Johns Hopkins University Laser Safety Program & Manual

Purpose

This Laser Safety Manual contains valuable information regarding policies and procedures for using laser-based equipment at Johns Hopkins University (JHU) for non-clinical research and education, and directly reflects our institution's commitment to fostering a culture of safety.

This manual is designed to be a framework to allow and encourage members of the JHU community to responsibly use and operate lasers as outlined in the following American National Standards Institute (ANSI) standards:

- ANSI Z136.1-2022, American National Standard for Safe Use of Lasers
- ANSI Z136.5-2020, American National Standard for Safe Use of Lasers in Educational Institutions
- ANSI Z136.6-2015, American National Standard for Safe Use of Lasers Outdoors
- ANSI Z136.8-2021, American National Standard for Safe Use of Lasers in Research, Development and Testing

This manual establishes minimum standards for safe operation of experiments undertaken for the purposes of recognized scientific and engineering research and development. Where appropriate, the language of these standards is utilized though not explicitly cited.

The Laser Safety Program will include:

- The appointment of a Laser Safety Officer (LSO)
- An education program for all faculty, staff, and students who may work with lasers or may be exposed to laser hazards on Johns Hopkins-owned or -leased property, or in Johns Hopkins-affiliated research or teaching areas.
- A program to register all Class 3R, 3B and 4 Lasers from entry to exit.
- An incident reporting and review process.

Contents

References / Resources

The JHU Health and Safety Manual –

HSE SP003 - Injury and Incident Reporting

HSE 007 - Use of Protective Eye and Face Equipment

HSE 018 – Compressed Gas Cylinders

HSE 808 – Response to Laboratory Emergencies

HSE 809 - Laboratory Clearance Policy

HSE 810 - Laboratory Equipment Clearance Policy

HSE G005 - Guidance For Basic Safety Training For All Staff And Students Who Are To Work In Laboratories

HSE G007 - Guidance and Prudent Practices for Chemical Use (by Hazard Class) in Laboratories

HSE G009 - Guidance For Laser Pointers

Terms and Acronyms

Acronyms

Other relevant acronyms not defined above:

- ANSI: American National Standards Institute
- CDRH: Center for Devices and Radiological Health
- FAA: Federal Aviation Administration
- FDA: Food and Drug Administration
- KSAS: Krieger School of Arts and Sciences
- LSO: Laser Safety Officer
- MOSH: Maryland Occupational Safety and Health
- OD: Optical Density
- OES/HSE: Occupational and Environmental Safety, a division of Health, Safety, and Environment
- OH: Occupational Health
- OSHA: Occupational Safety and Health Administration
- PI: Principal Investigator
- PPE: Personal Protective Equipment
- SOM: School of Medicine
- WSE: Whiting School of Engineering

Definitions

Johns Hopkins Laser Safety has defined several user roles based on responsibility for and management of equipment, training, and exposure to laser hazards.

- **PLS (Principal Laser Supervisor):** A staff or faculty member who has sign-off authority and responsibility for the acquisition, maintenance, and safety of lasers at the Johns Hopkins University. A PLS is typically a PI, but may also include staff who have completed the requisite training and have been approved by a PI and/or the LSO.
- **ALO (Authorized Laser Operator):** One who is recognized as having successfully completed requisite laser safety training and is recognized by the PLS for a designated laser lab as being fully capable of executing, monitoring, and adjusting experiments inside the NHZ as cleared by the LSO in accordance with reviewed and accepted SOPs.

The following list contains definitions for instances where exceptions occur from the ANSI standard, emphasis is required, or additional definitions supplement the ANSI list.

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

- **LCA (Laser Control Area):** The laser use area where the occupancy and activity of those within is controlled and supervised. This area may be defined by walls, barriers, or other means.
- **MPE (Maximum Permissible Exposure):** The level of laser radiation to which an unprotected person may be exposed without any adverse biological effects in 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.
- **NHZ (Nominal Hazard Zone):** 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.
- **Shall:** The word *shall* is to be understood as mandatory.
- **Should:** The word *should* is to be understood as advisory.
- **SOP (Standard Operating Procedure):** Formal written description of the safety and administrative procedures to be followed performing a specific task.

I. Responsibilities and Duties

University/Departmental Administration

Department Management is responsible for ensuring and promoting effective laser safety practices, and enforcing laser safety policies, as well as providing the necessary resources to ensure compliance with recommended safety practices.

Laser Safety Officer (LSO)

The LSO is designated by the Office of Occupational and Environmental Safety (OES), a division of Health, Safety, and Environment (HSE). This individual has the authority and responsibility to affect the knowledgeable evaluation and control of laser hazards, the implementation of appropriate control measures, as well as to monitor and facilitate compliance with recognized or required standards and regulations. Specific duties and responsibilities include:

- Establishing and maintaining policies and procedures for the control of laser hazards.
- Establishing and maintaining a laser safety education and training program.
- Developing plans to respond to incidents of actual or suspected exposure to potentially harmful laser radiation. These plans will include:
    - Provisions for providing prompt medical assistance to potentially exposed individuals.
    - Incident investigation, reporting, and follow-up.
- Classifying and/or verifying classifications of lasers and laser systems in non-clinical research spaces.
- Evaluating hazards of laser work areas with a focus on minimizing risk.
- Assuring that prescribed control measures are implemented and operable. This includes:
    - Avoiding unnecessary or duplicate controls and recommending or approving substitutes or alternate control measures when the primary ones are not feasible or practical.
    - Conducting periodic inspections to confirm the adequacy and functionality of safety controls and measures.
- Reviewing and approving the safety aspects of:
    - All installations, facilities, and equipment involving Class 3R, 3B, and 4 Lasers prior to use.
    - Written SOPs for all Class 3B and Class 4 laser systems and other procedures that may be part of the requirements for administrative and procedural controls.
    - Protective equipment, including laser safety eyewear, clothing, barriers, and screens.
    - The wording of all area signs and equipment, to be in accordance with the Standards wherever possible.
- Assuring that the necessary records required by applicable JHU policies and by governmental regulation are maintained.

- Accompanying regulatory agency inspectors (e.g. OSHA, MOSH, FDA/CDRH, etc.) reviewing the laser safety program or investigating an incident and documenting any discrepancies or issues noted. Assuring that corrective actions are taken where required.

Principal Laser Supervisor (PLS)

Principal Laser Supervisors are responsible for ensuring the safety of all individuals for whom they have responsibility and who may be exposed to laser radiation greater than Class I. PLS are most often also Principal Investigators (PIs), but may also include core facility directors or managers who have sign-off authority and ultimately responsibility for the acquisition, maintenance, and safety of lasers in an area, lab, or facility. As a result, they should have detailed understanding and knowledge of laser safety requirements. Their specific responsibilities include:

- Completing PLS training and obtaining approval by a PI or the LSO.
- Ensuring all personnel working in their labs are properly trained and supervised.
- Submitting plans for laser installations or modifications to the LSO for review prior to operating the equipment in their areas.
- Confirming to the LSO that relevant staff (administrative managers, purchasing, building management, etc.) are aware of the pending acquisition of a Class 3 or 4 laser or laser system.
- Preparing, submitting for review, and maintaining SOPs for all Class 3B and 4 lasers under their control. The SOPs shall be reviewed by the LSO before implementation.
- Maintaining records of individuals trained to work with lasers in their areas of responsibility and providing these to the LSO as requested
- Performing maintenance on laser systems to ensure safe operation.
- Ensuring the safe and responsible disposition of all unused, unneeded, but potentially hazardous Class 3B or Class 4 lasers and components.
- Ensuring the proper reporting of incidents where injury did or could have resulted from an exposure to laser radiation for those lasers under their control. This includes implementing the JHU laser emergency response plan (see Appendix C and HSE808), complying with JHU accident policies (refer to policy HSE004), and notifying the LSO.
- Implementing corrective actions to prevent recurrence of incidents when informed that they have occurred.
- Obtaining appropriate medical attention for any employee, student, or visitor involved in a laser accident (refer to policy HSE-SP003).
- Prohibiting the operation of a laser in their area unless there are adequate controls of all laser hazards to employees, students, visitors, and the general public.
- Prohibiting the operation of a new or modified Class 3B or Class 4 laser installation under their authority without the approval of the LSO.

All PLSs must be registered with the JHU Laser Safety Portal.

PLSs are not required nor recommended to perform servicing on laser equipment if they are not qualified and certified to do so and can provide documentation of such.

Authorized Laser Operator (ALO)

ALOs are responsible for the safe use of laser sources to which they have access. Because they are permitted to work within the NHZ, they have the additional responsibility of ensuring they are operating in a manner that will not adversely affect any individuals who may enter the laser area. Individual responsibilities include:

- Completing Authorized Laser Operator laser safety training offered or authorized by the LSO before working with any Class 3B and 4 laser systems.
- Using lasers safely while complying with safety rules and procedures as prescribed by the PLS and the LSO.
- Being familiar with all applicable SOPs they are expected to perform.
- Ensuring that others do not enter the NHZ when any lasers are active.
- Reporting suspected or actual incidents where injury did or could have resulted from an exposure to laser radiation they are operating to their supervisor, the PLS, or the LSO, per HSE004.
- Performing maintenance on systems, provided they are adequately trained.

Lab instructors where students will be actively using controlled lasers (including but not limited to teaching assistants, teaching lab managers, technicians, and design space managers) are required to be qualified ALOs. Additional responsibilities include:

- Ensuring that students using lasers have adequate training for laser hazards.
- Being present while students are using lasers.
- Securing all teaching lasers when not in use.

All ALOs must be registered with the Johns Hopkins Laser Safety program (https://redcap.link/JHU_LSPSurvey). See Section II for training and certification requirements.

ALOs are not required nor recommended to perform servicing on laser equipment if they are not qualified and certified to do so and can provide documentation of such.

II. Training Requirements

All individuals at Johns Hopkins who interact with Class 3 or 4 laser systems will be trained on safe use of laser systems. At a minimum this training will include:

- Completion of one or more online training module(s) that emphasizes safe practices OR attendance at a laser safety training class that covers general topics related to safe use of lasers.
- Successful completion of an online quiz that tests knowledge on laser safety.
- Introduction to practices and procedures in specific research groups.

The level of training should be commensurate with the level of interaction personnel have with these systems.

Institution Training

Online training is available through the Johns Hopkins myLearning platform.

PLSs are required to provide proof of ANSI-compliant laser safety training. If unable, they are required to take **"Becoming an Authorized Laser Operator."**

ALOs and anyone who will be interacting with a Class 3 or 4 Laser shall take the course: **"Becoming an Authorized Laser Operator."** All individuals who will be working on a Class 3 or 4 laser must successfully complete this course and provide certification of successful completion as part of their registration with the Laser Safety Program.

ALOs will be required to take the course **"The Safe Use of Lasers in the Laboratory" as initial training, and** annually thereafter to maintain their certification with the Laser Safety Program. This annual refresher course is optional for PLS.

Students or individuals who will be working with Class 1 systems or observing (but **not** interacting with) Class 3 or 4 lasers are recommended to take the **"The Safe Use of Lasers in the Laboratory"** course. Users who are not intended to be ALOs are not required to register with the program.

Operator Level	Initial Training (always Required)	Annual Refresher
ALO	"Becoming an Authorized Laser Operator"	"The Safe Use of Lasers in the Laboratory" [Required]
PLS	"Becoming an Authorized Laser Operator" or equivalent	"The Safe Use of Lasers in the Laboratory" [Optional]

The training shall include basic instruction, as described in Section 5 and Appendix E of ANSI Z136.1-2022 including, as appropriate to the user's role in laser operation:

- The biological effects of laser radiation
- Principles of laser operation and construction
- Classification of lasers
- Control of laser areas
- Significance of specular and diffuse reflections
- Basic safety rules
- Use of personal protective equipment (PPE)
- Control of non-beam hazards including electrical safety, fire safety, and chemical safety (handling and storage)
- Emergency response procedures
- Overall responsibilities of management, employees, and other laser users

Departmental

Safety training at the departmental level should include laser safety if laser systems are used in the department by any investigators. The level of training should be commensurate with the potential exposure of department personnel to laser radiation as well as the level of interaction with the laser system itself. For example, if lasers are routinely used in departmental facilities, then all departmental personnel should be educated on associated hazards and controls. If laser systems are only used at other facilities, then only personnel involved in the use of laser systems need training.

Research Group

Training at the level of the research group should focus on practices, procedures, and standard operating procedures relevant to the types of laser systems used for research in the group. PLS, PIs, and other supervisors are encouraged to document safety training for all group members and to retain related records.

III. Laser Acquisition, Transfer, and Disposal

Primary Laser Supervisors have an obligation to ensure that lasers are used safely from before purchase through to final disposition and disposal. All Class 3 and 4 lasers shall be tracked and monitored using the **JHU Laser Safety Portal** **(https://redcap.link/JHU_LSPSurvey).** All lasers should be purchased by the users with the understanding that they are responsible for ensuring that the lasers are disposed of properly as electronic or hazardous waste to prevent injury to others.

General decision tree for requirements at time of acquisition or planning is available in Appendix B of this manual.

New Installations and Registration

Acquisition or use of any new high-power (Class 3B or 4) lasers shall be reported to the LSO. New high-power laser installations are required to be evaluated for all safe usage in research. When a PI or other authorized PLS wishes to acquire a high-power laser, they will need to complete the following steps:

- Inform the LSO of your intended purchase or acquisition. Email HSEinfo@jhmi.edu to the attention of the Laser Safety Officer (LSO)
- Register the laser with the JHU Laser Safety Portal
    - Lasers can be registered at time of purchase; they do not need to be physically on site before registration
    - If not registered at time of purchase, laser must be registered before it may be powered on for normal operation
- Create SOPs for laser operation and maintenance procedures.
    - At time of registration, the SOP does not need to be complete, but shall at least include a description of the intended use
    - SOP should also include the names of all intended users
- Schedule a laboratory visit with the LSO
- Ensure all intended users registered in the JHU Laser Safety Portal are trained appropriately to their role
    - All users who are working within the NHZ must be trained and registered with OES/HSE
    - Users will be required to submit their myLearning certificates after successful completion of the required safety course(s). See Section II for individual training requirements.

All previous steps must be completed, and all documents and safety measures must be reviewed and approved by the LSO before the laser can be energized at full power for intended use.

Laser Disposal

When any laser is taken out of service, including Classes 1-3R, it is the responsibility of the registered PLS and/or PI to properly store, repurpose, or dispose of the equipment.

- When a laser is removed from service it can be:
    - Placed in safe secure storage under the control of the PLS and/or PI
    - Placed in safe secure storage for the purpose of reassigning labs
    - Donated to another registered laser lab within the university (who must register the laser with their group)
    - Sold or otherwise donated to other responsible laser users outside the university
    - Disposed as excess property

The LSO shall be notified if a laser is repurposed, decommissioned, or disposed of. In all cases, lasers shall be handled following best practices for lasers and other electronics and in compliance with the JHU laboratory equipment clearance policy (HSE 810). Wherever possible, laser components should be ultimately recycled.

IV. Laser Hazards and Control Measures

Laser Classifications

Laser hazard classes are assigned based on the capability of a laser to cause an eye injury. Classification is primarily designated based on the following parameters:

- Wavelength range
- The effective power of a continuous wave (CW) or repetitive-pulse laser
- The total energy per pulse in a pulsed laser

While the LSO will usually rely on the manufacturer's information for commercial products, there may be instances in which the LSO will be required to classify a university laser in accordance with the ANSI Z136.1 standard, based upon the LSO's distinction of the laser in its specific use.

The Laser Safety Program at JHU is predominantly concerned with the safe usage and control of Class 3 & 4 lasers, but users of all lasers are expected to understand the associated risks and should receive laser safety training. The fundamental objective is to ensure potential exposures are at or below the MPE.

Classifications are as follows:

- **Class 1:**
  - Considered incapable of emitting laser radiation levels that are damaging to the human eye during normal operations
  - Exempt from control measures and surveillance – UNLESS a Class 1 system with an embedded Class 3 or 4 laser
  - *Note: Previously referred to as "Class 2A" in old standards. Older model lasers may still bear this label*
- **Class 1M:**
  - "M": magnification
  - Incapable of producing damaging laser radiation during normal operation, unless the beam is viewed with an optical instrument (e.g., loupe, telescope)
  - Exempt from control measures and surveillance other than prevention of potentially hazardous optically-aided viewing – UNLESS a Class 1 system with an embedded Class 3 or 4 laser
- **Class 2:**
  - Visible light (400-700 nm)
  - Maximum CW power of 1milliwatt
  - Does not require eye protection, as the natural aversion response (blinking) will protect against injury
  - Exempt from control measures & surveillance
- **Class 2M:**

  - Visible light (400-700 nm)
  - Maximum CW power of 1 milliwatt
  - Does not require eye protection, unless viewed with an optical instrument (e.g., magnifying glass, telescope, loupe)
  - Exempt from control measures & surveillance other than prevention of potentially hazardous optically-aided viewing
- **Class 3R:**
  - "R": Reduced requirements
  - CW power range between 1-5 milliwatts for visible and invisible light
  - Also includes invisible lasers <1 mW
  - Does not require eye protection or other control measures, unless viewed with an optical instrument (e.g., magnifying glass, telescope, loupe).
  - *Note: Previously referred to as "Class 3A" in old standards. Older model lasers may still bear this label*
- **Class 3B:**
  - Includes both visible and invisible light
  - CW power range between 5-500 milliwatts or <30 mJ for pulsed systems
  - Requires multiple control measures and forms of surveillance, including eye protection.
  - LSO must be involved in the pre-startup review.
- **Class 4:**
  - Includes both visible and invisible light
  - Any laser with CW power above 500 milliwatts or 30 mJ for pulsed systems
  - Requires multiple control measures and forms of surveillance, including eye protection.
  - LSO must be involved in the pre-startup review.

Hazard Control Measures

A control hierarchy should be followed when selecting control measures. The hierarchy of controls has five levels that reduce or remove hazards in a process. From most to least effective, the generally accepted order is:

1. Elimination
2. Substitution
3. Engineering controls
4. Administrative controls
5. Personal protective equipment

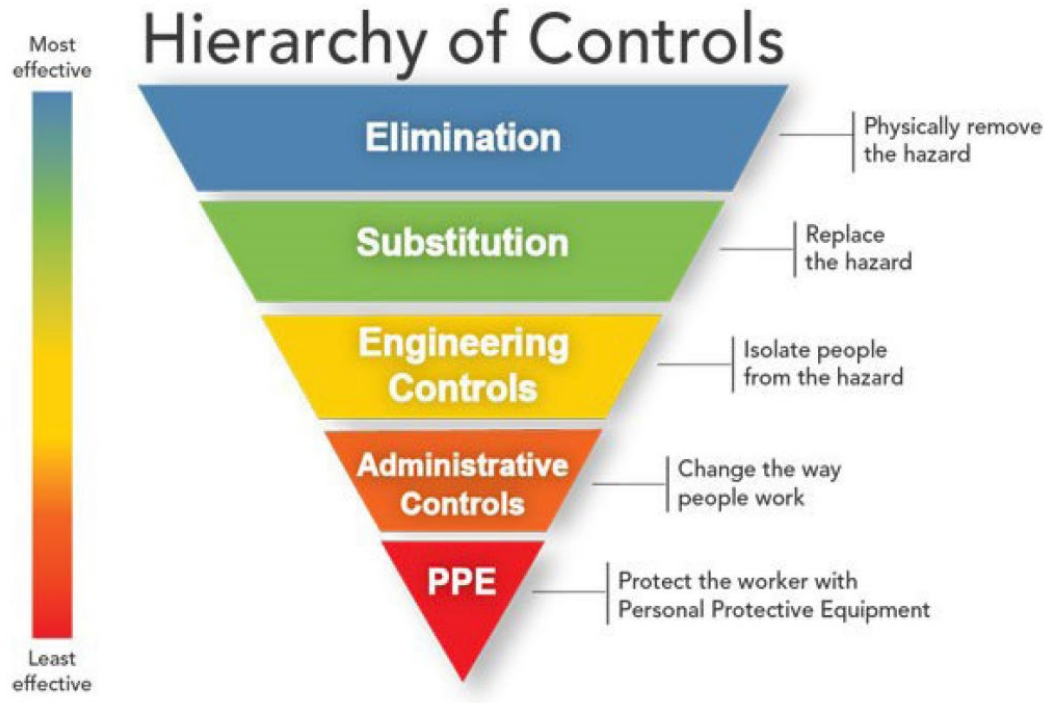


Figure 1: Hierarchy of controls. Source: NIOSH

Elimination

Elimination removes the hazard at the source. It is understood that risks cannot be eliminated, but they should never be greater than absolutely warranted (or than a level deemed acceptable). While it is likely not always possible, it should always be considered whether a laser is absolutely required for a process. In lieu of that, any additional materials should be considered for elimination to avoid exposure.

Substitution

Substitution seeks a safer alternative to the source of a hazard. The lowest power laser necessary should always be considered for existing or planned installations. Further, substitutions to direct viewing of a laser beam within the NHZ should always be evaluated. E.g. web cameras, thermal imagers, fluorescent papers, disposable targets

Engineering Controls

Engineering controls are physical features and design characteristics of laser systems implemented to protect from laser radiation by blocking or preventing laser light from escaping a

defined path in an uncontrolled manner. They are considered the first line of defense for laser safety and should be used before administrative controls and PPE when applicable.

Examples and recommended methods are as follows:

Protective Housing

Protective housing is a physical barrier and means to enclosing and limiting access to radiant energy emissions, electrical hazards, and other hazards associated with the laser's internal components. While many lasers are equipped with their own protective housing, secondary enclosures that encase the equipment components along with part or all of the beam path should be considered for implementation.

Protective housing is **required** for:

- Class 3R
- Class 3B
- Class 4

Key Control & Housing Interlocks

Key locks are a master control system in which the system is not operable without a physical key and/or knowledge of a password. These types of controls can be used to limit laser operation to authorized users by issuing physical keys or passwords only to qualified personnel. This type of operational control can be effective in facilities where monitoring of facility usage is necessary.

Key controls are **recommended** but not required for:

- Class 3B
- Class 4

Interlocks shall be designed such that they prevent exposure above MPE levels. If a laser has protective housing that is removable, the following lasers are **required** to have an interlock that will prevent exposure if the housing is removed during normal operation or maintenance of the equipment:

- Class 3R
- Class 3B
- Class 4

Entryway Interlocks

Remote interlocks allow for electrical connections to emergency controls at entrances to the Laser Control Area (LCA) in the event of an unexpected entry during operation. Entryway interlocks may be Non-Defeatable, Defeatable, or Procedural.

Non-Defeatable interlocks may include designs such as switches, pressure plates, proximity sensors that cannot be easily overridden or bypassed without specialized tools or procedures and can be used to prevent entry into spaces or access to equipment during operation or maintenance so as to reduce the risk of exposure.

Defeatable interlocks serve the same purpose, but are specifically designed to be intentionally able to be bypassed. This allows for uninterrupted operation during controlled operations (such as alignment or servicing), or provides the ability to enter a LCA without interrupting laser operation

- Entryway interlocks are **recommended** for Class 3B lasers.
- Entryway interlocks are **required** for Class 4 lasers.

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:

- A clearly defined LCA must be established with safety procedures posted
- All authorized personnel with access to the LCA shall be adequately trained on all hazards present, with recorded documentation of both institution and research group training.
- PPE shall be provided upon or prior to entry
- An adequately rated blocking barrier shall be used to prevent MPE exposure at the entryway.
- There shall be an area warning device indicating when the laser is energized.

Procedural controls should never be used as an alternative to remote interlocks where it is feasible to install a remote interlock.

Laser Protective Barriers and Curtains

A blocking barrier, screen or curtain should be used at the entryway to the LCA to prevent any laser radiation above the MPE from exiting. Commercially available barrier, screen, and curtain material shall be selected based on their rated ability, or barrier threshold limit, to withstand laser exposure in a worst-case scenario. All laser barriers, screens, and curtains shall be labeled with the beam exposure conditions under which protection is afforded.

Protective barriers and curtains are **recommended** but not required for:

- Class 3B
- Class 4

Administrative Controls

Administrative controls give workers more information by providing workers with relevant procedures, training, or warnings. Areas where lasers are in use should generally include the following administrative controls.

Standard Operating Procedures (SOPs)

SOPs should be written to effectively capture the hazards associated with the work generally being conducted and should not be written to require revision every time an experiment is re-configured. Contents of an SOP should include information regarding the laser(s) being used and should indicate the types of hazards that are present for the research being pursued. Control measures should be specified and general operational procedures should be listed. SOPs can reference other resources (such as this manual) to address topics that can be handled generically.

The Primary Investigator shall provide a written SOP, approved by the LSO prior to laser use, for all Class 3B and Class 4 laser systems. This SOP must be posted near the laser(s) and include:

- Scope of work
- A diagram with a general layout of the laser equipment (including safety barriers) within the intended room(s)
- Start-up and shutdown procedures for the laser and any related systems
- Hazard identification
- General laser safety measures
- Non-beam hazard safety measures
- PPE requirements and appropriate usage
- Alignment procedures
- Emergency procedures, including emergency shut downs, response for an incident, and contact information for the PI or responsible PLS and the HSE-designated LSO

See Appendix A for template examples.

Signage and Warnings

Class 3B and 4 laser areas shall be posted with a laser warning sign on each accessible entrance. Laser warning signage must be created in compliance with ANSI Z136.1 guidelines for design, using the template provided by HSE. See Appendix C.

Class 3R laser areas or laser systems should be posted with the appropriate sign as shown in the template.

Trainings and Sign-offs

All laser workers and students using systems containing controlled lasers must receive training to ensure that they are fully cognizant of the laser hazards they will face and what precautions they must take to ensure the safety of themselves and others. Initial training shall be given prior to using the laser system with annual refresher training being required for continual certification. See Section II for specific training requirements

Personal Protective Equipment

Eye protection

When other control measures are not applicable or practicable, Personal Protective Equipment (PPE) is the last line of defense for protecting yourself against laser radiation. PIs and PLSs are responsible for ensuring that any personnel working in the NHZ are provided with and are using appropriate PPE, to include protective eyewear.

Laser eye protection shall be used within the NHZ 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.

Eyewear is primarily concerned with protecting the retina as well as other ocular structures from exposure to laser light. Laser protective eyewear may include goggles, face shields, spectacles, or prescription eyewear using special absorptive filter materials or reflective coatings, or a combination of both, to reduce the potential ocular exposure to or below the applicable MPE.

However, protective eyewear is not meant to protect the wearer from constant exposure. Filters are designed to withstand exposure for up to 10 seconds, and eyewear should be used such that the damage threshold is not exceeded in a worst-case scenario.

The following should be considered:

- OD at the intended output wavelengths of the laser
- MPE
- Laser power and/or pulse energy
- Exposure time
- Adequate visible luminous transmission (VLT)

Skin Protection

In some cases, long sleeved laboratory coats and gloves may provide sufficient protection from scatter radiation. However, regular lab clothing may not be sufficient for high-power lasers above Class 3. Tight-woven and flame-retardant fabrics are recommended in these situations. For higher power Class 4 lasers, no PPE will provide adequate shielding, and users should stay as far from the beam as possible.

If the laser operates within the UV range, particular care should be taken to minimize exposure. Users should utilize beam shields and wear clothing rated to protect against UV wavelengths (typically long-sleeved items with dark colors and tight woven fabrics). If it is anticipated that users will be subject to extended or repeat exposure, for example in applications like welding and laser cutting, skin covers or sunscreen are also recommended.

Outdoor Control Measures

Special rules apply for outdoor use and laser control areas that do not provide complete containment. This is especially critical due to the proximity of multiple campuses to active hospital helipads.

Lasers of any type shall not be used outdoors or for public display without the permission of the Laser Safety Officer. Federal Aviation Administration (FAA) regulations shall be followed without unapproved deviation.

The operators of laser systems used for entertainment are required by law to file a "Report on Laser Light Show Display" (or a variance document), with the Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH). No laser light show, display, or device may vary from compliance with 21CFR1040.11(c) in design or use unless an approved Application for a Variance from 21CFR1040.11(c) for a Laser Light Show, Display, or Device has been issued by the FDA per 21CFR1010.4. If the venue is outdoors and the beam(s) may terminate in navigable airspace, then the operators are also required to file a report with the regional FAA office.

Any Class 3B or 4 laser used for entertainment, displays, demonstrations, or any related use intended for public viewing (indoors or outdoors) shall be operated in accordance with federal, state, local, and campus regulations and requirements.

Any Class 3B or 4 laser used outdoors for telecommunication applications or for research projects shall be registered with the LSO per the requirements of the Hopkins Laser Safety Policy.

V. Non-Beam Hazards

While beam hazards are the most prominent laser hazards, other hazards pose equal or possibly greater risk of injury or death. These hazards must be reviewed by the LSO and addressed by the PI or PLS in the SOP for the laser operation, where applicable

Non-beam hazards are separated into the following categories: Physical, Chemical, and Human.

Physical Hazards

Electrical Hazards

Lasers may use high-voltage power supplies, large capacitors, and other electrical equipment that present hazards including:

- Electric Shock
- Resistive Heating
- Arc Flash
- Spark Ignition

Nonlaser Radiation (NLR)

Interaction of an operating laser on the surrounding environment or target may generate other potentially hazardous forms of radiation:

- Ionizing Radiation:
  - X-Ray collateral radiation may be generated by electronic components, such as high-voltage vacuum tubes or plasma from pulsed beams with peak irradiance $>10^{16}$ $W*cm^{-2}$
- Optical Radiation
  - Collateral radiation from charge tubes, pump lamps, and plasma emissions may generate sufficient UV or blue light radiation to pose eye and skin hazards. Proper PPE should always be worn, and laser should not be operated with the housing removed. Integrity of the laser housing should also be regularly inspected
- Low frequency (microwave, RF, Static EM fields)
  - Power supplies and electrical components may be capable of generating low frequency EM fields.

Fire & Thermal

Fire prevention shall be implemented for all Class 4 lasers and lasers with average beam irradiance over 0.5 $W*cm^{-2}$. Fire prevention control measures implemented shall be in accordance with NFPA 115: Standard for Laser Fire Protection. The material used to terminate a Class 4 laser beam, including any materials used to create laser enclosures, shall be made of non-flammable material and be created to withstand the irradiance of the laser beam. Appropriate fire suppressive

measures must also be in place in any laser control area. Portable fire extinguishers shall be provided or located within a reasonable distance.

Explosion

High-pressure arc lamps, filament lamps, and capacitors may explode if they fail during operation. Keep these components enclosed in the laser housing, which will withstand the maximum explosive forces that may be produced. Laser targets and some optical components also may shatter if heat cannot be dissipated quickly enough. Ensure adequate mechanical shielding when exposing brittle materials to high intensity lasers.

Noise

Noise levels from certain lasers or laser systems may be of a high enough intensity that control measures are needed. Signage should be posted on entrances to warn of noise, and hearing protection should be provided to individuals who will be present during operation.

Chemical Hazards

Laser Generated Air Contaminants (LGACs)

Air contaminants may be generated when Class 3B and Class 4 lasers interact with materials such as plastics, composites, metals, and tissues, which may liberate toxic and noxious airborne contaminants when exposed to irradiance.

If a high-power laser is expected to be used for processing materials, or if operation regularly creates visible smoke, local exhaust ventilation and air filtration measures must be put in place and included in the SOP. Respiratory protection is not an acceptable alternative to local exhaust ventilation. This includes all Class 4 laser cutters, which shall have a ventilation system or be solely operated within a hood.

Compressed Gases

Gases may be used in laser applications, such as fluorine or hydrogen chloride in excimer lasers, and cooling systems may utilize cryogenic liquids. Any compressed gas cylinder shall always be secured to the wall or benchtop to prevent it falling over. Hazardous gases shall be properly secured and contained in the proper cabinet with proper sensors and alarms. The SOP should contain references for the safe handling of any compressed gases (refer to policy HSE018).

Other Hazardous Chemicals

Other chemicals associated with laser operation may be considered hazardous. Primarily, dyes used as the optically active medium are often toxic and/or carcinogenic chemicals dissolved in flammable solvents. All hazardous chemicals must have an associated SDS available with the SOP and laser documentation.

Human Hazards

Ergonomics

All laser users should be aware of potential hazards in the workplace environment. Hazard evaluations should include a review of workstation layout, worker-machine interface, handling techniques and area lighting that could lead to injury or long-term conditions

Limited Work Space

Limited space around a laser system could result in possible injuries from working around mechanical parts, high voltage equipment, trip hazards from small components and wires, or exposed laser beams. Equipment and workspace layout should account for sufficient room for personnel to maneuver and turn around freely. Likewise, installations should be situated to eliminate or reduce the presence of wires, cables, hoses, etc. on the floor or low enough to create a trip hazard.

VI. 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.

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.

All individuals who wish to use a Hopkins-owned laser cutter must successfully complete the myLearning course **"Proper Laser Cutter Operations"** to become an authorized user. Laser cutter operators do not need to register as LUs

VII. Emergencies & Incidents

In the event of a laser emergency /accident it is important to respond promptly and appropriately. All laser SOPs shall include a section covering what to do in the event of an equipment-related emergency. At a minimum, emergency protocols should include the following:

In the event of an incidents with continuing hazard (fire, explosion, gas leak, high voltage, etc.)

1. Shut down the laser and associated equipment using appropriate emergency procedures as established in the SOP.
2. Notify others in the immediate area of the hazard.
3. Evacuate the immediate hazard area.
4. In case of fire, pull the emergency alarm as you exit the building
5. (If at Homewood) Contact Public Safety at 410-516-7777 or using your cell phone or emergency station
6. (If at East Baltimore) call 410-955-4444
7. Wait for Public Safety and the emergency responders to arrive. DO NOT leave the general scene. Be prepared to provide details as to what was happening when you left the location of the incident.
8. As soon as is convenient and safe, notify your supervisor, PI, PLS, and the LSO

In the event of an injury:

1. Shut down the laser and associated equipment using appropriate emergency procedures as established in the SOP
2. Move the individual to a safe location
3. Contact Public Safety 410-516-7777 (Homewood) using the lab phone, a cell phone, or emergency station
    a. When describing laser incidents, be sure to let the person you are talking to know if it is an eye injury or other type of injury (gas inhalation, burn not to the eyes, electrocution, etc.)
        i. Eye injuries should be taken directly to the Eye Trauma Center at the Johns Hopkins Hospital ER
        ii. Other injuries will be directed to Occupational Health/Occupational Injury, Student Health Services, or the nearest available emergency room (Union Memorial for Homewood)
    b. Provide campus security with the name of the responsible PI or PLS
4. Wait for the security and the emergency responders to arrive. DO NOT leave the general scene. Be prepared to provide details as to what happened to cause the injury.
5. As soon as is convenient and safe, notify your supervisor, PI, PLS, and the LSO.
6. Note that an Employee Report of Incident form shall be filed with Occupational Health/Occupational Injury.

If a laser-related accident or incident occurs, but no injury or property damage occurs, the user shall still inform the PI, PLS, and 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 convey them to the LSO and OES/HSE. Always report unsafe work conditions to avoid potential future accidents or incidents.

Appendix A: SOP Template

I. Title

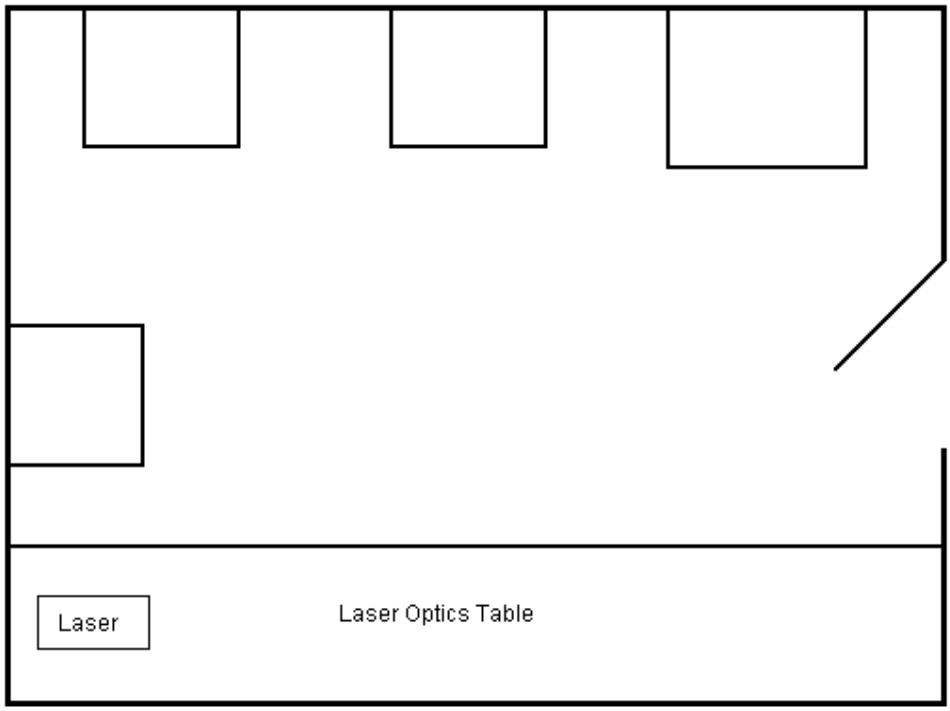
II. Scope

III. Equipment

- **a. PPE**
  - [Must include eye protection and OD]

IV. Laser Location

- **a. Room Diagram**



V. Description of Laser

- **a. Manufacturer**
- **b. Model**
- **c. Serial Number**
- **d. Class**
- **e. Medium**
- **f. Mode (Pulse/CW)**

VI. Hazards

- **a. Beam Hazards**
  (E.g., scatter, reflection)
- **b. Non-Beam Hazards**

(E.g., LGACs, electrical, hazardous experimental compounds)

VII. Controls

- **a. Access**
- **b. Beam**
- **c. Electrical**
- **d. Eye Protection**
- **e. Other Controls**

VIII. Operating Procedures

- **a. Area Preparation**
- **b. Alignment**

  Only experienced personnel will be involved with alignment of the laser. All individuals who perform alignment must have ALO status and be approved by the Primary Laser Supervisor.
- **c. Laser Setup**
- **d. Laser Shutdown**
- **e. Special/Emergency Procedures**
  - **i. In Case of Injury to Eyes**
    1. Turn off Equipment and lockout where applicable
    2. Determine extent of injury
    3. Contact Public Safety at **410-516-7777** (Homewood) or **410-955-5585** (East Baltimore)
    4. Inform the operator the incident location, who was injured and what happened
    5. Notify your supervisor and HSE of the incident
    6. Write down everything you remember about the incident

IX. Training

X. Responsibilities

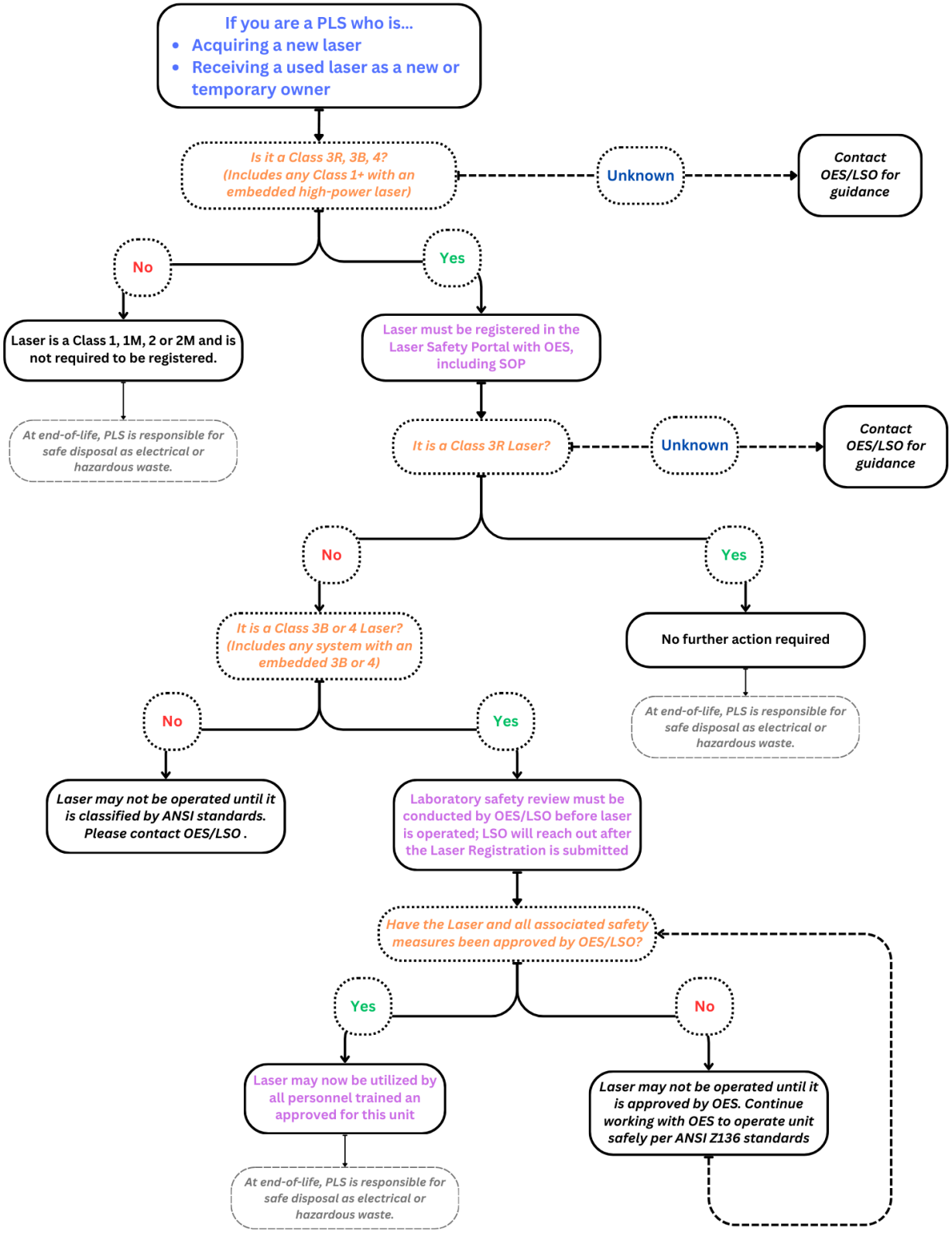
XI. Revisions

Version #	Section	Revision	Editor (full name)	Date of Change
1.0				
1.1				
2.0				

XII. Operator Sign-Off

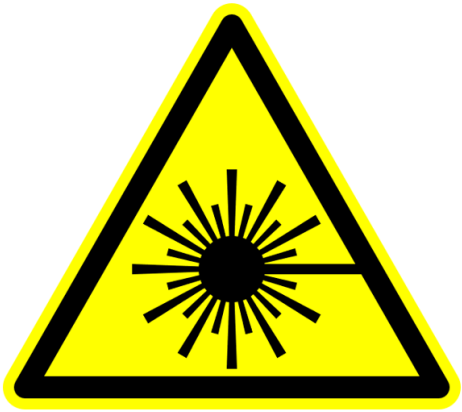
Name (Print)	User Signature	Date of Training Completion	Supervisor/PLS (Print)

Appendix B: Laser Acquisition Decision Tree



Appendix C: Warning Signage Examples

WARNING



Class 4 Laser Controlled Area

Avoid eye or skin exposure to direct or scattered radiation.

[Any additional optical warnings]

AUTHORIZED PERSONNEL ONLY

Laser Eye Protection [Not] Required:

OD>_____@____nm

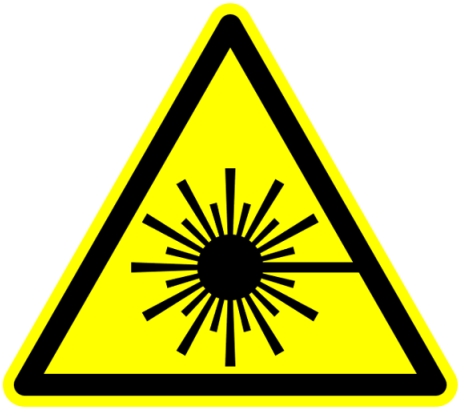
Laser Type:

Power: **Wavelength:** **nm**

[PI Name]: [PI phone number]

HSE: 410-516-0870 (Homewood), 410-516-8798 (SOM)

DANGER



Class 4 Laser Controlled Area

Avoid eye or skin exposure to direct or scattered radiation.

AUTHORIZED PERSONNEL ONLY

Laser Eye Protection Required

Laser Type:

Power: **OD≥**

Wavelength: **nm**

[PI Name]: [PI phone number]

HSE: 410-516-0870 (Homewood), 410-516-8798 (SOM)