infected tissue is the target of laser radiation

### Human Factor Non-Beam Hazards

#### Ergonomics

The lab workers and manager shall be aware of hazards created by neglecting the workplace environment. Poor workstation layout, worker-machine interface, handling techniques and area lighting can lead to injury.

These issues can lead directly to injuries such as arm, wrist, and back injuries as well as causing distractions that lead to primary laser beam injuries.

Always ensure the workspace around a laser system is designed for comfortable work.

#### Limited Space

If there is limited space around a laser system, it can result in possible injuries form working around mechanical parts, high voltage equipment, and exposed laser beams. There shall be sufficient room for personnel to maneuver and turn around freely.

Limited maneuverability and excessive cables and wires have often resulted in tripping hazards. Tripping hazards are extremely dangerous when combined with other non-beam laser hazards and open beam laser system.

#### Clutter

Clutter on the work surface or optical table where a laser is used is the greatest risk for a laser-caused fire. Ensure all flammable materials are removed from the beam path of a class 4 laser.

Leaving extra optical components on the work surface where a laser is used is one of the greatest risks of stray laser reflections. Ensure all reflective materials are removed from the beam path of any laser.

## Lock Out Tag Out

Lock Out Tag Out (LOTO) shall be considered during certain modes of operations for lasers. These modes of operations include normal operations, service, and maintenance. The LSO will have the authority to designate between the three operating modes.

* Normal operations are considered routine tasks completed by lasers users within a designated laser safety area. Alignment of the energized beam within its intended function is considered normal operation. This includes adjustment and repair of optics and creating and modifying the beam path.
* Service is considered infrequent repair work on the laser outside of its intended function. This includes internal work within the enclosure on electrical or optical parts of the laser itself.
* Maintenance is routine work performed to maintain performance of the laser.

LOTO is not required for normal operation, or minor service or maintenance. LOTO is only recommended in instances where unexpected energization or start-up of the laser is possible. This includes the laser being serviced outside of the laser safety area, the laser at the end of a long system of other lasers or machines being serviced, or the energization source of the laser is out of view of the personnel servicing it.

A hazard analysis will need to be completed by the LSO to determine if the control of hazardous energy needs to be implemented. If LOTO procedures are deemed necessary, they shall be included within the SOP of the laser.

The main form of laser LOTO is via an electrical main disconnect. Controlling the power supply or circuit that excites the lasing medium is the preferred method of laser LOTO. If electrical LOTO is impossible, alternate control methods can be used, such as: removing the key to the power supply, employing a laser shutter, or blocking the laser beam with appropriate material.

The exemption for LOTO procedures for lasers is if the laser is completely energized by a cord and plug into a wall outlet. This exemption holds providing the person servicing the laser has a direct line of sight to the cord and plug. If the laser is powered by cord and plug and the service personnel can see both, no LOTO is required no matter the type of operation or service.

# Laser Cutters

Laser cutters provide their own unique hazards compared to most other types of lasers. Specific safety precautions shall be taken when using a laser cutter. Please refer to the Laser Cutter Guidelines document found on the [EHS website](https://ehs.psu.edu/laser-safety/laser-safety-requirements-guidelines) for specific guidance on how to safely operate a laser cutter.

Classification confirmation of laser cutters is extremely important. Laser cutters are often manufactured in places that do not have laser classification regulations. They are either mis-classified or not classified at all. Anyone purchasing a laser cutter shall contact the LSO for guidance on classification if the laser cutter was purchased from a country without laser manufacturing regulations.

If a laser cutter was not classified using the FLPPS standard, then it shall be classified IAW FLPPS, and laser warning labels shall be added to the laser before it is put into service. The LSO has the right to review any laser that was classified with the FLPPS standard to confirm accuracy of the labeling.

# Special Considerations

This section will include special considerations or exemptions made for certain unique laser set-ups or configurations that the LSO has granted to individual labs.

If these unique laser or lab set-ups are exactly replicated in a different lab or space, these considerations or exemptions may be used for those labs as well.

Contact the LSO if you feel that your set-up or configuration matches one in this section and would like a review of your lab to receive a special consideration. The LSO has final say when granting special considerations or exemptions.

If your lab or laser set-up qualifies for one of these special considerations or exemptions, as confirmed by the LSO, you may follow this section over the applicable section located earlier in this document.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Table 3: Special Considerations for Laser Control Measure Exemptions** | | | | |
| **Date of Occurrence** | **Date Added** | **Situation** | **Special Consideration** | **Exemption** |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

# Third Party Lasers at Penn State

## Laser Light Shows

Lasers and laser projection systems have been used with other optical equipment to produce colorful, dramatic displays for entertainment purpose during multiple musical and other campus events at Penn State. Some laser light shows involve high power lasers including Class 3B and Class 4 Lasers, which can cause potential risks as eye injury, skin burns, fire and other safety risks for pilots, drivers and others who may be distracted or temporarily unable to see. To minimize the potential hazards from laser light shows and displays, Federal Drug and Administration (FDA), the Center for Devices and Radiological Health (CDRH) developed regulations to keep hazardous lasers away from audience. Therefore, for each laser light show at Penn State, EHS will require vendor to provide specific documentations to confirm that the applicable FDA regulations for laser light shows are complied with.

Prior to using Class 3B and Class 4 lasers in a laser light show in the United States, the manufacturer or laser light show vendor must submit the following documents to the FDA for approval:

* Product Report describing the laser projector,
* Laser Light Show Report describing the laser light show, and
* Application requesting FDA approval for a variance from the demonstration laser product hazard class limit of 3R (5 mW visible output).

The issuance of the variance for laser light shows is based upon the FDA’s determination that the product performs a function or is intended for a purpose which could not be performed or accomplished if required to meet the applicable standards, and suitable means for assuring radiation safety or protection are provided.

The facility manager or event organizer at Penn State has the responsibility to request the laser light show vendor to provide the LSO the following documents at least 48 hours prior to the show:

* Name and contact information for the laser show vendor,
* Laser information and planned laser layout for the show,
* Name and training record for the Laser Safety Officer (LSO) for the show,
* A copy of the last variance issued by the CDRH, FDA,
* A copy of the Laser Light Show Report filed with the CDRH for the show to be performed at the University, and

If the laser light show or display is outdoor, the Federal Aviation Administration (FDA) must be notified before any open air laser light shows operate. Notification to the FAA of a proposed open air laser light show should be made in writing at least two weeks and preferably four weeks in advance of the performance. For outdoor laser light shows, an approval letter from FDA should also be submitted to EHS for review.

After reviewing all required documents for the laser light show, the Penn State LSO shall schedule an onsite inspection that needs to be conducted after the setup and test of the laser show equipment, and before the performance. This on-site visit shall be conducted and the laser safety and control measures shall be approved before the show is allowed to commence.

## Laser Use in Construction

Laser use in construction is specifically outlined in OSHA standards. When lasers are being used for construction purposes at Penn State, the OSHA regulations shall be followed and are considered to supersede this document and ANSI Z136.1.

OSHA regulations on laser use in the construction industry are 29 CFR 1926 Subparts D and E.

In addition to applicable OSHA standards, the LSO shall be notified of any laser use on Penn State Property.

## Lasers on Lease to Laser Labs

If a laser is leased or lent to a lab at Penn State from another institution, the PI of the lab receiving the laser shall notify the LSO prior to the laser’s arrival. The arriving laser(s) is not required to be registered with the University if it will not remain on University property, or be used by university personnel, for a period of less than 6 months’ time. If the laser will be at Penn State University for greater than 6 months, the receiving PI shall follow all procedures outlined in Section 10 of this document for laser registration.

If the laser will not be at Penn State University for greater than 6 months’ time, the PI, AU, or Lab Manager will still need to ensure all proper control measures are in place. These include:

* A temporary laser controlled area.
* Proper engineering and administrative control measures are in place to reflect the class of the laser.
* An SOP for the laser
  + This SOP may be provided by the lending institution or entity and considered acceptable pending review by the LSO.

The PI, AU, or Lab manager shall also ensure all training requirements from section 7 are followed.

If the laser will be at Penn State for greater than 6 months’ time, all applicable sections of this document shall be followed as if the laser will be a permanent fixture at the University. If the initial plan was for the laser to be at Penn State for less than 6 months’ time, but the need for the laser extends past that time period, the laser shall be registered with the LSO and all applicable sections of this document shall be followed.

# Revision History

|  |  |
| --- | --- |
| Revision Date | Purpose or Description |
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# Forms: SOP Acknowledgement Form; Laser Specific Training Documentation; Registration Form.

**SOP Acknowledgement Form**

Instructions:

* Please have all individuals who use the laser this document references complete part 1 of this form if the SOP has had any updates within the last calendar year
  + If the SOP has been updated, send any changes to the LSO
* Please have the PI of the laser sign part 2 of this form if the SOP has not been changed within the last calendar year.
* If part 1 has been completed, attached a copy of this form to the back of the SOP and discard of any previous copies. If only part 2 has been completed, the LSO will keep the copy of this document.

Laser or laser system:

Serial number:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Model number:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Manufacturer:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Part 1:**

I acknowledge that I have read and understand the Standard Operating Procedures for the laser listed above and take full responsibility for my safety while operating this equipment.

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| --- | --- | --- |
| Name (Print) | Signature | Date |
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**Part 2:**

I acknowledge that no changes have been made to this laser’s SOP in the last calendar year.

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Signature:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



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| --- | --- | --- | --- |
| Laser Supervisor: |  | Laser ID: |  |
| Laser Location: |  | Laser Type: |  |

Your signature below indicates that you have received training on the laser system listed above. The training includes the Standard operating procedure, alignment procedures, maintenance procedures, and emergency procedures as applicable associated with the listed laser.

|  |  |  |  |
| --- | --- | --- | --- |
| Date | Printed Name of Person Receiving Training | Signature of Person Receiving Training | Name of Person Giving Training |
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(Required forClass 3B, Class 4, and any Class with embedded 3B or 4)

1. **Supervisor/PI information (**For non-first time registration, only **name** information is required)

First Name: Last Name: PSU ID:

College/Institution: Department: Position:

Mailing address: Office address:

CAC ID: Phone (O): Phone (L):

Phone (C): Phone (Home, emergency use only):

1. **Alternative Contact Person Information** (Skip this section if alternative contact not changed)

First Name: Last Name: Office address:

CAC ID: Phone (O): Phone (L):

Phone (C): Phone (Home, emergency use only):

1. **Laser Location**

Campus: Location if “other” selected:

College/Institution: Department:

Building: Room No.:

1. **Laser Identification and Properties**

Serial No.: Manufacture: Model No.:

Date Manufactured (Please estimate if unknown): Use code:

Laser Class: Embedded Class 3B: Embedded Class 4:

Laser Media (ex. Argon, He-Ne, diode, Dye, Ti:Sapphire, Nd:YAG, Nd:YLF):

Operation mode: Maximum output power if CW:

Repetition frequency if pulsed: Maximum output pulse energy:

Pulse Duration: Wavelength(s):

Beam diameter: Beam delivery method:

Current laser status: Is laser portable and used in more than one location?

If portable list all other location that is used:

Provide a brief description of the laser application:

**Note: For single laser system, this is the end of the registration. If this laser is part of a laser system, please provide the following information of each component.**

1. **Component #1**

Serial No.: Manufacture: Model No.:

Operation mode: Output power/energy:

Repetition Frequency: Wavelength (s):

1. **Component #2**

Serial No.: Manufacture: Model No.:

Operation mode: Output power/energy:

Repetition Frequency: Wavelength (s):

1. **Component #3**

Serial No.: Manufacture: Model No.:

Operation mode: Output power/energy:

Repetition Frequency: Wavelength (s):

1. **Component #4**

Serial No.: Manufacture: Model No.:

Operation mode: Output power/energy:

Repetition Frequency: Wavelength (s):

**Please email your registration to Austin Olson at azo2@psu.edu. Print out a copy and put it in your laser safety documentation binder as a record. After you finish the registration, please write a SOP for this laser and email to Yuanqing Guo for approval. The users for this laser are required to take the On-line General Laser Safety Training at** [**www.ehs.psu.edu/training/index.cfm**](http://www.ehs.psu.edu/training/index.cfm)**, and be specifically trained in the approved SOP before they use this laser.**

Form completed by: Date:

# Signs and Labels: Examples of Laser Warning Signs and Labels





