

LASER SAFETY PROGRAM

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1.0 PURPOSE

The objective of this program is to provide guidance and practices for the safe operation of lasers and laser systems. It is based upon elements in ANSI Z136.1-2014, Z136.8-2012 and Z136.4-2010.

2.0 SCOPE

This program covers the use of lasers and laser systems that operate at wavelengths between 180 nm and 1000 um on University property and during activities or events (including fieldwork) sanctioned by University officers, units, or department heads. This program is intended to prevent unintended exposure to laser radiation and the associated non-beam hazards.

Research that involves the intentional exposure of lasers to individuals' eyes or skin (such as ophthalmic research) must meet the requirements of this program for the protection of those using the lasers, and the researcher must independently provide evidence that the laser will not cause damage or harm to the individual or individuals that will be exposed to the beam.

Laser users must also comply with other University of Waterloo safety programs and follow appropriate guidelines to ensure hazards are controlled, for example, appropriate electrical certifications.

3.0 LASER CLASSIFICATION

To use lasers and laser systems safely, they must first be classified according to their relative hazards and specify appropriate controls for each classification.

Hazard classification is based on the laser beam's ability to cause damage to the eye or skin during use. Lasers and laser systems manufactured or imported into Canada are required to meet federal requirements and fall into one of the following classes.

3.1 CLASS 1

Considered to be incapable of producing damaging radiation levels during operation. These are exempt from this program.

3.1.1 CLASS 1M

Considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope) and is exempt from any control measures other than to prevent potentially hazardous optically aided viewing.

3.2 CLASS 2

Emits in the visible portion of the spectrum (400 nm to 700 nm) and eye protection is normally afforded by the aversion response (e.g., blinking) for unaided viewing.

3.2.1 CLASS 2M

Emits in the visible portion of the spectrum (400 nm to 700 nm) and eye protection is normally afforded by the aversion response (e.g., blinking) for unaided viewing. However, Class 2M is potentially hazardous if viewed with collecting optics (e.g., telescope).

3.3 CLASS 3

3.3.1 CLASS 3R

Has reduced control requirements and is potentially hazardous under some direct and specular viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser does not pose fire or diffuse reflection hazards.

3.3.2 CLASS 3B

May be hazardous under direct and specular reflection viewing conditions, but is normally not a fire hazard, diffuse reflection hazard, nor a laser generated air contaminant (LGAC) production hazard.

3.4 CLASS 4

Is a hazard to the eye or skin from the direct beam, may pose a fire hazard or a diffuse reflection hazard, and may also produce LGAC and hazardous plasma radiation.

4.0 ROLES AND RESPONSIBILITIES

4.1 SUPERVISOR/MANAGER

Laser supervisors must be knowledgeable of the education and training requirements for the lasers under their control. This includes knowledge of:

- The potential laser hazards and associated control measures required.
- Manufacturer's requirements for care and operation of the lasers.
- Operating procedures developed for the work being undertaken.

The supervisor shall also:

- Ensure laser workers complete the laser safety training outlined in Section 6 of this Program.

- Report known or suspected accidents to the laser safety officer.
- Ensure lasers under their control are not operated or modified without approval by the laser safety officer.
- Ensure that all administrative and engineering controls are followed.
- Ensure that standard operating procedures (SOPs) are written and available to laser workers under their supervision.

4.2 WORKERS

- Must complete the laser safety training outlined in this program.
- Must comply with regulations and standards prescribed by the Laser Safety Committee, laser safety officer, and the laser supervisor.
- Must be familiar with SOPs and specific safety hazards of the lasers they are operating or working in proximity to.
- Must not operate a class 3B or 4 laser unless authorized by the laser supervisor.
- Must report known or suspected accidents to their laser supervisor and the laser safety officer.
- Must ensure all spectators are properly informed of and protected from all potential laser hazards.

4.3 SAFETY OFFICE - LASER SAFETY OFFICER (LSO)

The LSO is directed by the Laser Safety Committee and must be knowledgeable in evaluation and control of laser hazards. The LSO also has the following responsibilities:

- Issue permits authorizing the use of Class 3B and Class 4 lasers.
- Maintain an inventory of all class 3B and 4 lasers. Classify or verify classification if necessary.
- Complete an initial inspection of laser work areas and establish nominal hazard zones.
- Approve SOPs, alignment procedures, and other control measures.
- Provide consultative services on evaluation and control of laser hazards and worker training programs.
- Inspect all active class 3B and 4 lasers at least annually for compliance with this Laser Safety Program. Ensure any required corrective action is taken.
- Suspend, restrict, or terminate the operation of a laser or laser system that does not have adequate hazard controls; and advise the Laser Safety Committee of such action.

- Approve wording on area signs and equipment labels.
- Maintain records required by various regulatory bodies.

5.0 PERMIT APPLICATION

A permit is required for using Class 3B and 4 lasers. To obtain a permit:

1. The Principal Investigator, should complete the webform to request a permit on the [Safety Office's Laser Safety website](#);
 - a. The PI must log in to complete the web form
 - b. The web form collects basic information about the laser or lasers being used.
2. Once the PI has completed the webform, a Laser Safety Officer (LSO) will contact the researcher to provide them with a permit number.
3. The LSO then determine if Nominal Hazard Zones are required and what type of eye protection is necessary.
4. The LSO then sets up a folder in the Laser sharepoint site with appropriate permissions for the PI to populate with required SOPs and other documentation as necessary.
5. The LSO then arranges an initial meeting and inspection of the room in which the laser will be used. During this meeting the LSO will determine what precautions must be taken.
6. The PI then develops the required SOPs and Risk Assessments and sends them to the LSO for review
7. Upon review of the SOPs and Risk Assessments a preliminary inspection is scheduled to confirm that appropriate signage and controls are installed and if everything is in order so research may commence.

6.0 RISK ASSESSMENT

Several aspects of the application of a laser or laser system influence the total laser risk assessment and application of control measures:

- The laser or laser systems capability of injuring or interfering with task performance
- The environment in which the laser is used, including access to the beam path (e.g., considering enclosures, baffles, beam)
- The personnel who may use or be exposed to laser radiation

- The use of optics, such as hand magnifiers will be used within 10 cm of the beam source or beam waist
- Non-beam hazards

Risk Assessment must be completed for all Class 3B and 4 lasers purchased after the release of version 3 of the Laser Safety Program. The Risk Assessment may be found on the [Safety Office's Laser Safety website](#).

6.1 LASER ENVIRONMENT

How and where the laser is used is required to determine if any additional control measures are necessary or if some control measures can be relaxed or eliminated. The probability of exposing personnel or the public to hazardous laser radiation must be considered and can be influenced by whether the laser is used indoors or outdoors. Indoor locations include classrooms, machine shops, research laboratories or theatres/music venues. Outdoor locations include light shows, construction projects or communications. Outdoor use of lasers will require advanced notice to the LSO as additional permits may be required and additional considerations such as planes, windows, and working near the public must be considered.

6.2 NOMINAL HAZARD ZONES (NHZ)

The nominal hazard zone is the area in which the direct, indirect, or scattered laser radiation exceeds the maximum permissible exposure level, and additional controls may be needed to reduce exposure. For example, if a laser has an NHZ of 75 m the entire room could be considered as the main control to protect those outside the room but those inside the room would need to take additional steps to control their own exposure. Another example could be building housing around the entire laser system which effectively contains the laser radiation.

The Laser Safety Officer will review the Nominal Hazard Zones during the initial inspection process and ensure goggle OD requirements are met. Yet, it is the responsibility of the PI to know the Nominal Hazard Zones of their laser(s) including how optics, fibers, other devices, or reflected beams may change the NHZ. Principle Investigators, workers and students may use the [Kentek online tool](#) to aid in their calculations and contact the LSO if they need any support.

6.3 LASER USE LOCATION

The decision to use additional or relax or eliminate some control measures as indicated earlier is influence by location considerations of Class 3B and Class 4 lasers. The following defines the terms and conditions for each location.

- Unrestricted location: Access is not limited. There are no laser radiation hazards and these locations can be occupied by the public, visitors, and spectators without implementing administrative or engineering controls or requiring personal protective equipment (e.g., a corridor in a building).
- Restricted location: Access is granted for authorized people and limited for the public through administrative and engineering control measures. These are locations where Class 3B and Class 4 lasers are present and control measures are required. Administrative controls include posted warning signs, mandatory training, and following established SOPs for the laser(s). Engineering controls include access control, barriers, curtains and interlocks (e.g., research labs) that may be defeated.
- Exclusion location: Occupancy by people is possible but access is denied during laser operation (e.g., Class 3B or Class 4 lasers as end effectors on robots).

6.4 CONTROL MEASURES

Class 1M laser systems are generally exempt from controls except:

- When optically aided direct viewing of the beam is expected
- Unattended operation where the beam is directed into a location where it can be directly viewed by the public and or personnel that may be uninformed or unaware of the hazard

Class 2M laser systems are generally exempt from any control measures except for:

- Intentional direct viewing of the beam or its specular reflection
- Potentially hazardous optically aided viewing of the beam

Class 3R laser systems are generally exempt from any control unless:

- Direct viewing of the beam or its specular reflection
- Unattended operation where the beam is directed into a location where it can be directly viewed by the public and or personnel that may be uninformed or unaware of the hazard

Class 3B laser systems require approval of control measures by the LSO.

Class 4 laser systems require approval of control measures by the LSO.

Control Measures consist of:

- Engineering controls
- Administrative controls
- Personal Protective Equipment (PPE)

Enclosure of the beam path or laser system is the preferred method. When the actual room itself is the containment additional barriers blocking outside viewing through windows or doors and interlocks may be required. Administrative controls such as

Standard Operating Procedures (SOP) for laser operation and training are required. All Class 3B and Class 4 lasers require inspection and approval from the LSO before being used.

6.4.1 ENGINEERING CONTROLS

Protective housings

All Class 3B and Class 4 lasers should ideally have a protective housing encompassing the beam path. In some circumstances operation of lasers may take place without a protective housing. These open beam path lasers generally require strict control measures and may only occur in approved Laser Controlled Areas (LCA). The use of barriers, shrouds and beam stops are mandatory and must be incorporated into the standard operating procedures for the system.

Interlocked removable protective housings

Class 3B or Class 4 Lasers that have fail-safe interlocked protective housings that fully enclose the beam during operation require no additional controls to protect operators from the beam. If an interlock can be bypassed or defeated to allow access for any reason an appropriate hazard assessment must be performed, and procedures must be implemented to prevent exposures above the Maximum Permissible Exposure (MPE).

Service access panels

If a portion of the protective housing is intended to be removed from the laser to perform specific tasks, such as sample loading, the panel shall either be interlocked, or require a tool for removal and have a warning label indicating the hazard.

Open beam paths

Class 3B and Class 4 lasers that have beam paths that are not enclosed, or partially enclosed require additional measures to ensure exposures above the MPE do not occur. A hazard assessment must be conducted, and multiple controls may be required to prevent exposure. Controls can include the use of PPE, laser curtains or barriers surrounding the laser, posting of area warning signs including activation warning systems such as lights or audible devices placed outside of the laser control area.

Class 3B laser controlled area (LCA) requirements:

- Be operated in such a manner that the path is well defined
- Be under the direct control or supervision of someone trained and authorized to use the laser
- Be located so that access by spectators is limited and requires approval
- Have any potentially hazardous beam terminated in a beam stop of an appropriate material

- Have only diffusely reflecting materials in or near the beam path where feasible
- All personnel within the LCA to wear appropriate eye protection
- Ensure the laser is set up in such a way that the beam path is either below or above eye level of any person in a standing or seated position
- Have all windows, doors or portals facing into the LCA covered or made of an appropriate optical density for the laser

Class 4 laser control areas must meet the requirements for Class 3 lasers above and must also have:

- Warning devices located outside the LCA indicating that the laser is in operation. These devices may require to be interlocked to the laser shutter or power source
- Devices that are not interlocked must be included in the SOP for operation of the laser
- An entryway that is set up so that laser radiation is prevented from escaping the LCA

6.4.2 ADMINISTRATIVE CONTROLS

User control measures

These are measures that are implemented by the laser user in addition to the manufacturer's control measures to render safe operation and maintenance of the laser system. The laser safety officer may require additional user control measures if indicated by a hazard analysis.

Laser application - operation, maintenance, and service control measures

The selection and implementation of specific controls depends on how the system is being used.

Operation - the use of the laser over the full range of its normal intended use.

Maintenance – the performance of those adjustments or procedures specified by the manufacturer that are carried out by the user to ensure the optimal intended operation of the laser (e.g., preventative maintenance)

Service - the performance of procedures, usually repair, to bring the laser back to full and normal operation. This is quite often performed by service technicians, but operators can perform this function if properly qualified due to training, knowledge, or experience.

Standard operating procedures must be developed and implemented for each application (e.g., operation, service and maintenance) of the laser to ensure safe operation. These procedures must be located near the laser for use by operators, maintenance and service personnel.

Beam alignment and other open beam procedures

Alignments and other beam procedures are only to be performed by trained and authorized personnel.

Whenever possible, lower power settings below the MPE or use of Class 2 lasers should be used for alignment of Class 3B and Class 4 lasers. Lasers that operate outside of the visible spectrum should also use lower power lasers in the visible spectrum for alignment.

Alignment of optical devices (e.g., mirrors, lenses, beam deflectors) must be performed in such a manner that the primary beam, or a reflection of the beam, does not expose personnel to a level above the MPE.

Written procedures outlining the alignment operations must be developed. These procedures must ensure that correct selection, operation, and orientation of the optical devices is considered.

Other open beam procedures may include but are not limited to setting up, testing, use of measurement equipment within the laser beam and experimental laser runs. The additional following actions should also be taken when applicable:

- Exclude unnecessary personnel from the laser area
- Use low-power visible lasers whenever possible
- Wear appropriate protective eyewear and clothing when necessary
- When aligning invisible beams use a visible laser for co-alignment or display devices such as phosphor cards to locate beams
- Use remote monitoring devices such as cameras
- Use shutters or beam blocks to block high-power beams at the source except when needed for alignment
- Place beam blocks behind optics to terminate beams that might miss targets during alignment
- Locate and block all stray reflections from the optic before proceeding to the next optical component or section
- Ensure all beams and reflections are properly terminated before high-power operation
- Replace any panels or enclosures removed as part of the alignment process

Supervision of laser operation

Operation of lasers and laser systems generally requires visual surveillance to ensure safe use and termination of laser emission in the event of malfunction or any other

condition of unsafe use. Surveillance of lasers may be through remote means such as cameras.

Unsupervised laser operation

Class 1M, Class 2, Class 2M or Class 3R lasers may operate unsupervised provided that they are marked with a clearly visible sign or label that includes the following information:

- The class of the laser system
- The emitted wavelength, pulse duration (if appropriate), and maximum output power
- A precautionary statement for users
 - For Class 2 lasers – “Laser Radiation – Do Not Stare into Beam”
 - For Class 2M lasers – “Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments”
 - For Class 3R lasers – “Laser Radiation – Avoid Direct Eye Exposure to Beam”

The unsupervised use of Class 3B and Class 4 lasers must be approved by the LSO. Unsupervised use of these lasers will only be approved when appropriate control measures are in place such as beam traps, barriers, windows, or other means of area control. All areas where unsupervised use of Class 3B or Class 4 lasers must be clearly marked with laser safety area warning signs containing the “Warning” signal word and appropriate instructions regarding the hazards of entry into the space when no operator is present.

7.0 TRAINING

All personnel using Class 3B or Class 4 lasers must complete the following training prior to working with these laser systems:

1. Online Laser Safety training course SO1066
2. Hands-on practical training must be completed for each laser that will be used. The training is to be delivered by the supervisor (or suitable and designated alternate) and include:
 - a. Laser operation as described in the manufacturer’s laser operation manual
 - b. Specific hazard training related to each laser (e.g., chemical, high voltage)
 - c. Training on the standard operating procedures needed to operate, maintain, and shutdown the laser

The laser permit holder must keep records of online training and hands-on practical training for all workers and students. These records must be easily accessible by the LSO come inspection time.

The University of Waterloo Site-Specific Training Form on the [Safety Office's Training page](#) may be used by supervisors to document site specific training.

8.0 COMPLIANCE

Laser Safety Officers will complete laser safety inspections on an annual basis. This will include, but is not limited to:

- Training verification
- Presence of SOPs
- Visual verification that appropriate controls have been implemented

Failure to meet these criteria can result in research suspension, permit revocation, and re-training.

9.0 RECORD KEEPING

The following records will be kept in relation to this program:

- The Safety Office will maintain records of online training and an inventory of all Class3B and Class 4 lasers in use on campus
- The Supervisor shall document, maintain, and keep records of:
 - Online and Practical training delivered to their researchers
 - Standard operating procedures and Risk Assessments
 - Permit application

10.0 RECORD OF REVISIONS

| Date | Author/Editor | Change | Version |
|---------------|------------------|--|------------------------------------|
| November 2021 | Katelyn Versteeg | <ul style="list-style-type: none"> ▪ Updated section 7.0 Training to indicate that training records (including practical training) are to be maintained by PIs. ▪ Removed inspections for inactive laser permits from the duties of the LSO in section 5.0 Permit Application. ▪ Changed section 6 title from Hazard Assessment from Hazard to Risk Assessment and added a new Risk Assessment Template to the program webpage. ▪ Reworded the PI/LSO responsibilities in calculation of NHZ in section 6.0 Risk Assessment. ▪ Updated Appendices by removing Laser Records of Training and completed a major update to the inspection template. | Laser Safety Program_v.3.0_NOV2021 |
| November 2020 | Douglas Dye | <ul style="list-style-type: none"> ▪ Updated section 2.0 Scope to indicate that this program does not cover research that intentionally exposes people to lasers. ▪ Added section 3.0 Laser Classification ▪ Removed medical surveillance and eye exam requirements <ul style="list-style-type: none"> ▪ Medical surveillance does not add to the safety of the program. Eye exams do not lessen potential injuries. Removal of the eye exam reduces the collection of private medical information and streamlines the application process by reducing the number of requirements an individual must complete to perform research. ▪ Medical surveillance requirements in the ANSI standard have been drastically reduced from previous iterations and have been moved to optional status as the evidence over the years indicates that they do not provide significant benefits to safety. ▪ Added section 6.0 Hazard Assessment ▪ Added section 7.0 Compliance ▪ Added the following appendices: <ul style="list-style-type: none"> ▪ University Laser Worker Record of Training ▪ Laser Safety Inspection Checklist ▪ Sample Laser SOP | Laser Safety Program_v.2.0_OCT2020 |
| November 2019 | Douglas Dye | <ul style="list-style-type: none"> ▪ No changes | Laser Safety Program_v.1.0_OCT2019 |
| November 2018 | Douglas Dye | <ul style="list-style-type: none"> ▪ No changes | Laser Safety Program_v.1.0_OCT2017 |

11.0 APPENDIX 1: LASER SAFETY INSPECTION CHECKLIST

Inspection Date: _____

Researcher Name: _____ Location: _____

Laser Safety Officer: _____ Signature: _____

Signage and Access

| Item | Pass | Fail | NI | N/A |
|--|------|------|----|-----|
| <i>Entrances are properly signed.</i> | | | | |
| <i>Doors are interlocked and interlock is functioning.</i> | | | | |
| <i>Laser status indicator is present outside of the room and is in good working condition.</i> | | | | |
| Comments: | | | | |

Engineering Controls For All Lasers

| Item | Pass | Fail | NI | N/A |
|---|------|------|----|-----|
| <i>Beam stops, beam shutters, and/or beam barriers are in use. No evidence of stray beams is present.</i> | | | | |
| <i>Beam path is enclosed when practical.</i> | | | | |
| <i>Laser is secured to the table when possible.</i> | | | | |
| <i>Laser curtains or similar barriers are used as appropriate.</i> | | | | |
| <i>Window coverings are in place as appropriate.</i> | | | | |
| <i>Reflective materials are kept out of beam path.</i> | | | | |
| <i>Protective housings are in place as necessary.</i> | | | | |
| <i>Laser unit interlocks in place as necessary.</i> | | | | |
| <i>Laser activation indicators are present, practical and working.</i> | | | | |
| <i>Seating areas are not set up within beam height within the lab. Laser beams at eye level are enclosed.</i> | | | | |
| Comments: | | | | |

Administrative Controls For All Lasers

| Item | Pass | Fail | NI | N/A |
|--|------|------|----|-----|
| <i>All Class 3B and 4 lasers are registered with the safety office.</i> | | | | |
| <i>All required equipment is CSA certified.</i> | | | | |
| <i>All lasers have an SOP available that contains controls, set up, and aligning protocols.</i> | | | | |
| <i>Manuals are readily available for all lasers.</i> | | | | |
| <i>All personnel have completed laser training, including online training and documented practical training.</i> | | | | |
| <i>Proper PPE is available, in good condition, and appropriately worn.</i> | | | | |
| <i>Alignment completed at reduced beam intensity if possible.</i> | | | | |
| Comments: | | | | |

Non-Beam Hazards

| Item | Pass | Fail | NI | N/A |
|--|------|------|----|-----|
| <i>Additional risks of the process are included in SOP and controlled for such as welding, chemicals, vacuum, heat, compressed gases, and cryogenes.</i> | | | | |
| <i>High voltage hazards are appropriately controlled.</i> | | | | |
| <i>Noise hazards are appropriately controlled.</i> | | | | |
| <i>Laser generated air contaminants are appropriately controlled.</i> | | | | |
| <i>Cords and cables across walkways are covered using cable trays.</i> | | | | |
| <i>Laboratory housekeeping is maintained.</i> | | | | |
| Comments: | | | | |

Next Scheduled Follow-Up

Two Weeks One Month Next Annual Inspection Other

NI – Needs Improvement N/A – Not Application