Laser Safety Manual

V1. October 2025

Department of Environmental Health and Safety

Contents

Manual Approvals

This Laser Safety Manual was prepared by the University Laser Safety Officer (LSO) and reviewed by members of the university with expertise in the use of Laser and Laser Systems.

Signature of Laser Safety Officer  _____ Date:____10-23-2025__

Reviewers

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Future changes to this Manual must be reviewed and approved by the LSO.

Name	Role	Modification	Revision Date
Raico Laria Lamela	ULSO	Created	10-23-2025

Queen's University Laser Safety Manual – Summary

Queen's University's Health & Safety Policy requires conformance to all applicable health and safety regulations and standards. The Queen's University Laser Safety Manual is designed to assist members of the university community in meeting the requirements of the Ontario Ministry of Labour, the American National Standards Institute (ANSI) standards, and other relevant federal and provincial regulations.

Applicable Standards and Regulations

The Laser Safety Manual ensures compliance with the following standards and regulations:

- Ontario Ministry of Labour
- ANSI Z136.1–2022 – Safe Use of Lasers
- ANSI Z136.8–2021 – Safe Use of Lasers in Research, Development, or Testing
- ANSI Z136.5–2020 – Safe Use of Lasers in Educational Institutions

Application of the Manual

The Laser Safety Manual applies to all activities involving lasers and laser systems performed within Queen's University facilities, with specific standards applying to different laboratory settings:

- Teaching Laboratories – Must comply with ANSI Z136.5 (Safe Use of Lasers in Educational Institutions).
- Research or Development Laboratories – Must comply with ANSI Z136.8 (Safe Use of Lasers in Research, Development, or Testing).
- Outdoor Laser Activities – Not covered by this manual. Such activities require review and approval by the Laser Safety Officer (LSO) following the guidance in ANSI Z136.6 (Outdoor Use of Lasers) and ANSI Z136.2 (Free-Space Optical Communication).
- Class 1 and 1M lasers – Excluded from this manual.

Elements of the Queen's University Laser Safety Manual

Queen's Laser Safety Manual includes the following elements:

A. Scope: Defines the purpose, applicability, and exclusions of the manual.
B. Laser Safety Roles, Definitions, and Duties: Describes responsibilities of the Laser Safety Officer (LSO), supervisors, and users.
C. Laser Classification: Identifies lasers according to ANSI standards and manufacturer labeling.
D. Laser Hazards: Covers both beam hazards (optical exposure) and non-beam hazards (electrical, chemical, mechanical, etc.).
E. Hazard Evaluation and Documentation: Outlines the process for assessing risk and maintaining records.
F. Control Measures: Describes engineering, administrative, and procedural controls to minimize risk.
G. Laser Area Signs: Specifies requirements for signage and labeling in laser-controlled areas.
H. Laser Inventory: Details the requirements for maintaining an up-to-date university-wide laser inventory.
I. Laser Safety Training: Defines mandatory training for all individuals working with or near laser systems.

J. Medical Surveillance: Specifies requirements for health monitoring, including pre-placement and post-incident eye examinations.
K. Laser and Laser Systems Internal Inspections: Outlines regular internal inspections and maintenance requirements.
L. Laser and Laser System Incident Reporting and Investigations: Describes procedures for reporting, investigating, and documenting incidents or near misses.

SCOPE

The **Laser Safety Manual** applies to all research and teaching activities involving the use of laser and laser systems Class 2, 2M, 3R, and 3B or Class 4 with particular attention to class 3B and 4.

All persons ,including employees, students and visitors, operating or working in proximity to a laser or laser systems Class 2, 2M, 3R, and 3B or Class 4 and laser and laser systems with embedded laser Class 3B and 4 when beam access by the employee is required during service and maintenance work must comply with the safety requirements and recommendations outlined in this manual.

LASER SAFETY ROLES DEFINITIONS AND DUTIES

According to ANSI Z136.1 (1.3.3) Employees who work with lasers or laser systems and their supervisors have responsibilities for establishing the safe use of those lasers within their purview. At Queen's University the following roles and responsibilities are applicable to the provision of this program.

Laser Safety Officer (LSO)

The Laser Safety Officer (LSO) is an individual designated by the employer with the authority and responsibility to evaluate and control laser hazards and to monitor and enforce the control of those hazards. The LSO at Queen's University is the University Radiation Safety Officer (URSO).

The LSO shall review the Laser Safety Manual annually and after any significant change or incident. The LSO may delegate duties to qualified designees in writing. All hazard analyses, training records, and incident reports shall be maintained for a minimum of five years

Responsibilities

1. Establish and maintain policies and standard for the control of laser hazards.
2. Recommend appropriate laser safety training program materials.
3. Maintain an awareness of applicable new or revised laser safety standards.
4. Maintain inventory of all Class 3B and Class 4 lasers and laser systems, including those with embedded with Class 3B and 4 lasers. Classify, re-classify, or verify classification if necessary.

5. Be responsible for hazard evaluation and documentation of laser work areas, including the establishment of Maximum Permissible Exposure (MPE) and Nominal Hazard Zones (NHZ).
6. Approve standard operating procedures (SOP), alignment procedures, and other control measures. Verify that **SOPs and signage** are current after laboratory changes.
7. Provide consultative services to Principal Investigators on evaluation and control of laser hazards and worker training programs.
8. Inspect at least annually all Class 3B and Class 4 lasers for compliance with the Queen's University Laser Safety Manual. Ensure any required corrective action is taken.
9. Conduct periodic **self-inspections** between annual LSO audits
10. Approve wording on area signs and equipment labels.
11. Maintain records required by various regulatory bodies. Ensure records are maintained of training that has been provided.
12. Suspend, restrict, or terminate the operation of a laser or laser system without adequate hazard controls.
13. Develop a plan to respond to notifications of incidents of actual or suspected exposure to potentially harmful laser radiation.

Laser Supervisors

Laser supervisors will be responsible for the education and training requirements for laser safety, the potential laser hazards, and associated control measures for all lasers under the supervisor's authority. The supervisor will be familiar with general operating procedures of lasers under their control.

Responsibilities

1. Complete **Laser Registration Form** located in the EH&S website
2. Ensure that laser workers have been trained in the safe operation of the lasers or laser systems.
3. Ensure that laser workers prior to operating or working in proximity to Class 3B or Class 4 lasers participate in the Laser Safety Program Training (provided by EH&S) and complete the Laser Worker Registration Form (Appendix 2).
4. Report known or suspected accidents to the Laser Safety Officer (LSO).
5. Ensure that lasers under their control are not operated or modified without approval by the Laser Safety Officer (LSO).
6. Ensure that all administrative and engineering controls are followed.
7. Ensure that Standard Operating Procedures (SOP's) are written and available to Laser Workers under their supervision.

Laser Workers

Laser workers are employees working with lasers or laser systems Class 3B and 4.

Responsibilities

Every laser worker

1. Will complete and submit a Laser Worker Registration Form (Appendix 2) to Environmental Health and Safety.
2. Will comply with regulations and standards prescribed by the Laser Safety Officer and the laser supervisor.
3. Will participate in the Laser Safety Training Course through the Department of Environmental Health and Safety.
4. Will be familiar with standard operation procedures (SOP's) and specific safety hazards of lasers which they are operating.
5. Laser workers shall verify eyewear OD before each use and report any equipment malfunctions or unsafe conditions to their supervisor or the LSO
6. Will not operate a Class 3B or Class 4 laser unless authorized by the laser supervisor.
7. Will report known or suspected accidents to their laser supervisor and the Laser Safety Officer.
8. Will ensure that all spectators are properly informed of and protected from all potential laser hazards.

Spectators/Visitors

Spectators or visitors shall not be permitted within a laser control area unless:

1. Appropriate supervisory approval has been obtained
2. The degree of hazard and avoidance procedure has been explained
3. Appropriate protective measures are taken

Service Personnel

Personnel who require access to Class 3b or 4 lasers or laser systems enclosed with a protective housing or protected area enclosure shall comply with the appropriate control measures of the enclosed or embedded laser or laser system. The LSO should confirm that the service personnel have the education and safety training commensurate with the class of the laser or laser system contained within the protective housing.

Entry of visitors or service personnel into a laser-controlled area shall be logged, and temporary access shall be granted only under the supervision of trained personnel

LASER CLASSIFICATION

All lasers are classified by the manufacturer and labelled with the appropriate warning labels. Any modification of an existing laser or an unclassified laser must be classified by the Laser Safety Officer prior to use. The following criteria are used to classify lasers:

1. **Wavelength** if the laser is designed to emit multiple wavelengths the classification is based on the most hazardous wavelength.
2. For continuous wave (CW) or repetitively pulsed lasers the **average power** output (Watts) and **limiting exposure time** inherent in the design are considered.
3. For pulsed lasers, the **total energy per pulse** (Joule), **pulse duration, pulse repetition frequency,** and **emergent beam radiant exposure** are considered.

Class 1 Lasers
These are lasers that are not hazardous for continuous viewing or are designed in such a way that prevent human access to laser radiation. These consist of low power lasers or higher power embedded lasers. (i.e., laser printers)

Class 1 AEL (accessible emission limit)
laser λ< 700 nm T*max* exposure no more than 30,000s
laser λ> 700 nm T*max* exposure shall be 100 s

- **Class 1M** any laser or laser system that are incapable of producing hazardous exposure conditions during normal operating conditions unless the beam is view with an optical system (i.e. telescope). This laser class cannot emit, during operation, accessible laser radiation levels in excess of Class 1 AEL for the unaided eye but exceeds the Class 1 AEL for telescoping viewing.

Class 1M AEL< class 1 AEL unaided eye
AEL > class 1 AEL telescoping viewing
AEL < Class 3B AEL T*max* 30,000 s

Class 2 Visible Lasers (400 to 700 nm)
Lasers emitting visible light (Continuous Wave (CW) or repetitive pulse output) which because of normal human aversion responses, do not normally present a hazard, but would if viewed directly for extended periods of time. (like many conventional light sources).

Class 2 AEL > Class 1 AEL Tmax < 0.25s

Class 2M Visible Lasers (400 to 700 nm) any laser or laser system that cannot emit, during operation, accessible laser radiation levels in excess of Class 2 AEL for the unaided eye but exceeds the Class 2 AEL for telescoping viewing. Lasers emitting visible light not intended for viewing, and under normal operating conditions would not produce an injury to the eye if viewed directly for less than 1000 seconds. (i.e., bar code scanners)

Class 2M AEL< class 2 AEL unaided eye
AEL > class 2 AEL telescoping viewing
AEL < Class 3B AEL T*max* 0.25s

Class 3RLasers
Lasers that normally would not cause injury to the eye if viewed momentarily but would present a hazard if viewed using collecting optics (fibre optics loupe or telescope).

Include those that have an accessible output between one and five times the Class 1 AEL for λ< 400 nm or λ> 700 nm or less than five times the Class 2 AEL for λ between 400nm and 700 nm (visible)

Class 3B Lasers include lasers operating outside the retinal hazard region $\lambda < 400$ nm and $\lambda > 1400$ nm. These lasers present an eye and skin hazard if viewed directly. This includes both intrabeam viewing and specular reflections. Class 3B lasers do not produce a hazardous diffuse reflection except when viewed at close proximity.

Class 3B AEL > Class 3R AEL

Class 4 Lasers These are lasers that present an eye hazard from direct, specular, and diffuse reflections. In addition, such lasers may be fire hazards and produce skin burns.

Class 4 AEL > Class 3B AEL

LASER HAZARDS (BEAM AND NON-BEAM HAZARDS)

Improperly used laser devices are potentially dangerous. Effects can range from mild skin burns to irreversible injury to the skin and eye. There are different hazards associated with laser media but also with the different laser system components.

The following hazards are related to the use of laser and laser systems:

- **Beam-Related Hazards:** bio effects of the laser coming in to contact with the eye or skin. caused by direct exposure of the eyes or skin to a laser beam
- **Non-Beam Related Hazards:** all hazards arising from the presence of a laser system, excluding direct exposure of the eyes or skin to a laser beam; for example, electrical and chemical, and/or high-pressure gases.

Beam-Related Hazards

The biological damage caused by lasers is produced through thermal, acoustic and or photochemical processes.

Thermal effects are caused by a rise in temperature following absorption of laser energy. The severity of the damage is dependent upon several factors, including exposure duration, wavelength of the beam, energy of the beam, and the area and type of tissue exposed to the beam.

Acoustical effects result from a mechanical shockwave, propagated through tissue, ultimately damaging the tissue. This happens when the laser beam causes localized vaporization of tissue, causing the shockwave analogous to ripples in water from throwing a rock into a pond.

Photochemical effects occurs when photons interact with tissue cells. A change in cell chemistry may result in damage or change to a tissue. Photochemical effects depend greatly on wavelength.

Summary of biological effects caused by direct exposure to a laser beam are listed in the table 1 below.

Photobiological Spectral Domain	Eye	Skin
Ultraviolet C (200 nm - 280 nm)	Photokeratitis (i.e. burn of cornea, snowblindenss)	Erythema (sunburn) Skin Cancer Accelerated skin aging
Ultraviolet B (280 nm - 315 nm)	Photokeratitis	Increased pigmentation
Ultraviolet A (315 nm - 400 nm)	Photochemical cataract (opacity of the lens)	Pigment darkening Skin burn
Visible (400 nm - 780 nm)	Photochemical and thermal retinal injury	Pigment darkening Photosensitive reactions Skin burn
Infrared A (780 nm - 1400 nm)	Cataract and retinal burn	Skin burn
Infrared B (1.4μm - 3.0 μm)	Corneal burn, aqueous flare, cataract	Skin burn
Infrared C (3.0 μm - 1000 μm)	Corneal burn only	Skin burn

Table1. Summary of biological effects caused by direct exposure to a laser beam

Non beam related hazards

Non-beam hazards (NBH) are all hazards arising from the presence of a laser system, excluding direct exposure of the eyes or skin to a laser beam. These non-beam hazards, in some cases, can be life threatening, e.g., electrocution, fire, and asphyxiation.

Non beam hazards can be broken down into three categories: Physical, Chemical, and Biological. Human factors play a big part also. The LSO will incorporate the recognition, assessment, and control of NBH and advise on control measures mitigating the hazards.

Electrical Hazards

The use of lasers or laser systems can present an electric shock hazard. These exposures can occur during laser set up or installation, maintenance, modification, and service, where equipment protective covers are removed to allow access to active components. Contact with energized electrical conductors contained in device control systems, power supplies, and other components is another way to receive an electric shock. With the use of large power supplies and repetitively pulsed lasers, there is great potential for electric shock. Shocks usually happen when a person is working on equipment that is not properly grounded or has a large capacitor bank that was not discharged.

Equipment malfunctions can lead to electrical fires. In addition, electrical sparks can serve as an ignition source in the presence of flammable vapors.

An electrical arcing fault can produce an arc flash that includes intense radiant energy, elevated temperature air, high-pressure waves, and high-velocity shrapnel from the electrical apparatus and housing. Causes of arc flash are human error while working on energized electrical equipment, and malfunction due to equipment age, poor maintenance, or poor design. Workers involved in arc flash may incur severe injury or death.

Fire Hazards
A fire can occur when a laser beam (direct or reflected) strikes a combustible material such as paper products, plastic, rubber, human tissues, human hair, and skin treated with acetone and alcohol-based preparations. The risk of fire is much greater in oxygen-rich atmosphere. In general, Class 3B lasers do not pose a fire hazard, while Class 4 lasers do.

Operators of Class 4 lasers should be aware of the ability of unprotected wire insulation and plastic tubing to catch on fire from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths.

Hazards Explosion
Many metals or their oxides can represent fire or explosion hazards under certain circumstances, such as exposure to air, moisture, water, chemicals, shocks, and impacts. Explosions can be caused by the beam from a Class 4 laser hitting a gas cylinder, regulator, or delivery hose.

Laser Generated Air Contaminants (LGAC)
Air contaminants may be generated when certain Class 3B and Class 4 laser beams interact with matter. The quantity, composition, and chemical complexity of the LGAC depend greatly upon target material, cover gas, and the beam irradiance. While it is difficult to predict what LGAC may be released in any given interaction situation, it is known that contaminants, including a wide variety of new compounds, can be produced with many types of lasers. When the target irradiance reaches approximately 10^7 W/cm^2, target materials including plastics, composites, metals, and tissues may liberate carcinogenic, toxic and noxious airborne contaminants. The amount of the LGAC may be greater for lasers that have most of their energy absorbed at the surface of the material.

Types of Beam Exposure

Exposure to the laser beam is not limited to direct beam exposure. Particularly for high powered lasers, exposure to beam reflections may be just as damaging as exposure to the primary beam.

- Intrabeam exposure means that the eye or skin is exposed directly to all or part of the laser beam.

- Specular reflections from mirror surfaces can be nearly as harmful as exposure to the direct beam. Examples: watch glasses, reflections from steering optics (prisms, mirrors) carry 10-20% of the intensity

- Diffuse Reflections from Class 4 lasers can initiate fires. Examples: tool handles, jewelry, rings, bracelets, optics mounts, foils, etc. Whether a surface is a diffuse reflector, or a specular reflector will depend upon the wavelength of the beam. A surface that would be a diffuse reflector for a visible laser may be a specular reflector for an infrared laser beam.

HAZARD EVALUATION AND DOCUMENTATION

Before using a laser or laser system, it is required to conduct a hazard analysis to identify all beam and non-beam hazards associated with the system set up and operation. The result of the hazard analysis will be documented in the Laser Standard Operating Procedure (Appendix 2) prepared by the laser supervisor and approved by the LSO.

For each Class 3B or 4 lasers, except for those reclassified as class 1, the LSO shall perform and document a hazard evaluation including MPE, NHZ, OD for eyewear, and applicable engineering and administrative controls. This evaluation must be reviewed annually or upon equipment modification.

The Laser Supervisor will provide the following information when filling in the Laser Registration Form or as requested by the LSO.

Laser parameters	Units	Value
Wavelength	nm	
Mode (pulse or CW)		
Beam Power	W	
Beam Energy	J	
Pulse duration	sec	
Pulse repetition freq.	Hz	
Duty cycle (0-1)		
Pulse train duration	sec	
Beam divergence	mrad	
Beam size at aperture	mm	
Beam size at lens	mm	
lens focal length	mm	
focus spot diameter	mm	
MPE: 8 h	(w/cm2)	
MPE:10sec	(w/cm2)	
MPE:0.25 sec	(w/cm2)	

NHZ – The NHZ defines the boundary around the laser where an unprotected person could be overexposed. It is the space within which the level of direct, reflected, or scattered laser radiation exceeds the applicable Maximum Permissible Exposure (MPE). (ANSI Z136.1 §3.2.3; Z136.8 §8.2)

The NHZ distance r_{NHZ} depends on the laser's output power/energy, beam divergence, beam diameter, and the MPE for the specific wavelength and exposure time.

Laser Type	NHZ Equation	Main Parameter
CW (general)	$r_{NHZ} = \frac{r_0}{\theta}\left(\sqrt{P/(\pi r_0^2 E_{MPE})} - 1\right)$	Power (W)

Laser Type	NHZ Equation	Main Parameter
CW (far-field)	$r_{NHZ} \approx \frac{1}{\theta}\sqrt{P/(\pi E_{MPE})}$	Simplified
Pulsed	$r_{NHZ} = \frac{D_0}{2\theta}\left(\sqrt{4H_0/(\pi D_0^2 H_{MPE})} - 1\right)$	Pulse energy (J)

- r_{NHZ} = distance to NHZ boundary (m)
- P= laser output power (W)
- r_0= 1/e² beam radius at the aperture (m)
- θ= beam divergence (radians)
- E_{MPE}= MPE irradiance (W/m²) for the wavelength & exposure time

The MPE values are wavelength- and exposure-time-specific (ANSI Z136.1 Tables 5–10). The LSO will use the worst-case exposure (continuous or single-pulse, whichever yields the larger NHZ). Optical aids, specular reflections, and beam paths will be always considered in the hazard analysis.

Input parameters, assumptions, and calculated NHZ will be documented in the Laser Hazard-evaluation form (NHZ_Calculator_ANSI_Z136_Queens University V.2025) and retained as part of the laboratory documentation.

CONTROL MEASURES BY LASER CLASSIFICATION

Control measures are devised to reduce the possibility of exposure of the eye or skin to hazardous levels of laser radiation. A controls hierarchy should be followed when implementing controls to mitigate laser hazards: engineering controls should be the first line of defense, followed by administrative controls, and the last line of defense is PPE. A Laser Safety Standard Procedure (SOP-Radiation-02), prepared by the LSO outlines the basic safety rules to be considered by an authorized user working with laser and laser products, especially for class 3B and 4, to eliminate the exposure to beam and non-beam hazards.

All Class 3b and 4 laser and laser system shall conform at minimum to the engineering and administrative controls indicated in the ANSI Z136.1 *Safe us of lasers*. Details are indicated in Appendix 1 and 2 of this procedure.

Substitution of engineering controls with administrative controls may be done with the approval of the Laser Safety Officer (LSO).

Class 1 and 1M – no control measures required except when access to an embedded Class 3B or 4 lasers during service or maintenance is required.

Class 2, 2M and 3R - no control measures required unless direct viewing aide is required or when the laser beam is left in operation unattended, and it is pointing to a location where it can be directly viewed by the public and personnel that may be uninformed about the hazard.

1. In these two scenarios a laser sign (CAUTION) must be posted at the entrance of the laboratory and removed when the laser is not in operation.
2. An equipment label is required

Class 3B – requires the approval of the appropriate control measures by the LSO to reduce the risk of a hazardous exposure to the eye from direct or specularly reflected beam. Control measure may also be required to prevent access to hazards from a diffuse reflection or fire hazard.

Class 3B Laser Controlled Area requirements.

1. Posted with the appropriate warning sign(s)
2. Operated by qualified and authorized personnel
3. Under the direct supervision of an individual knowledgeable in laser safety
4. Located so that access to the area by spectators is limited
5. A laser shall have a protective housing preventing laser radiation more than the Maximum Permissible Exposure (MPE).
6. Protective housings shall have an interlock system which is activated when the protective housing is opened during operation and maintenance. *Further control not required if laser is in enclosed in a protective house and there are interlocks in the removable protective housing (LSO may reclassified this laser or laser system as a Class 1).*
7. Appropriate warning labels affixed to a conspicuous place on the laser housing or control panel.
8. For the operation of laser or laser systems without a protective housing the LSO shall determine the Nominal Hazard Zone (NHZ) and ensure that controls are instituted appropriate to the class of maximum accessible emission to ensure safe operation.
9. Service access panel which are portions of the protective housing and are intended to be removed only by service personnel to permit direct access to laser radiation, must either be interlocked (fail-safe interlock not required) or require a tool for removal and shall have an appropriate warning label.
10. A master switch key or computer access code should be required to operate the laser
11. All collecting optics (such as lenses, telescopes, microscopes, endoscopes, etc.) intended for viewing use with a laser shall incorporate suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation transmitted through the collecting optics to levels at or below the appropriate MPE, under all conditions of operation and maintenance.
12. All viewing portals and or display screens included as an integral part of a laser shall incorporate a suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation at the viewing position at or below the applicable MPE for all conditions of operations and maintenance.
13. Where the entire beam path is unenclosed a laser hazard analysis shall be affected by the LSO to establish the Nominal Hazard Zone (NHZ) if not furnished by the manufacturer or available as part of the classification.
14. Should have a remote interlock connector to reduce the accessible radiation below the MPE on entry to the area protected.

15. Have any potentially hazardous beam terminated in a beam stop of an appropriate material
16. Have only diffuse reflective materials in or near the beam path, where feasible
17. A written SOPs approved by the LSO (see Appendix II) shall be maintained with the laser equipment for reference by the operator, and maintenance or service personnel.
18. Have personnel within the controlled area provided with the appropriate eye protection if there is any possibility of viewing the direct or reflected beams
19. Have the laser secured such that the beam path is above or below eye level of a person in any standing or seated position, except as required for medical use.
20. Have all windows, doorways, open portals, etc. from an indoor facility be either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the appropriate ocular MPE
21. Require storage or disabling (for example, removal of the key) of the laser or laser system when not in use to prevent unauthorized use.

Class 4 – requires the approval of the appropriate control measures by the LSO to reduce the risk of a hazardous exposure to the eye from direct, diffuse, or specularly reflected beam. Control measure may also be required for potential fire hazard, and other non-beam hazards (NBH) such as LGAC or plasma radiation.

Class 4 Laser Controlled Area requirements.

Fulfil all items of Class 3B Control areas and in addition incorporate the following.

1. Personnel who enter a Class 4 controlled area shall be adequately trained, provided with appropriate protective equipment, and follow all applicable administrative and procedural controls.
2. Shall have an alarm, a warning light or a verbal "countdown" command used during activation or start-up of the laser.
3. Shall have a remote interlock connector to reduce the accessible radiation below the MPE on entry to the area protected.
4. Class 4 area/entryway safety controls shall be designed to always allow both rapid egress by laser personnel and admittance to the laser-controlled area under emergency conditions.
5. For emergency conditions there shall be a clearly marked "Panic Button" (remote controlled connector or equivalent device) available for deactivating the laser or reducing the output to the appropriate MPE levels.
6. Area or entryway safety controls to deactivate the laser or reduce the output to the appropriate MPE levels in the event of unexpected entry into the laser-controlled area. These controls may be non-defeatable, defeatable or procedural as determined by the LSO using ANSI Z136.1-2022.
7. A remote firing and monitoring console to allow the laser to be operated from a remote location, removing the operator from the hazard should be required
8. Emission delay provides sufficient time prior to emission of laser radiation to allow appropriate action to be taken to avoid exposure to the laser radiation.

Special Controls for Ultraviolet and Infrared Lasers

Since infrared (IR) and ultraviolet (UV) wavelengths are normally invisible, particular care must be taken when using these types of lasers. In addition to the recommended control measures that apply for each laser classification, the following should also be employed:

Infrared

1. The collimated beam from a Class 3 laser should be terminated by a highly absorbent backstop wherever practicable. Many surfaces which appear dull visually can act as reflectors of IR.
2. The beam from a Class 4 laser should be terminated in a fire-resistant material wherever practicable. Periodic inspection of the absorbent material is required since many materials degrade with use.
3. Areas that are exposed to reflections from Class 3 or 4 lasers, at levels above the MPE, should be protected by appropriately screening the beam or target area with IR absorbent material. This material should be fire-resistant for use with Class 4 lasers.

UV

1. Exposure to UV should be minimized by using shield material which attenuates the radiation to levels below the appropriate MPE for the specific wavelength.
2. Special attention should be given to the possibility of producing undesirable reactions in the presence of UV, for example, ozone formation.

Control of Non-beam Hazards (NBH)

The control of NBH must be defined by the PI in consultation with the Laer Safety Officer after completing the Hazard Analysis. All measures must be recorded in the laser Standard Operating Procedure approved by the LSO (Appendix 2).

The following recommendations can be used to address some of the most common NBH:

X-Rays – Some of the high voltage systems with potentials greater than 30 kV may generate X-rays at significant dose rates. Plasma systems and ion sources operated at high voltages should also be checked for X-rays. High power (kilojoule) electron pumped Excimer lasers can generate significant X-ray levels (300 mrad per pulse at 15 feet). These devices must be checked by the Radiation Safety Office upon installation to ensure adequate shielding is included.

Plasma Radiation – Materials can be made incandescent when exposed to laser radiations. These incandescent spots are very bright and can cause serious photochemical injuries to the eyes. Laser protective eyewear may not protect against such exposures. Whenever possible, view such spots through suitable filters such as TV cameras, etc.

Fire Hazards – Class 4 visible and infrared beams with irradiances above 10 W/cm2 can ignite combustible beam enclosure materials. Keep flammables materials out of the beam line and maintain segregation between reactive reagents in the lab. Never use cardboard or paper for high power visible or infrared containment. For combustible and electrical fires, a fire extinguisher of the proper class (i.e. ABC or general purpose) must be readily accessible.

Laser Generated Air Contaminants (LGAC) – Air contaminates, produced by the interaction of the laser beam with the target material, can result in the production of hazardous materials. During surgical procedures, biohazardous aerosols containing blood-borne pathogens are created. Fumes produced when laser radiation vaporizes or burns a target material whether metallic, organic or biological may be hazardous. Adequate local exhaust ventilation needs to be provided in the laser target zone. Contact LSO for assistance.

Chemical Hazards – Many gases and all laser dyes and solvents used in some laser systems are highly toxic. Several laser dyes are carcinogenic. When dimethyl sulfoxide (DMSO) is the solvent, the dyes may be particularly hazardous if spilled on the skin because DMSO promotes absorption through the skin. If toxic chemicals are used in a laser system, material Safety Datasheets (SDS) must be reviewed prior to using them.

Potential exposures to dyes and solvents are most likely to occur during solution preparation. During solution preparation, dye and solvent mixing should be done inside a chemical fume hood. Dye pumps and tubing/pipe connections should be designed to minimize leakage. Pumps and reservoirs should be set inside spill pans. Tubing/pipe systems should be pressure-tested prior to using dye solutions and periodically thereafter. Dye solutions can be corrosive. Stainless steel heat exchangers are recommended. Keep dye handling areas clean and segregated from other operations. Gas cylinders, dyes and solvents must be properly disposed of through the University Chemical Waste Collection Program. Contact the Environmental Health and Safety department for assistance.

Hazardous Gases- Flammable gases, e.g., hydrogen, and oxygen tanks present significant hazards if proper handling, manifolding, and storage precautions are not followed. Other hazardous gases may also require special handling and ventilation. Gas cylinders must be properly anchored with metal linked chains, fastened at the top and near the base of the tank to prevent falling. Such tanks can become high velocity projectiles and can cause significant property damage and injuries. A number of laser systems utilize toxic gases (e.g., HF). These gases must be contained in approved ventilation and manifold systems.

Cryogenic Materials: Wear appropriate protective clothing and face shields when handling large quantities of liquid nitrogen (LN) or other cryogenic materials. The normal moisture and oils present on the skin will protect against a few drops of LN spilled on the skin, but large quantities can cause severe frostbite. LN and inert gases can displace air in a room or confined area and cause asphyxiation. Good ventilation is required in areas where these gases and cryogenic liquids are used. Open dewars of liquid nitrogen can condense oxygen from the room air and cause fire or explosion hazards if the oxygen contacts a fuel.

Electrical Hazards – Most laser systems involve high potential, high current power supplies. The most serious accidents with lasers have been electrocutions.

- Only qualified personnel may perform all internal maintenance to the laser, and more than one user must be present when performing said maintenance.
- Make sure that high voltage systems are off and locked out, and especially that high-energy capacitors are fully discharged prior to working on a system.
- Beware that capacitors may have their charges restored after initial discharge.
- Systems should be shortened during repair or maintenance procedures.
- The discharge of large capacitors requires proper equipment and procedures because significant levels of stored energy can be released as heat or mechanical energy.

- Class 3B and/or Class 4 lasers should have a separate circuit and local cut-off switch (breaker) for the circuit.
- Label and post electrical high voltage hazards and switches.
- Clearly identify the main switches to cut-off power.
- Before working on a laser, de-energize the machine.
- Keep cooling water connections away from main power and high voltage outlets and contacts.
- Use double hose clamps on cooling water hoses.
- Inspect cooling water hoses and connections and power cables and connectors periodically as part of a regular equipment inspection.

UV Lasers – Since UV radiation scatters easily from many surfaces, and exposure to UV radiation can cause cancer and it is important to contain UV radiation as much as possible. Wear gloves, (when hands are near the beam) long sleeve lab coats, and face and eye protection against UV radiation exposure. Avoid putting hands into the invisible beam (use fluorescent screens to define the beam). When intense UV radiation is absorbed in air, ozone will be produced, and proper ventilation may be needed. Contact LSO for assistance on ozone concerns and UV radiation hazards.

Noise – Certain lasers and associated electrical devices can generate painful and unpleasant noises at high frequency or repetitive rate that are harmful to the ears. Noise levels from certain lasers, and their work environment, may be of such intensity that noise control may be necessary.

Temporary Laser Controlled Area

Where removal of panels or protective housings, over-riding of protective housing interlocks, or entry into the NHZ becomes necessary (such as for service or during alignment procedures), and the accessible laser radiation exceeds the applicable MPE, a temporary laser-controlled area shall be set up. This control area shall provide all safety requirements for all personnel, both within and without and a sign shall be posted outside the temporary laser-controlled area to warn of the potential hazard.

Laser alignment procedures

Alignment shall be performed using the lowest practical power and, when possible, visible surrogate beams. Alignment procedures must be approved by the LSO and reviewed annually.

During alignment procedures performed by Queen's employee or Service representative, the following steps must be taken to ensure laser safety:

1. When open beam work is ongoing, the room shall be vacated by untrained and/or non-service persons and signage is affixed to indicate that the space is a temporary Laser Controlled Area during servicing.
2. The use of beam attenuators to align visible lasers will reduce laser beam intensities to a level that will allow the operator to align the beam without personal protective

equipment. Laser alignment cards for Ultraviolet and Infrared radiation allow operators to locate the beam during alignment procedures.
3. Proper laser safety eye protection must be worn by the personnel conducting the alignment.
4. Upon completion of the alignment service work, the beam path will be enclosed and interlocked as per laser safety guidelines and the User Documentation.
5. Door sign will be removed.

LASER PROTECTIVE EYEWEAR REQUIREMENTS

1. Laser Protective Eyewear (LPE) is to be available and worn in by all personnel within the Nominal Hazard Zone (NHZ) of Class 3B and Class 4 lasers where the exposures above the Maximum Permissible Exposure (MPE) can occur.
2. The attenuation factor (optical density) of the laser protective eyewear at each laser wavelength shall be specified by the Laser Safety Officer (LSO).
3. All laser protective eyewear shall be clearly labelled with the optical density and the wavelength for which protection is afforded.
4. Laser protective eyewear shall be inspected for damage prior to use. All damaged PPE should be removed and replaced immediately.
5. LPE should be stored properly
6. A mean of disinfection prior and after each use should be available in case LPE are shared between laboratory personnel.

To determine the proper Laser Eye Protection, use the following procedure:

1. **Determine the wavelength of the laser**. Eye protection is wavelength specific. Eyewear that provides protection for CO_2 lasers will not necessarily protect against Nd:YAG lasers.
2. **Determine the maximum anticipated viewing duration.** Viewing duration usually fall into one of three categories:
    1. Unintentional, accidental exposure to **visible lasers** (400-700 nm), use **0.25 seconds**
    2. Unintentional, accidental viewing of **near infrared** (700-1000 nm) beams, use **10 seconds**
    3. For all other lasers, use 600 seconds or laser on time, up to 8 hours.
3. **Determine the maximum irradiance or radiant exposure to which the eye may be exposed (MPE).** Consider the following:
    1. If the emergent beam is not focused down to a smaller spot and is greater than 7 mm in diameter, the emergent beam radiant exposure/irradiance may be considered the maximum intensity that could enter the eye.
    2. If the beam is focused after emerging from the laser or if the beam diameter is less than 7 mm, assume that all of the laser energy/power could enter the eye *Maximum Output Power/Energy.* (see Appendix IV for MPE values)
4. **Determine the optical density needed.**
   OD is a logarithmic function where H_0 is the anticipated worst case exposure conditions (in joules/cm^2 or watts/cm^2) and the MPE is expressed in the same units as H_0.

$$OD = \log_{10}\left[\frac{H_0}{MPE}\right]$$

You can also use as a reference the table of Optical density needed for particular lasers, based on the worst-case exposure duration (Appendix V)

5. **Select the type of eye protection needed.** Laser eye protection is available in the form of glasses and goggles. The lens may be made out of glass or crystalline filter material or plastic. Generally, glass or crystalline lenses are recommended for harsh environments, such as areas where solvents and corrosives are used.
6. **Test the eye protection.** Always check the integrity of the lens before use. At very high beam intensities, filter materials become bleached out or otherwise damaged. A continuous wave power exceeding 10 W can fracture glass and burn through plastics.

LASER AREA SIGNS

Laser area warning signs shall be posted in laboratories operating Class 2, 2M, 3R, 3B and 4 lasers.

The purpose of the signs is to convey a rapid visual hazard- alerting message of:

a) The presence of a laser hazard in the area
b) Specify procedure in effect relative to laser control,
c) Severity of the hazard, and
d) Appropriate action(s) to take to avoid the hazard

Class 2 and 2M and 3R laser the signs must use the word **CAUTION** to indicate a hazardous situation that, if not avoided, could result in minor or moderate injury.

Class 3B and 4 lasers sings will use the word **WARNING** to indicate and imminent hazardous situation that, if not avoided, could result in death or severe injury.

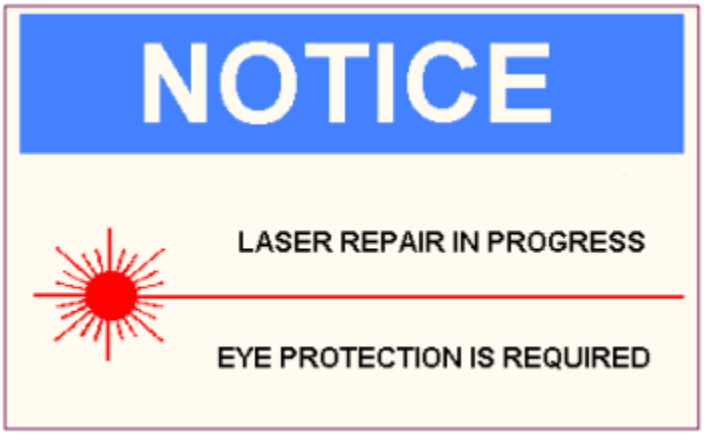
A sign with the signal word **DANGER** will be limited to Class 4 exposed beam lasers with multikilowatt output power or high pulse energies. It will indicate that death or severe injury will occur in the Laser Controlled Area (LCA) if necessary,
control measures are not implemented to mitigate the hazards.

In addition to the warning signs and words, the LCA sign must include the following information:

a) Hazard class (the highest hazard class of the laser or laser systems within the LCA)
b) The appropriate OD and Wavelength of the Laser Protective Eyewear (LPE)
c) Name and contact of the Laser Safety Officer (LSO) or Laboratory laser supervisor
d) Any special precautionary instruction that may be appropriate (i.e)
    - Knock before entering
    - Invisible Laser Radiation
    - Laser Protective Eyewear required
    - Do not enter when light is illuminated
    - Restricted Area, Authorized Personnel Only

Approved laser warning signs can be obtained from the EH&S website in the Radiation Section under the Laser Safety tab (https://www.queensu.ca/risk/safety/radiation)

Temporary Laser Control Area Signs Post a notice sign outside any area or laboratory designated as a temporary laser control area. Temporary laser control areas are required when accessible laser radiation exceeds the acceptable MPE. Use wording that describes the required precautionary procedures.



LASER INVENTORY

Any laser or laser containing system, must be registered with the Queen's University Environmental Health and Safety Department before being used for the first time. The person in charge of the laser device needs to submit a Radiation Laser Registration Form as shown in Appendix 2 including the following information.

- name of PI and Queen's Department
- type of laser (CO2, Nd: YAG, He-Ne, etc.)
- production class (commercial, modified, homemade)
- laser classification
- location (bldg. and room)
- proposed use (research, teaching, medical, etc.)
- name, telephone and e-mail address of the contact person.

The LSO is responsible for maintaining a university wide central inventory of all class 2, 2M, 3R, 3B, and 4 laser and laser systems, and include hazard class and location of every laser and laser system. Updates to this inventory must be submitted within 30 days of acquisition, modification, or decommissioning of a laser system.

LASER SAFETY TRAINING

Laser safety training requirements depends on the magnitude of the potential laser hazard that it is operated in the laboratory. The training shall ensure that the users are knowledgeable of the potential hazards and the control measures for laser equipment they may have occasion to use.

The primary responsibility of ensuring the safe use of lasers and laser systems belongs to the Principal Investigator associated with the laser(s) and/or laser system(s) for which he or she

is responsible. The PI is responsible for providing laser safety training to people using lasers or entering controlled areas under his or her supervision.

Laser users who operate a Class 3B or 4 laser or laser system must:

- Read this Laser Safety Procedures Manual
- Read the SOP-Radiation-02 -*Laser Safety Standard Procedure*.
- Complete EHS- Laser Safety training.
- Read all relevant Standard Operating and Emergency Procedures
- Read all manufacturers supplied safety instructions for relevant laser systems
- Receive PI training on the specific laser equipment to be used.

A) A Laser Safety Training shall be provided to users of Class 3B and 4 lasers. The training includes:

1. Review and know the content of the Queens' Laser Safety Program including but not limited to:
   - Fundamental of laser operation
   - Significance of specular and diffuse reflections
   - Overall responsibilities of management and employee
   - Bio effects of the laser radiation on the eyes and the skin.
   - Laser and Laser System Classification
   - Control Measures
   - Medical Surveillance

The training material can be accessed through the training section of the EH&S department. A training certification will be provided upon passing the course with a score greater than 80% and an annual refresher must be taken to maintain this certification. Laser safety supervisors will ensure employees complete an annual refresher.

B) A Laser Safety Awareness should be provided to users of class 1M, 2, 2M, and 3R lasers and laser systems and to employees operating laser systems that enclose higher power lasers.

This training must include but not limited to:
- Definition of laser
- Laser and Laser System Classification
  - Bio effects of the laser radiation on the eyes and the skin.
- Control measures focusing on human aversion response

C) A laser pointer safety information is available through the Environmental Health and Safety website.

Laser Safety Awareness and Laser Pointer Safety do not require a written test nor annual refresher. Certificate of completion is provided upon completion of all the instruction materials.

LASER AND LASER SYSTEMS INTERNAL INSPECTIONS

The University LSO is responsible for conducting annual inspection of laboratories using Class 3B and 4 laser and laser systems to ensure compliance with the Laser Safety Manual and operational procedures. After the inspection, the LSO will provide a copy of the inspection report to the Principal Investigator (PI) or Laboratory Laser Supervisor (Appendix III). The PI is responsible for reviewing and implementing any corrective action for all non-compliance or minor- findings listed in the inspection report. The University LSO will retain records of inspections for at least five years.

LASER AND LASER SYSTEM INCIDENTS REPORT AND INVESTIGATIONS

Laboratory Laser Supervisors or PI are responsible for reporting accidents and incidents involving lasers or laser systems. They must complete and sign an Incident Report and submit to the Environmental Health and Safety Department as soon as possible, including a description of the incident, persons involves and potential causes.

Accidental eye or skin exposure to laser radiation, and accidents related to non-beam hazards, are most often associated with the following conditions:

- Failure to follow SOPs.
- Equipment malfunction.
- Modification of the beam path.
- Lack of protection for non-beam hazards.
- Operators unfamiliar with laser operations.
- Eye or skin injury of photochemical origin.
- Improper methods of handling high voltage.
- Available LPE not used.
- Fires resulting from the ignition of materials.
- Unanticipated eye exposure during alignment and or laser usage.
- Intentional exposure of unprotected personnel.
- Misaligned optics and upwardly directed beams.
- Improper restoration of equipment following service or maintenance.
- LPE not appropriate for laser use.
- Inhalation of LGAC or viewing laser generated plasmas.
- Introduction of foreign materials, for example, pages of loose paper, paper clips, falling items or objects.

Reportable accidents/incidents:
- result in personal injury; or
- have the potential to result in significant personal injury or property damage; and
- occur to any person on premises; or
- occur to an employee during her/his work either on or off premises

In case of Critical Injuries (E.g.: loss of sight in an eye, burns to major portion of the body) PI must also:
- Ensure that the site of the accident remains undisturbed

– Investigate and prepare a written report on the circumstances of the accident

Any laser worker with known or suspected injury will be referred to the University Occupational and Health Services (Walsh and Associates)

All incidents and near misses shall be reviewed by the LSO to determine root cause, corrective actions, and program implications. Lessons learned shall be disseminated to laser users.

MEDICAL SURVEILLANCE

Pre-use medical examinations are not required prior to the use of lasers. Yet, medical examinations must be performed as soon as practically possible when there is a suspected injury or laser exposure. It is important that an expert assesses any laser worker to detect early signs of any ocular damage and to initiate prompt treatment if required.

Queen's employees and students working in or around laboratories with radiation or laser hazards may use the services of the Walsh and Associates Occupational Health Services clinic for routine matters such as:

- respiratory assessments related to respirator use for those with certain medical conditions
- eye screening (Central Field Testing using Amsler Charts) at the beginning and end of employment for Queen's employees who use 3B and 4 lasers
- medical counselling as necessary for certain hazards for which a Queen's SOP has been written

If there is an exposure incident for which you have a Standard Operating Procedure that indicates you should contact Walsh and Associates during normal business hours, contact their main office in Belleville at **613-966-4114.**

- Outside of those defined incident types, or if unable to contact Walsh and Associates, **if there is an exposure incident requiring urgent medical attention then workers should go to the Kingston Health Sciences Centre – Kingston General Hospital (KHSC – KGH) Emergency.** Location of the **Emergency Room Entrance** (Google Maps) at Kingston General Hospital**.**

APPENDIX

Appendix I. Laser worker registration form

The undersigned worker will participate in the Queen's University Laser Safety Program

Laser Safety Training

The undersigned has successfully completed the Laser Safety Training module and associated quiz. A grade of 80% or greater on the quiz is required.

Laser Safety Manual

The undersigned has read and is familiar with the contents of the Queen's University Laser Safety Manual.

Standard Operating Procedures

The undersigned has read and is familiar with the contents of the Standard Operation Procedures for the laser(s) listed below.
SOP-Radiation-02 Laser Safety Standard Procedure
Laser Standard Operating Procedure: Title of the procedure

Personal Protective Equipment

The undersigned has the personal protective equipment described in the SOP available to them and is familiar with their care and use.

Description of Laser(s)

Location _____

Manufacturer _____ Model _____ Class _____

Manufacturer _____ Model _____ Class _____

Manufacturer _____ Model _____ Class _____

Supervisor _____ Signature_____

Worker _____ Signature_____

Date _____

Please return the completed form to:
University Radiation Safety Officer (URSO)
Department of Environmental Health and Safety
Queen's University |355 King Street | 1st Floor, West Wing, Room 107 | Kingston, ON | K7L 2X3
Email: raico.l@queensu.ca
Phone: 613-533-6000 ext. 78820
Website: www.queensu.ca/risk/safety

Appendix II. - Laser Standard Operating Procedure

Introduction:
This procedure is part of Queen's Laser Safety Program and shall be reviewed annually by all persons who use Class 3B & 4 lasers or laser systems listed in this SOP. This procedure shall also be reviewed every two years by the Permittee or Laboratory Laser Safety Supervisor (LSS) to ensure it reflects the most current conditions. Changes in the operating procedure shall be forwarded to EHS – Laser Safety for review and approval.

Laboratory Information:

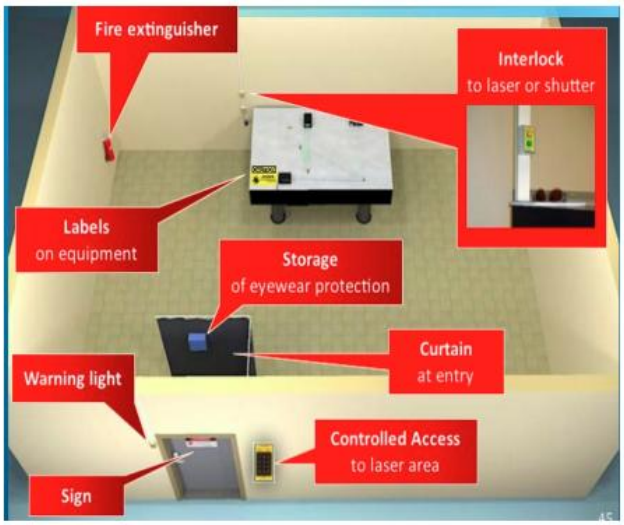
Laboratory PI name:		Date of creating:	
Department:		Revision #:	
Building and Room #:		Author:	

Emergency **Contact Information:**

Role	Full Name	Contact number
Department Safety Officer		
University LSO		
Maintenance/ Repair		
Medical Emergencies		

Laser Description: *Describe the laser(s) setup and how it is used including general beam parameters, optics, and equipment. Include a diagram or picture with the beam path depicted. This may be included as an attachment if necessary.*

EXAMPLE DIAGRAM:



(Show the location of beam stops, interlocks, shielding, mirrors, and other relevant details or attach drawing. Include laser location, beam path, emergency shutdown location(s), and fire extinguisher(s)

Laser Parameters: *Complete the table below using the operating conditions (power output, pulse energy, duration, etc.) of the laser. If more than one laser is used, copy and paste this table to complete the laser parameters for the other lasers. Laser eyewear is to be inspected by the user for lens applicability and integrity prior to each use.*

Make:		Wavelength (nm):	
Model:		Power Output (W):	
Serial Number:		Beam Diameter (mm):	
Class:		Beam Divergence (1/e2) (mrad):	
Cont. or Pulsed:		Duration (ns) & Rate (Hz):	
Eyewear Make:		Eyewear Wavelength:	
Eyewear Model:		Eyewear Optical Density:	

Operating Procedures:
All Class 3B and 4 lasers and laser systems shall have a documented operating procedure that provides the end user the necessary instruction for completing their experiment safely. The operating procedure shall include instructions for all times it is necessary for the laser to be powered on including normal operation, alignments, service, and repairs as applicable. The procedure shall incorporate all safety measures including when to don/doff eyewear, room securement, signs and warning labels, housekeeping, and other control measures identified in the hazard section above. This procedure shall be updated to reflect current operations prior to commencing the experiment.

a) **Entering Laser Room** (Specify below the engineering and/or administrative controls you have in place to protect against unauthorized personnel entering the laser control area

b) **Setup** (Explain in sufficient detail the process of setting up the laser operating system)

c) **Start-up and Operation** (List the basic sequential events that describe the complete operation, including when to turn on the laser warning light, laser setting, etc. The procedures shall be written for the benefit of the laser user who must read and understand them to perform the operation safely)

d) **Shutdown** (Describe normal and emergency shutdown procedures)

e) **Alignment procedures** (Describe applicable safety)

Physical Controls: *Describe the physical controls of the laser setup in the condition which the setup is intended to be operated. Edit the comment section as necessary to depict the lab specific controls implemented. EHS will review and approve the described control measures*.

Check If Applicable:	Control:	Comments:
☐	Entryway (door) Interlocks or Controls	Entry to the lab is restricted to authorized and properly trained lab personnel only with an active keypad lock. The lab door is to always remain closed unless the laser is shutdown and under the direct supervision of an authorized person.

☐	Laser Enclosure Interlocks	Any laser enclosure interlocks will be engineered to fail safe and require manual re-activation if defeated.
☐	Laser Housing Interlocks	Fail-safe or redundant interlocks shall be provided if they can be removed or displaced during operation and still allow access to Class 3B or 4 laser radiation. Warning labels shall be provided near the interlock if it can be defeated or by-passed.
☐	Emergency Stop	A power strip located on the optical table next to the microscope provides power to the entire system. In the event of an emergency shutdown, the red switch on the power strip shall be used to immediately shutdown the lasers.
☐	Beam Stops	The beam terminates in an aluminum beam block capable of withstanding the heat from the laser setup without degradation.
☐	Master Switch	The laser is only operable via computer-controlled software. The computer is password locked to ensure only authorized individuals can operate the laser devices.

Hazards & Controls:

Check If Applicable:	**Hazard:**	**Controls:**
☐	Housekeeping	The beam path and surrounding areas will be kept free of clutter and obstructions. Hand clearing of clutter from the optical table and beam area will be performed prior to each laser operation. All optical fibers must be clear of clutter so they can be inspected prior to each use.
☐	High Voltage	The building manager and facilities electrical shop shall be consulted prior to operation/maintenance involving high voltage exposure including any adjustments needed.
☐	Capacitors	Any capacitors will be enclosed within a protective panel during operation and fully discharged prior to maintenance.
☐	Unenclosed Beam Access to Beam	The beam is contained within the fiber optic cables and microscope until the sample stage. Objective lenses have a high divergence that reduces the nominal hazard zone to several centimeters from the objective optic. Laser

		intensity is reduced with microscope software to ensure <5mW laser power at the sample stage.
☐	Fumes/Vapors	Any fumes/vapors generated during operation will be exhausted through a fume hood or local ventilation apparatus.
☐	Ultraviolet Radiation or Blue Light	Appropriate barriers and PPE to protect skin and eyes from UV and eyes from blue light will be in place upon consultation with EHS if needed. This may include lab coats, eyewear, gloves, fade shields or topical sunblock applications.
☐	Compressed Gases	Compressed gases will be properly secured and labeled. Safety caps will be in place for unused cylinders. Flammable and oxidizing cylinders shall be stored at least 20 feet apart unless specifically required for an experiment upon consultation with EHS.
☐	Hazardous Chemicals/Waste	No hazardous waste is expected to be made during ordinary operation. If hazardous waste is generated, all waste properly handled, labeled and stored per EHS guidelines.
☐	Reflective Material in Beam Path	The open beam paths will be kept free of clutter to prevent inadvertent ignition of materials, specular and diffuse reflections, and laser generated airborne contaminants.
☐	Fire	A fire extinguisher is located within a few steps of the table. Laser operators will ensure familiarity with its location. Beam blocks will be used to absorb laser energy capable of generating hazardous levels of heat.
☐	Laser at eye level of person sitting or standing	The laser is mounted below the eye level of a person sitting normally. Beam blocks and additional barriers will be used to prevent the cohesive beam from travelling beyond the limits of the optical table.
☐	Infrared Lasers	Invisible lasers will be properly blocked and attenuated. Adequate viewing equipment such as IR viewers, cards, cameras, etc. must be available to the end user to ensure reflections are minimized.
☐	Correct Eyewear	Appropriate EHS approved laser eyewear protection with labelling of wavelength and optical density will be present and worn by all lab personnel working in rooms with accessible laser radiation. The eyewear will be made readily available prior to entering a nominal hazard zone at the door or curtain entrance, properly maintained, cleaned, and stored per manufacturers recommendations.

☐	Secured Laser	Lasers are located in a closed laser combiner that is secured to the optical table. Laser fiber optic cables that run from the combiner shall be kept free of clutter and without extreme bends that could damage the fiber.

Laser Protective Eyewear
For enclosed beams, all personnel utilizing a Class 3B and/or Class 4 laser or laser system MUST wear laser protective eyewear. Inspect all eyewear periodically and ensure it is in good condition. Ensure eyewear with the correct Optical Density (OD) and wavelength is provided to all laser operators and individuals in the Laser Control Area during open beam operation.

Eyewear Manufacturer	**Eyewear Model**	**Rated Wavelength (nm)**	**Optical Density (OD)**
Newport Optics	*G3982*	*770-810*	*5+*

Standard Operating Procedure Approvals
These Standard Operating Procedures have been reviewed and approved by the University LSO. Future changes to this SOP must be submitted, reviewed, and approved by the LSO.

Signature of Authorized Laser Supervisor: _____ Date_____

Signature of Laser Safety Officer _____ Date:_____

Operator Review:
By signing this form, I agree that I have read and understand the contents of this SOP and will adhere to it' instructions. Furthermore, I agree that I have successfully complete the University's Laser Safety Training and I am aware that it is my responsibility to operate in a safe manner.

Full Name	Signature	Date

Appendix III. Annual Inspection Checklist

Queen's University Laser Safety Program – Annual Inspection Checklist
Version Oct. 2025

Section 1 – Administrative Information

Facility Name Click or tap here to enter text.
Department / Lab Click or tap here to enter text.
Inspection Date Click or tap to enter a date.
Inspector Name Click or tap here to enter text.
Principal Investigator (PI) Click or tap here to enter text.
Room / Location Click or tap here to enter text.
Laser Controlled Area? Yes ☐ No ☐

Section 2 – Laser System Information

Laser Manufacturer Click or tap here to enter text.
Model / Serial Number Click or tap here to enter text.
Wavelength (nm) Click or tap here to enter text.
Output Power / Energy Click or tap here to enter text.
Laser Type (e.g., Nd:YAG, CO_2, Diode) Click or tap here to enter text.
Laser Classification: ☐ 1 ☐ 1M ☐ 2 ☐ 2M ☐ 3R ☐ 3B ☐ 4
Operation Mode: ☐ Continuous Wave ☐ Pulsed

Section 3 – Engineering Controls (ANSI Z136.1 § 4.3)

- Protective housing intact Yes ☐ No ☐ N/A ☐
- Beam path enclosed where practical Yes ☐ No ☐ N/A ☐
- Interlocks operational Yes ☐ No ☐ N/A ☐
- Key control / master switch Yes ☐ No ☐ N/A ☐
- Beam stops / attenuators present Yes ☐ No ☐ N/A ☐
- Remote interlock connection Yes ☐ No ☐ N/A ☐
- Shutter or beam block functioning Yes ☐ No ☐ N/A ☐

Section 4 – Administrative & Procedural Controls

- Written SOP available Yes ☐ No ☐
- SOP matches current configuration Yes ☐ No ☐
- Authorized user list current Yes ☐ No ☐
- Laser warning signage posted Yes ☐ No ☐
- LSO approval documented Yes ☐ No ☐
- Training current (per ANSI Z136.1 § 1.3.2) Yes ☐ No ☐
- Alignment procedure available Yes ☐ No ☐

Section 5 – Personal Protective Equipment (PPE)

- Eyewear labeled for wavelength and OD Yes ☐ No ☐
- Eyewear in good condition Yes ☐ No ☐
- Eyewear available for all personnel Yes ☐ No ☐
- Protective clothing / gloves used Yes ☐ No ☐
- Eyewear cleaning and storage adequate Yes ☐ No ☐

Section 6 – Environmental / Facility Controls

- Controlled area clearly marked Yes ☐ No ☐
- Access limited to authorized users Yes ☐ No ☐
- Warning lights functional Yes ☐ No ☐
- Entryway barriers operational Yes ☐ No ☐
- Beam height below eye level (standing/sitting) Yes ☐ No ☐
- Adequate ventilation / exhaust Yes ☐ No ☐

Section 7 – Emergency Equipment

- Emergency stop tested Yes ☐ No ☐
- Fire extinguisher accessible Yes ☐ No ☐
- First-aid kit available Yes ☐ No ☐
- Spill or incident reporting procedure posted Yes ☐ No ☐
- Emergency contacts visible Yes ☐ No ☐

Section 8 – Educational / Research-Specific Controls (ANSI Z136.5 / Z136.8)

- Student supervision documented Yes ☐ No ☐
- Training appropriate for laser class Yes ☐ No ☐
- LSO reviewed experimental setup Yes ☐ No ☐
- Alignment under direct supervision Yes ☐ No ☐
- Equipment secured between sessions Yes ☐ No ☐

Section 9 – Inspector Notes / Corrective Actions

Observations / Non-conformances	Corrective Action Required	Responsible	Follow-up Date

Section 10 – Signatures

Inspector Name / Signature / Date _____
Laser Safety Officer _____
PI / Supervisor _____

Appendix IV Maximum Output Power/Energy

Maximum Output Power/Energy for selecting Laser Eye Protection for Intrabeam Viewing for 400 - 1400 nm Wavelengths

Q-Switched (1 ns - 0.1 ms)		**Non-Q-Switched (0.4 ms - 10 ms)**		**CW Momentary View (0.25 s to 10 s)**		**CW Starting (more than 3 hours)**		**Attenuation Factor**
Max Output Energy (J)	Max Beam Radiant Exposure (j/cm^2)	Max Laser Output Energy (J)	Max Beam Radiant Exposure (J/cm^2)	Max Power Output (W)	Max Beam Irradiance (W/cm^2)	Max Power Output (W)	Max Beam Irradiance (W/cm^2)	
10	20	100	200	na	na	na	na	100,000,000
1	2	10	20	na	na	na	na	10,000,000
10^-1	2x10^-1	1	2	na	na	na	na	1,000,000
10^-2	2x10^-2	10^-1	2x10^-1	na	na	10^-1	2x10^-1	100,000
10^-3	2x10^-3	10^-2	2x10^-2	10	20	10^-2	2x10^-2	10,000
10^-4	2x10^-4	10^-3	2x10^-3	1	2	10^-3	2x10^-3	1,000
10^-5	2x10^-5	10^-4	2x10^-4	10^-1	2x10^-1	10^-4	2x10^-4	100
10^-6	2x10^-6	10^-5	2x10^-5	10^-2	2x10^-2	10^-5	2x10^-5	10

Appendix V LPE Optical density

Optical density needed for particular lasers, based on the worst-case exposure duration.

Laser Type/ Power	Wavelength (mm)	OD for 0.25 sec	OD2 for 10 seconds	OD for 600 seconds	OD for 30,000 seconds
XeCl/50 watts	0.308a	---	6.2	8	9.7
XeFl/50 watts	0.351a	---	4.8	6.6	8.3
Argon/1.0 watt	0.514	3	3.4	5.2	6.4
Krypton/1.0 watt	0.53	3	3.4	5.2	6.4
Krypton/1.0 watt	0.568	3	3.4	4.9	6.1
HeNe/0.005 watt	0.633	0.7	1.1	1.7	2.9
Krypton/1.0 watt	0.647	3	3.4	3.9	5
GaAs/50 mW	0.840c	---	1.8	2.3	3.7
Nd:YAG/100 watt	1.064a	---	4.7	5.2	5.2
Nd:YAG/(Q-switch)	1.064a	---	4.5	5	5.4
Nd:YAGc/50 watts	1.33a	---	4.4	4.9	4.9
CO2/1000 watts	10.6a	---	6.2	8	9.7

[a] Repetitively pulsed at 11 Hertz, 12 ns pulses, 20mJ/pulse
[b] OD for UV and FIR beams computed using 1 mm limiting aperture which presents a “worst case scenario." All visible/NIR computation assume 7 mm limiting aperture.
[c] Nd:YAG operating at a less common 1.33 mm wavelength.
NOTE: All OD values determined using MPE criteria of ANSI Z-136.1

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