Rowan University

ENVIRONMENTAL HEALTH & SAFETY

Laser Safety Manual

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Contents

I. Introduction

The purpose of this manual is to ensure the safe use of lasers in research and instructional laboratories at Rowan University. To achieve this goal, the Rowan University Department of Environmental Health and Safety (EHS) has developed a safety program based upon the American National Standards for Safe Use of Lasers, ANSI Z136.1. ANSI Z136.1 is the recognized standard for laser safety throughout the United States.

Many lasers are capable of causing eye injury from the direct beam and specular reflections. Class 4 lasers are also capable of causing eye injury from diffuse reflections, burning exposed skin, igniting combustible materials and generating hazardous air contaminants. Equipment used to produce the lasing action and control/direct the laser beam may introduce additional hazards associated with high voltage, high pressure, cryogenics, noise, radiation, and toxic gases.

Individuals can minimize the risk of a laser injury if they adhere to the requirements of this manual, obtain both formal and hands-on training in safe laser use, and follow the established laser Standard Operating Procedures (SOPs).

Throughout this document the use of the word "shall" indicates a requirement and the use of the word "should" indicates a recommendation.

II. Scope

The contents of this manual apply to all University personnel, employees, students and visitors, who operate lasers or work in locations where lasers are used.

III. Definitions

Accessible emission limit (AEL): the maximum accessible level permitted within a particular laser hazard class. The AEL is used to classify lasers into hazard classes.

Alignment: the process of adjusting the laser beam (using mirrors, lenses, etc.) so that it travels along its desired path.

American National Standard for Safe Use of Lasers (ANSI Z136.1): document that provides guidance for the safe use of lasers and laser systems by defining control measures for each laser classification. Rowan University has adopted this standard as the basis for its safety program.

Attenuation: the decrease in the radian flux as it passes through an absorbing or scattering medium.

Average power: the total energy in an exposure or emission divided by the duration of the exposure or emission.

Aversion response: closure of the eyelid, eye movement, papillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. Aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of an individual's retina to 0.25 seconds or less.

Baseline eye exam: a pre-assignment exam recommended (but not required) by the ANSI standard for Class 3B and Class 4 laser operations. The ANSI baseline eye examination consists of an ocular history evaluation, a visual acuity test, an amsler grid test, and a color vision test.

Collateral radiation: any electromagnetic radiation, except laser radiation, emitted by a laser or laser system that is physically necessary for its operation.

Collecting optics: lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars or loupes.

Continuous wave (CW): the output of a laser that is operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser operating with a continuous output for a period >0.25 is regarded as a CW laser.

Controlled area: an area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation and related hazards.

Diffuse reflection: change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Embedded laser: an enclosed laser with an assigned class number higher than an inherent capability of the laser system in which it is incorporated, where the systems lower classification is the result of engineering features which limits the accessible emission.

Failsafe interlock: an interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

Infrared radiation (IR): electromagnetic radiation with wavelengths that lie within the range 0.7µm to 1mm.

Intrabeam viewing: the viewing condition whereby the eye is exposed to all or part of a laser beam.

Irradiance (E): radiant power incident per unit area upon a surface, expressed in watts per centimeter squared.

Joule (J): unit of energy or work, equal to the energy used to accelerate a body with a mass of one kilogram using one Newton of force over a distance of one meter. 1 joule = 1 watt second. Commonly used to characterize the output from pulsed lasers.

Laser-Controlled Area: the area that confines the nominal hazard zone (NHZ) or regulates access to the NHZ. In some cases, the walls, ceiling and floor of the room often define the laser controlled area. Laser curtains and free standing laser barriers are sometimes used to limit the size of the laser controlled area.

Laser Operator: individuals approved by the Laser Supervisor to operate, align, or maintain laser equipment. In this manual the term “operator” does not include non-university laser service personnel.

Laser Safety Officer (LSO): one who has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser Supervisor: one who is responsible for, and enforces, the safe use of a laser. The Laser Supervisor controls who uses the laser and how it will be used. This must be a Rowan Faculty or Staff Member.

Laser system: an assembly of electrical, mechanical, and optical components that includes one or more lasers.

Laser workstation enclosure: an enclosure completely surrounding a laser and associated experimental elements designed to limit accidental physical access to the beam and/or to attenuate reflected beams to harmless levels. May or may not be designed with failsafe interlocks. Not to be confused with a protective housing.

Maximum permissible exposure (MPE): the level of laser radiation to which an unprotected person may be exposed to without adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant (joules/cm^2) or irradiance (watts/cm^2).

Mode-locked laser: laser that emits extremely short duration (picoseconds to femtoseconds), high power pulses by means of mode-locking. Mode-locking is achieved by inducing a fixed phase relationship between the modes of the lasers resonant cavity.

Nominal hazard zone (NHZ): the space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). Does not include Maintenance or Service.

Optical density: the logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength. The higher the optical density, the lower the transmittance.

Peak irradiance: peak power incident per unit area on a surface, expressed as watts per cm^2.

Peak power: the maximum occurring optical power in units of watts. For mode-locked lasers, the peak power can exceed 10 gigawatts.

Photochemical effect: the biological effect produced by a chemical action brought about by the absorption of photons by molecules that directly alter the molecule. Primarily produced by ultraviolet and some blue wavelengths.

Principal Investigator (PI): is the individual responsible for the preparation, conduct, and administration of a research grant, cooperative agreement, training or public service project, contract, or other sponsored project.

Protective housing: enclosure that surrounds a laser or laser system preventing access to laser radiation above the MPE and access to electrical hazards. Laser manufacturers are required to provide protective housings for all classes of lasers. Fail-safe interlocks which interrupt the laser beam when the housing is opened are required on class 3b and class 4 lasers.

Pulse duration: The time interval (in seconds) between the half-power points on the leading and training edges of a laser pulse.

Pulse repetition frequency (PRF): number of pulses occurring per second, expressed in hertz (Hz)

Pulsed laser: a laser that delivers its energy in the form of a single pulse or a train of pulses. The duration of a pulse is regarded to be <0.25 seconds.

Q-switched laser: a laser that emits short (~ 10 to 250 ns), higher power pulses by means of a Q-switch (Q-switch enhances the storage and dumping of electronic energy in and out of the lasing medium).

Radiant exposure (H): surface density of the radiant energy received, expressed in units of joules per centimeter squared.

Repetitive pulse laser: a laser with multiple pulses of radiant energy occurring in sequence.

Reversible bleaching: the absorbing filter of laser eyewear may become temporarily saturated from an ultrashort laser pulse, causing the beam to pass through.

Service: the performance of procedures, typically defined as repair, to bring the laser or laser system back to full and normal operational status. Normally performed by qualified technical personnel provided by the manufacturer or other service companies.

Shall: in this manual "shall" indicates that the action is mandatory.

Should: in this manual, "should" indicates that the action is recommended but not mandatory.

Specular reflection: a mirror-like reflection

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

Ultraviolet radiation (UV): electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of this manual 0.18 to 0.4 µm.

Visible radiation (light): electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range of 0.4 to 0.7 µm.

Watt (W): the unit of power, used to express the rate at which energy is emitted, transferred, or received. 1 watt = 1 joule per second.

IV. Laser Classifications

Lasers and laser systems are classified based on their capability of injuring personnel. Lasers with a higher laser hazard class value are more capable of injuring exposed and unprotected individuals.

Lasers manufactured after August 1, 1976 must be classified and labeled by the manufacturer. The Laser Supervisor shall classify lasers and laser systems that are constructed or modified by the laboratory. Upon request, the Laser Safety Officer (LSO) can assist the Laser Supervisor with this task.

Laser Classifications:

- **Class 1 or 1M** – Class 1 and 1M lasers and laser systems are considered safe and incapable of producing damaging laser radiation levels during normal operation.
    - Example: CD/ DVD players
    - Class 1 and 1M lasers and laser systems are exempt from control under this Laser Safety Manual.
- **Class 2 or 2M** – Class 2 and 2M are low-powered lasers with an output of approximately 1 milliwatt (mW) of continuous wave. All class 2 lasers operate in the visible portion of the electromagnetic spectrum of 400–700 nanometers (nm).
    - Example: barcode scanners
    - Eye protection is usually afforded by aversion response and blink reflex (0.25 seconds). However, a class 2 laser beam could be hazardous if one were to intentionally expose the eye for longer than 0.25 seconds.

    - Class 2 and 2M lasers and laser systems are exempt from control under this Laser Safety Program.
- **Class 3R** (replacement for Class 3a) – Class 3R lasers operate at 1–5 mW of continuous-wave.
    - Example: laser pointers
    - Class 3R lasers and laser systems are exempt from control under this Laser Safety Program unless the laser radiation exceeds the MPE.
- **Class 3B** – Class 3B lasers operate at 5–500 mW of continuous-wave. Specific control measures are required to prevent direct or reflected beam viewing.
    - Principal investigators must meet these requirements for class 3B use:
    - Provide and document laser safety training for personnel using class 3B laser equipment.
    - Develop SOPs (see Appendix A).
    - Register all class 3B lasers or laser systems with EHS (see Appendix B).
    - Follow class 3B control measures (see section XI-XVI in this document).
- **Class 4** – Class 4 lasers and laser systems operate at greater than 500 mW (continuous), can emit any wavelength, and are considered an eye, skin, fire, and diffuse reflection hazard. The most stringent control measures have been established for these lasers.
    - Specific control measures to prevent eye and skin exposure to direct and diffusely reflected beam are required.
    - Principal investigators must meet these requirements for class 4 use:
    - Provide and document laser safety training for personnel using class 4 laser equipment.
    - Develop SOPs (see Appendix A).
    - Register all class 4 lasers or laser systems with EHS (see Appendix B).
    - Follow class 4 control measures (see section XI-XVI in this document).

Class to be determined - Manufacturers are required by the U.S. Food and Drug Administration to label lasers with a hazard classification. In cases where the laser class is unknown (e.g., if a researcher fabricates a laser or laser system), do the following:

- Contact the LSO to evaluate and classify the laser system.
- Converting High Hazard Class Lasers and Laser Systems to a class 1 Laser System:
    - If Class 3B and/or Class 4 lasers are embedded into an appropriate protective housing, they may be reclassified as a Class 1 laser system and the control measures established in this manual will no longer apply. However, whenever the protective housing is removed, a temporary laser controlled area must be established and control measures applicable to the class of the embedded laser(s) must be implemented.
    - Laser Supervisors who wish to convert a Class 3B and/or Class 4 laser into a Class 1 laser system shall consult with the LSO to ensure that all the requirements of a Class 1 laser system will be met.
    - Some of the requirements for a Class 1 protective housing are listed below:
        - Completely confines the laser beam or limits the emitted beam, to a level below that of the applicable Class 1 Accessible Emission Limit (AEL) as defined in Appendix C of the ANSI Z136.1 Standard.
        - Prevents access to the embedded laser(s) during normal operations.
        - Equipped with safety interlocks wherever the protective housing can be opened, removed, or displaced.

- Safety interlocks designed to prevent access to laser radiation above the Maximum Permissible Exposure (e.g. terminates laser power or activates a beam blocking shutter).
- Safety interlock is fail safe (the use of redundant electrical series-connected interlocks would fulfill this requirement).
- Labeled in accordance with ANSI Z136.1 Standard.

V. Laser Beam Bio-Effects

Laser exposure exceeding the Maximum Permissible Exposure (MPE's) may cause eye and skin injury which is sometimes permanent and debilitating. The MPE for each wavelength and exposure situation can be found in the ANSI Z136.1 Standard. Consult with the LSO if you require assistance determining the MPE for the laser you operate.

The probability that biological damage will occur and the tissue of the body will be at risk depends on a number of factors including: the laser wavelength, the power or energy of the beam, the beam diameter at the exposure site, the exposure duration, pulsed beam characteristics, etc.

The table below summarize the risks to the eye and skin for different laser wavelengths:

EYE

Spectral Region	Structure of the Eye at Risk	Biological Effect
UVC (200 – 280 nm)	Cornea	Photokeratitis
UVB (280 – 315 nm)	Cornea	Photokeratitis
UVA (315 – 400 nm)	Lens	Cataract
Visible (400 – 780 nm)	Retina	Retinal injury*
IR-A (780 – 1400 nm)	Retinal, lens	Retinal burn, cataract
IR-B (1400-3000 nm)	Retinal, lens	Corneal burn, cataract
IR-C (3000 – 1,000,000 nm)	Cornea	Corneal burn
*- Retinal injury can be thermal, acoustic, or photochemical.		

Skin

Spectral Region	Biological Effects
UVC (200 – 280 nm)	Erythema, cancer, accelerated aging
UVB (280 – 315 nm)	Erythema, increased pigmentation, cancer, accelerated aging
UVA (315 – 400 nm)	Erythema, increased pigmentation, skin burn
Visible (400 – 780 nm)	Photosensitive reactions, skin burn
IR-A (780 – 1400 nm)	Skin burn
IR-B (1400-3000 nm)	Skin burn
IR-C (3000 – 1,000,000 nm)	Skin burn

VI. Responsibilities

Laser Supervisors have a responsibility to:

- Supervise the use of lasers under their control.
- Comply with rules, regulations, laws, Rowan University's Laser Safety Manual, etc. on the Safe Use of Lasers.
- Implement and enforce the requirements outlined in this manual.
- Register all Class R's that exceed the MPE, Class 3B, and Class 4 lasers with EHS (see Appendix B).
- Develop SOPs for their Class 3B and Class 4 lasers/laser systems (see Appendix A) and upload them under the Documents tab in BioRAFT. Review SOPs annually; update in BioRAFT when needed.
- Ensure that Class 3B and Class 4 laser operators complete laser safety training conducted by EHS prior to starting laser work and annually thereafter.
- Provide Class 3B and Class 4 laser operators with training in procedures to operate their lasers.
- Provide laser safety awareness training to individuals working around, but not with, their lasers.
- Ensure that all lasers in their laboratories are properly classified and labeled.
- Post proper laser warning signs at the entrances to their laboratories.
- Ensure that effective, properly fitting laser safety spectacles and/or goggles are available. Replace eyewear in damaged or poor-condition.
- Notify EHS immediately in the event of a laser-related injury and assist the LSO with an investigation into the cause of the injury. Complete the Rowan University Incident Report Form as soon as possible.
- Review the plans of lab staff members fabricating lasers and provide close supervision throughout the fabrication process.
- Consult with LSO if planning to convert a Class 3B or Class 4 to a Class 1 laser /laser system.
- Inform EHS before disposing of a laser or transferring a laser to a new owner.
- Respond to communications from the LSO.
- Laser Supervisors may delegate laser safety tasks to qualified members of their staff but remain ultimately responsible for performance of those tasks.

Laser Operators have a responsibility to:

- Complete laser safety training conducted by EHS prior to beginning Class 3B and Class 4 laser operations and at the required frequency thereafter.
- Obtain training from the Laser Supervisor or his/her qualified designee in procedures to operate, align, maintain, and service the lasers to be used.
- Follow Standard Operating Procedures SOPs approved by the Laser Supervisor and inform the Laser Supervisor prior to any planned departure from the SOPs.
- Comply with the requirements outlined in this manual.
- Wear the correct laser safety eyewear as dictated by the requirements of this manual and by the SOPs approved by the Laser Supervisor. Inform Laser Supervisor when eyewear needs replacement.
- Do not defeat or bypass any safety interlock or engineering control device unless so directed by a written SOPs approved by the Laser Supervisor. Return interlock/device to functioning status at completion of procedure.
- Discontinue use of lasers if malfunctioning laser safety devices are observed and report such problems to the Laser Supervisor.
- Immediately notify the Laser Supervisor and/or EHS in the event of any laser-related injury or incident. Complete the Rowan University Incident Report Form as soon as possible.

- Inform their Laser Supervisor if they are aphakic (no lens in eye), have a history of photosensitivity, or use photosensitizing medications (such as phenothiazines and psoralens) and work with, or around lasers emitting ultraviolet radiation.

Laser Safety Officer (LSO) has a responsibility to:

- Work cooperatively with Laser Supervisors and Laser Operators to ensure the safe use of lasers at Rowan.
- Conduct safety audits of all laser facilities. Inform Laser Supervisors of conditions or practices that do not meet the requirements of the laser safety program as outlined in this manual.
- Provide Laser Supervisors and Laser Operators with assistance in any laser-related matter.
- Disseminate information regarding new laser safety products or techniques to Laser Operators.
- Assist Laser Supervisors in laser classification and labeling and the posting of laser warning signs.
- Maintain records of campus laser information including a listing of lasers and laser operators.
- Assist laser operators in the selection of laser safety equipment.
- Conduct laser safety training for all personnel working with lasers.
- Review SOPs.
- Participate in accident investigation involving lasers.
- Help coordinate the disposal of unwanted lasers.

VII. Personnel Training and Qualifications

Only qualified personnel are permitted to operate a laser. The Laser Supervisor determines who is a qualified person based on departmental training, technical training, and other appropriate learning experience. Laser Supervisors must obtain authorization from the LSO in writing before allowing a minor (person who is less than 18 years of age) to operate a Class 3B or Class 4 laser.

All individuals planning to operate a Class 3B or Class 4 laser are required to be properly trained in the safe use of lasers prior to working with lasers.

Before operating a Class 3B or Class 4 laser, laser operators shall:

- Review the Rowan University Laser Safety Manual.
- Complete a training presentation on the safe use of lasers provided by EHS.
- Receive and document training from the Laser Supervisor (or the Laser Supervisors qualified designee) covering safe operation of the laser to be used, administrative procedures, alignment procedures, and any other applicable SOPs.
- Review any operating and safety instruction furnished by the laser manufacturer.

Each calendar year after their initial training, laser operators must complete laser safety training provided by EHS in order to retain authorization to use Class 3B or Class 4 lasers. Should an operator fail to complete a refresher session by the end of the calendar year, their authorization is terminated and the operator must cease laser activities. The operator must complete training to regain authorization.

Individuals working in Class 3B or Class 4 laser facilities who are not laser operators must be trained in the following topics: laser hazards, methods to work safety around lasers, how to identify unsafe laser conditions, and what to do in case of laser injury. The training must occur before the individual is allowed access to the Class 3B or Class 4 laser facility. It is the responsibility of the Laser Supervisor to

ensure that such individuals receive and document the training. The training may be provided directly by the laser supervisor or by his/her qualified designee.

Ancillary personnel (e.g. custodial and maintenance personnel) are not be permitted to enter laser facilities when open or partially open, beams from Class 3B or Class 4 lasers are present. In cases where this is necessary, such individuals may be trained by the Laser Supervisor, the LSP, or the LSO's designee in the topics listed in the paragraph above.

Visiting, short term laser operators are those individuals who are conducting research or otherwise working at Rowan University for less than four (4) consecutive weeks. In place of EHS training requirements, such individuals may submit to the LSO written documentation from their home institution that they have been trained in the safe use of lasers. The following requirements must be completed:

- Review Rowan University's Laser Safety Manual.
- Receive and document training from the Laser Supervisor (or the Laser Supervisor's qualified designee) covering safe operation of the laser to be used, administrative procedures, alignment procedures, and any other applicable SOPs.
- Review operating and safety instructions furnished by the laser manufacturer.

VIII. Laser Registration

The Laser Supervisor shall register all Class 3B and Class 4 lasers and upload their Laser Device Registration Form (Appendix B) into BioRAFT. The Laser Supervisor shall update his/her laser registry when:

- New lasers are purchased, accepted as donations, or otherwise acquired.
- Lasers are taken out of storage for re-use.
- Lasers can be registered by using the form in Appendix B.

IX. Baseline Eye Exam

Individual working with, or around, lasers are not required to obtain a baseline eye exam. Such exams are not mandatory requirement of the ANSI Z136.1 Standard for Safe Use of Lasers.

X. Suspected or Actual Laser – Induced Injuries

Medical examinations shall be performed as soon as practical (usually within 48 hours) when a suspected injury or adverse effect from a laser exposure occurs. For injury to the eye from lasers operating in the retinal hazard region (wavelengths from 400 to 1400 nm), examination should be performed by an ophthalmologist. Individuals with a skin injury should be seen by a physician.

For injuries that require immediate medical assistance, Rowan University Department of Public Safety shall be contacted at 856-256-4911 or 911.

The injured individual shall notify the Laser Supervisor and EHS as soon as practical after a suspected or adverse effect from a laser exposure has occurred. The Laser Supervisor will complete the Rowan University Incident Report Form. Accident investigation will be conducted by the LSO together with the Laser Supervisor and injured individual.

XI. Control Measures

The purpose of control measures is to reduce the possibility of exposure of the eye and skin to hazardous levels of laser radiation and to protect individuals from non-beam hazards.

- **Engineering controls** are those items incorporated into the laser by the manufacturer or designed into the laser installation by the owner which isolates or prevents access to hazardous radiation. This is typically the most effective method of protecting individuals working with, or around, lasers. One example is the use of an interlocked laser enclosure that terminates power to the laser when opened.
- **Administrative and procedural controls** are employed when engineering controls are impractical or inadequate to completely eliminate the risk of laser injury. Safety instruction and written SOPs are examples of such controls.
- **Personal protective equipment (PPE)** are items (e.g., laser safety eyewear) that protect individuals when engineering, administrative, and procedural controls fail.
- A complete safety program in a laser facility will generally include a combination of engineering controls, procedural controls, and PPE use.

Adherence to the established control measures will minimize the probability of incidents. Below are the causes of most reported laser incidents:

- Eye exposure during alignment.
- Misaligned optics and upwardly directed beams.
- Available eye protection not worn or incorrect eye protection worn.
- Improper methods of handling high voltage.
- Operators unfamiliar with laser equipment or safety practices.
- Unanticipated eye or skin exposure during laser usage.
- Failure to follow SOPs.
- Fires resulting from ignition of materials.

XII. Engineering Controls

Protective Housing

Lasers of any class are required to have a protective housing to prevent access to optical and electrical hazards inside the laser. For Class 3B and Class 4 lasers the housing must be interlocked in a manner to eliminate the hazard if the housing is removed or opened.

If it is necessary to temporarily defeat the interlock and operate Class 3B or Class 4 lasers without the housing, operators must follow a written SOPs which incorporates measures to protect all present in the laser facility.

The SOPs must include provisions to:

- Restrict access to the area
- Control of the beam to prevent the beam and hazardous reflections from extending beyond the area
- Removal of reflective materials in and near the beam path
- Wear appropriate laser eye protection

After the operation that necessitated the interlock bypass is complete, the interlocks shall be restored to their operational condition.

Activation Warning System

An activation warning system shall be used with Class 3B lasers and Class 4 lasers during laser activation or start-up. The system may be audible (bells, chimes, buzzer, etc.) or visible (flashing light). An audible countdown by the laser operator may be used as an alternative warning method. If this means of warning is selected, it shall be written into the SOPs for use of the laser.

Beam Stop or Attenuator

Class 4 lasers shall have a permanently attached beam stop or attenuator which is capable of reducing laser radiation to levels below the MPE when the laser output is not required, as in warm-up procedures. Class 3B should have a permanently attached beam stop or attenuator.

For lasers that do not require a warm-up time, the main power switch may be substituted for the requirement of a beam stop or attenuator.

Collecting Optics

Lenses, telescopes, microscopes, loupes, etc. intended for viewing use with a laser shall incorporate a suitable means (such as interlocks, filters, attenuators) to prevent eye exposure at levels exceeding the MPE.

Window covers

When a laser is in operation and partially or fully exposed Class 3B or Class 4 beam paths are present, all windows which allow viewing into the laser facility by passers-by shall be covered with an opaque material or a laser filter material with sufficient density to reduce laser radiation to levels below the MPE. When the laser is not in operation the window covers may be retracted or removed.

Emergency Stop

For emergency conditions in facilities with Class 4 lasers, there shall be a clearly marked “Emergency Stop” device available for deactivating the laser or reducing the laser output to levels below the MPE. The stop device shall be in close proximity to the laser it controls.

Laser Workstation Enclosure

When at all practicable, the entire laser experiment should be confined within an enclosure when Class 4 lasers are used. When full enclosure is not practical, beam guide tubes and barriers shall be used to the maximum extent practical.

Nominal Hazard Zone (NHZ)

A NHZ shall be established for Class 3B and Class 4 laser applications which require an open beam. The NHZ is the area in which the level of direct, reflected or scattered laser radiation exceeds the MPE. The LSO defines the NHZ with the assistance of the Laser Supervisor.

Laser-Controlled Area

A laser-controlled area shall be established for Class 3B and Class 4 lasers. The laser-controlled area is the area that confines the NHZ or regulates access to the NHZ.

The walls, ceiling and floor of the room often define the laser controlled area. Laser curtains and free standing laser barriers may be used to limit the size of the laser-controlled area. Laser Supervisors should consult with the LSO prior to purchasing and installing curtains and barriers to confirm they are compatible with laser operation and will define the laser-controlled area as intended.

Entryway Controls

Entryway controls prevent unauthorized individuals from entering a laser-controlled area (especially when the laser is operating unattended) and also prevent authorized individuals with unprotected eyes from entering the laser-controlled when a potential eye hazard exists at the entryway.

One of the following controls shall be present at the entryway to all Class 4 laser-controlled areas when partial or fully open beam paths are present.

- Non-Defeatable Entryway Safety Controls: Non-defeatable safety latches or interlocks (such as pressure sensitive floor mats, infrared detectors, and motion sensors) shall be used to deactivate the laser or reduce the output to levels below the MPE in the event of unexpected entry.
- Defeatable Entryway Safety Controls: If non-defeatable controls limit the intended use of the laser, defeatable entryway safety controls may be used. Defeatable entryway controls allow authorized personnel to override the controls. Defeatable entryway controls may be used only if there is no laser radiation hazard at the point of entry. Personnel must be properly trained and provided with adequate personal protective equipment.
- Procedural Entry Controls: If safety latches or interlocks are not feasible, procedural entryway controls may be used.
- When procedural entryway controls are used, the following conditions must be met:
    - Appropriate laser eyewear and any other required personal protective equipment shall be accessible prior to entering the laser-controlled area.
    - A door, barrier, screen or curtains shall be used to block or attenuate the laser radiation below the MPE at the entryway.
    - The entryway shall be equipped with an illuminated laser warning sign or warning light that indicates the laser is operating at Class 4 levels. The sign or light shall have the following statement “DO NOT ENTER WHEN LIGHT IS ON, NO ONE MAY ENTER except for laser operators” (or words with similar intent).
    - When a Class 4 laser is operating unattended* and partially or fully open beams are present, unauthorized access to the laser-controlled area shall be limited by locking a

deadbolt lock in addition to the regular entry lock. The key to the deadbolt lock shall be provided to only those that have received and documented adequate training in laser safety. To allow access in the case of an emergency, such facilities shall have a key to the deadbolt lock stored in an emergency box located at the entryway. The keybox shall have a breakable window. *-unattended means that no one trained in the use of the laser is physically present to prevent untrained persons (e.g., custodians, repair personnel, etc.) from entering the laser-controlled area.

Laser Fabrication

A fabricated laser or laser system is one that is built from electronic and optical components as opposed to being obtained, already assembled, from a commercial laser manufacturer or distributor. Fabricated lasers may be lasers built at the University or obtained from research colleagues or other entities.

Fabricated lasers shall be constructed in a manner that complies with the engineering control requirements in Section XII. Lasers fabricated at the University shall comply with these requirements once they are operable and placed in use. During the period of non-compliance with the engineering control requirements, the Laser Supervisor shall develop and enforce alternate control measures that provide an equal measure of safety. Laser fabrication at a location outside the University shall be modified, as needed, to comply with the engineering control requirements prior to placing them in use.

Fabricated lasers shall also comply with laser labeling requirement described in the section, Warning Signs and Equipment Labels.

XIII. Administrative and Procedural Controls

Standard Operating Procedures (SOPs)

Written SOPs are required for operating, aligning, maintaining, and servicing Class 3B and Class 4 lasers or laser systems. The Laser Supervisor is responsible for the development of the SOPs and shall ensure that they are provided to the LSO. SOPs are reviewed by the LSO. The manufacturer's operating manual is not a substitute for an SOP.

SOPs shall include (See Appendix A for guidance on developing a SOP):

- Laser data
- Contact information
- Laser application
- Control measures
- Personal protective equipment
- Start up and shut down procedures
- Experimental procedures
- Emergency procedures
- Storage
- Non-beam hazards

The Laser Supervisor or his/her qualified designee shall provide and document training to operators in the SOPs (see the Personnel Training and Qualifications section).

SOPs shall be stored in BioRAFT under the Documents Tab within the lab that contains the laser. Operators shall know the location of the SOPs for the laser(s) they operate.

The Laser Supervisor is responsible for revising SOPs as conditions change and submitting revised SOPs to the LSO. The Laser Supervisor is responsible for ensuring that SOPs are reviewed on at least an annual basis.

Operators shall follow the established SOPs. Operators shall discuss any proposed change to an SOP with their Laser Supervisor.

Beam Control Measures

The following measures apply when working with Class 3B or Class 4 lasers. The use of the word "shall" indicates a mandatory measure; "should" indicates a recommended, but not mandatory measure.

- The beam height should not be positioned at the typical eye location of a person who is standing or seated. A beam control device (such as a beam block) shall be used to protect a standing or seated person if the beam must be at those heights.
- The laser should not be positioned so that the beam is directed toward entryways or windows. If this is not possible, a beam control device (such as a beam block) shall be used to protect those passing through the entryway or outside the window.
- Lasers shall be securely mounted to maintain the beam in a fixed position during operation.
- The beam shall be terminated at the end of its useful path with a beam block. The beam block for Class 4 beams shall be composed of fire resistant material.
- The laser operator shall remove or cover reflective personal jewelry and other objects when working near an open laser beam. This includes (but is not restricted to) rings, bracelets, watches, dangling necklaces, pens, belt buckles, etc.
- Beam blocks shall be positioned behind turning mirrors so the beam is blocked from leaving the perimeter of the optical table if it misses the mirror. Beam blocks are not required if there is another barrier that will serve the same function (e.g., a laser enclosure, panels affixed to the sides of the optical table, etc.). Beam blocks and barriers used with Class 4 lasers shall be constructed of fire-resistant materials.
- Beams and specular reflections shall be confined to the optical table. Diffuse reflections exceeding the MPE shall not extend past a plane extending vertically from the edges of the optical table (e.g., to a nearby second optical table). A physical barrier, such as a beam guide tube, shall be used to prevent accidental exposure.
- Unnecessary loose items (tools, meters, unused optical components, notebooks, pens, etc.) shall not be stored on the optical table or near the beam path.
- When feasible, laser operators should consider the use of optical cable for beam delivery as an alternate to open air beams.

Other Procedural Control Measures

The following measures apply when working with Class 3B or Class 4 lasers. The use of the word "shall" indicates a mandatory measure; "should" indicates a recommended, but not mandatory, measure.

- When a laser operator energizes a laser, he/she shall assume responsibility for controlling the laser operation in a manner which is safe for all those present in the laser-controlled area.
- The entryway to the laser-controlled area shall be closed when operating a laser.

- Operators shall alert others in the laser-controlled area prior to operating the laser. Operators shall inform those that enter the laser-controlled area when the laser is in operation.
- Whenever feasible, operators using visible and near-infrared lasers should consider turning all room lights ON to maximize constriction of the pupil and, thereby, reduce the probability of a beam entering the eye and focusing on the retina.
- Skin coverings, such as gloves, long sleeved shirts/lab coats, and face shields, should be used when manipulating or working near ultraviolet laser beams. Chronic UV exposure may have long term adverse health effects.

Control Measures During Alignment of Class 3B and Class 4 Lasers

More laser accidents occur during beam alignment than any other laser operation! Even a brief, unanticipated eye exposure to a Class 3B or Class 4 laser beam (or beam reflection) during alignment may result in permanent damage to the affected eye. Extreme care must be exercised when conducting beam alignments.

Although this section focuses on beam alignment, operators should recognize that other laser operations may present a hazard similar to alignments if the operations involve manual beam manipulation in close physical proximity to the laser beam. Examples are inserting a glass attenuator plate, a phosphor card, or reflective experimental sample into the beam path. For such operations, many of the techniques below are useful in minimizing the possibility of an injury.

Alignments shall be performed in such a manner that the primary beam, or a specular or diffuse reflection of the beam, does not expose the eye to a hazardous level of laser radiation. **Adherence to the following techniques is the single most important thing laser operators can do to prevent serious eye injuries to themselves and other in the laser area.**

- Follow the alignment SOPs developed by the Laser Supervisor. Obtain hands-on instruction in alignment procedures from your Laser Supervisor or his/her qualified designee.
- Exclude unnecessary personnel from the laser-controlled area during alignment.
- Be mentally prepared to do the work by being well rested, allocating enough time to align the beam safely, and eliminating visual and audible distractions.
- Whenever practical, use one or more of the following methods to reduce the intensity of the laser beam to be aligned to a safe level (i.e., blow the MPE) when performing Class 3B or Class 4 laser beam alignments:
    - Adjust laser settings to reduce the output intensity of the laser to as low a level as possible while still allowing alignment to take place.
    - Use a temporary beam attenuator over the beam aperture to reduce the intensity of the laser beam.
    - Perform the alignment using a low-powered visible beam laser (Class 2 or 2M, Class 3A or 3R) instead of the beam from a high power laser.
- When the methods described above cannot be used or when they do not fully reduce the intensity of the laser beam to a safe level (i.e., below the MPE), wear appropriate laser safety eyewear during the alignment. Use of special “alignment” eyewear may reduce unintended laser eye exposure to a safe level and still allow the beam visualization necessary to align a visible laser beam.
- Beam display devices (such as, image converter viewers or phosphor cards) may be useful for locating beams during alignment. USE CAUTION!! The reflections from phosphor cards in some circumstances may be hazardous.

- Use shutters or beam blocks to block high intensity beams at their source except when needed during the alignment process.
- Use beam blocks to block high intensity beams downstream of the optics being aligned.
- Use beam blocks or protective barriers when alignment beams could stray into other areas.
- Place beam blocks behind optics such as turning mirrors to terminate beams that may miss the mirrors during alignment.
- Locate and block all hazardous stray reflections before proceeding to the next optical component or section.
- Once alignment is complete, confirm that necessary blocks/barriers are in place before initiating laser experiments/measurements.
- Report any problems experience during an alignment to your Laser Supervisor.

Demonstrations Involving Lasers and Tours of Laser Facilities

The safety of participants during demonstrations involving lasers and tours of laser facilities at Rowan University is paramount. The Laser Supervisor and Laser Operator share the responsibility for the safety of the individuals involved and shall assure that the following requirements are met.

If the demonstration or tour involves operation of Class 3B or Class 4 lasers with open beam, then:

- The Laser Supervisor shall notify the LSO, the Chair of the Department and the Director of the Program. If minors are involved, the Laser Supervisor must also obtain written approval from the LSO in advance.
- The Laser Supervisor or Laser Operator shall advise participants or visitors of the hazards present in the laboratory or area involved in the demonstration or tour. Information regarding appropriate safety measures shall be provided.
- The Laser Operator shall minimize the laser hazard as much as practical by reducing laser power, increasing use of barriers, etc. Whenever possible, open beams exceeding the MPE should be avoided; consider mock set ups using Class 2 lasers.
- Terminate hazardous operations in the demonstration area or lab that are unrelated to the purpose of the demonstration or tour.
- All participants in the demonstration or tour must be provided, and don, the same level of eye protection that the Rowan University Laser Safety Manual requires for laser operators. This means that, in some cases, the number of participants must be limited to the number of pairs of appropriate laser safety eyewear that is available.
- The Laser Operator shall be continuously present during laser operations and shall monitor and supervise participants at all times. The Laser Operator shall position her/himself so she/he can immediately terminate the laser beam, if necessary.
- Demonstrations performed off campus or in an area, on or off campus, not designed as a laser facility requires the approval of the LSO.

XIV. Warning Signs and Equipment Labels

Illuminated Warning Signs

All illuminated warning signs that are activated when the laser is energized shall be located at the entryway(s) to all Class 4 laser-controlled areas that do not have non-defeatable entryway safety

controls. Exceptions may be requested in certain cases, such as facilities containing laser scanning microscopes, laser tweezers, and other similar laser-containing devices.

Printed Warning Signs

A warning sign is required to be posted at the entryway(s) to Class 3B and Class 4 laser-controlled areas and shall comply with the design specified in the ANSI Z136.1 Standard. Note: although not required, area warning signs for classes other than 3B and 4 use the signal word "CAUTION" in black letters on a yellow background.

Laser controlled area warning signs shall be of the three panel format unless additional panels are needed for a second language.

Three panel requirements:

- Top panel (signal word panel) shall contain:
    - Safety alert symbol
        - Equilateral triangle surrounding an exclamation mark
    - Signal word
        - Class 4 with high output power (example: multi-kilowatt) or pulsed energies with exposed beams – "DANGER" in white letters on a red background
        - Class 4 without high output power or pulsed energies – "WARNING" in black letters on an orange background
        - Class 3B – "WARNING" in black letters on an orange background
        - Class 3R whose output exceeds the applicable MPE – "WARNING" in black letters on an orange background
- The two other panels (message panel and safety symbol panel) shall contain:
    - Laser radiation hazard safety symbol
        - Equilateral triangle surrounding a sunburst pattern consisting of two sets of radical spokes of different lengths and one spoke, radiating from a common center
    - Message panel
        - The hazard class of the laser controlled area
        - Special precautionary instructions or protective actions that may be applicable. For example:
            - Laser Eye Protection Required
            - Invisible Laser Radiation
            - Knock Before Entering
            - Do Not Enter When Light is Illuminated
            - Restricted Area, Authorized Personnel Only
        - The highest hazard class of the laser or lasers within the laser controlled area. Additional information such as type of laser, pulse duration (as appropriate), and maximum output may be included.
        - The optical density of laser eye protection to be worn within the area
        - The name and contact information of the LSO

NOTE: When a temporary laser controlled area is created, the area outside the temporary area remains Class 1 while the area within is either Class 3B or Class 4. An appropriate warning sign is required within the temporary laser controlled area.

Examples of printable signs:

Equipment Labels

All lasers and laser systems shall have a warning conspicuously affixed to the protective housing that conforms to the ANSI Z136.1 Standard. The label shall incorporate the sunburst symbol. The label shall indicate:

- The class of the laser or laser system
- The emitted wavelength, pulse duration (if appropriate), and maximum output power
- A precautionary statement for users such as:
    - For Class 2 lasers and laser systems – "Laser Radiation – Do Not Stare into Beam"
    - For Class 2M lasers or laser systems – "Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments"
    - For Class 3R and 3B laser and laser systems – "Laser Radiation – Avoid Direct Exposure to Beam"
    - For Class 4 lasers and laser systems – "Laser Radiation – Avoid Eye Exposure to Direct or Scattered Radiation; Avoid Skin Exposure to Direct Radiation"

Examples of equipment labeling:

XV. Personal Protective Equipment

Enclosure of the laser equipment or beam path is the preferred method of control since the enclosure will isolate or minimize the hazard. This may not always be feasible so engineering, administrative, and

procedural controls are established. Laser safety eyewear and skin protective covering are worn to protect eyes and skin in situations when, for whatever reason, such controls fail to prevent a hazardous laser exposure.

Eyewear

Most laser eye injuries have occurred when (1) a person was not wearing laser eyewear or (2) a person was wearing incorrect laser eyewear. **The risk of a laser eye injury is greatly reduced when proper laser eyewear is worn.**

When operating a Class 3B laser or laser system, all those present in the laser-controlled area shall wear appropriate laser safety eyewear when:

- a laser beam alignment is being performed (unless laser intensity is sufficiently reduced using the techniques in this manual section XIII. Control Measures During Alignments of Class 3B and Class 4 Lasers), or
- items are being inserted into the beam which may result in specular reflections, or
- laser operation results in unconfined specular reflections, or
- it is required by the SOPs established for use of the laser by the Laser Supervisor.

When operating a Class 4 laser or laser system all those present in the laser-controlled area shall wear appropriate laser safety eyewear when –

- the laser beam path is not completely confined by enclosures, tubes, or barriers that would prevent personnel exposure to stray beams or reflections at levels exceeding the MPE for the eye, or
- a laser beam alignment is being performed (unless laser intensity is sufficiently reduced using the techniques in this manual section XIII. Control Measures During Alignments of Class 3B and Class 4 Lasers), or
- items of any kind are being inserted into the beam, or
- laser operation results in unconfined reflections exceeding the MPE for the eye, or
- it is required by the SOPs established for use of the laser by the Laser Supervisor.

An operator shall not intentionally look directly into a laser beam even if he/she is wearing laser safety eyewear. The Laser Supervisor is responsible for ensuring 1) that appropriate and properly-fitting laser safety eyewear is available and 2) that workers know when eyewear must be worn.

Individuals are advised to consult with the LSO prior to purchasing laser safety eyewear to confirm that the eyewear to be purchased will offer the desired protection. Eyewear features to be considered when purchasing eyewear include: filters protect against wavelength in use, optical density (OD) is sufficient to reduce laser radiation to safe levels, frames fit face of operator, filter is tested to withstand exposure to ultrafast pulsed laser radiation (if such radiation is present).

Properly-fitting oversized laser safety spectacles or laser safety goggles shall be available for individuals who wear prescription glasses. The Laser Supervisor shall provide prescription laser safety eyewear for such individuals if oversized eyewear does not fit properly.

Prior to putting on eyewear, individuals shall check the wavelength and optical density (OD) markings on the eyewear frame or lens to confirm that the eyewear offers protection for the laser beam present and that the OD is high enough to provide an adequate level of protection. The LSO can assist individuals to calculate the OD requirement. In multi-laser environments where there may be many different pairs of

laser safety eyewear, it may be useful to use a color-coding or other marking system to assist in proper eyewear selection.

The filters used in some laser safety eyewear may exhibit non-linear effects such as saturable absorption when exposed to laser beams of ultrashort (e.g. femtosecond) pulse durations. Those working with such lasers should confirm with the manufacturer of their laser eyewear that it has been tested against, and been proven to be effective for, ultrashort pulsed lasers.

Laser operators should use caution when using phosphor cards which reflect radiation at a different wavelength than the incident laser beam radiation. Use laser safety eyewear that also offers protection at the reflected wavelength if the intensity of the reflection exceeds the MPE for the eye.

Eyewear should be periodically cleaned and inspected. Follow manufacturers' instructions when cleaning laser safety eyewear. Eyewear with lenses that are pitted, crazed, cracked, discolored, or otherwise damaged shall be either tested for acceptability or discarded and replaced.

Skin Protection

All laser users shall wear PPE to protect their skin whenever there is a risk of exposure to a hazardous beam. Closed toe shoes, long pants, lab coats, appropriate gloves, and eye protection are always required when working with open beams. In addition, there are other forms of PPE that may be required while working with certain lasers. Flame resistant lab coats, face shields, and hearing protection may be necessary, depending on the laser/laser system and activity performed.

The following chart can be referred to when choosing appropriate PPE:

Personal Protective Equipment (PPE) Guide – Laser Hazards

Activity	Y/N	Potential Hazard	Applicable PPE
Open Beam Hazards			
Performing alignment, trouble-shooting or maintenance that requires working with an open beam and/or defeating the interlock(s) on any Class 3 or Class 4.	If yes	Eye damage.	Appropriately shaded goggles/glasses with optical density based on individual beam parameters.
Viewing a Class 3R laser beam with magnifying optics (including eyeglasses).	If yes	Eye damage.	Appropriately shaded goggles/glasses with optical density based on individual beam parameters
Working with a Class 3B laser open beam system with the potential for producing direct or specular reflections.	If yes	Eye damage, skin damage.	Appropriately shaded goggles/glasses with optical density based on individual beam parameters, appropriate skin protection.
Working with a Class 4 laser open beam system with the potential for producing direct, specular, or diffuse reflections.	If yes	Eye damage, skin damage.	Appropriately shaded goggles/glasses with optical density based on individual beam parameters, appropriate skin protection
Non-Beam Hazards			
Handling dye laser materials, such as powdered dyes, chemicals, and solvents.	If yes	Chemical hazards,	Gloves, safety glasses, lab coat (flame-resistant if applicable) or coveralls.

		explosion, fire.	
Maintaining and repairing power sources for large Class 3B and Class 4 laser systems.	If yes	Electrocution, explosion, fire.	Electrical isolation mat, flame-resistant lab coat or coveralls.

Laser supervisors are advised to consult with the LSO when choosing the appropriate PPE for their SOPs.

XVI. Non-Beam Hazards

Lasers operators should be aware that there exist other hazards associated with laser use that are not related to the laser beam. In some cases the potential injury associated with non-beam hazards exceeds that posed by the laser beam. This section identifies non-beam hazards and provides safety guidance but does not attempt to fully instruct the laser operator in safe practices. Operators may be required to obtain additional training as dictated by other applicable regulations or University policies.

Electrical Hazards

Many lasers utilize high-voltage power supplies and/or capacitors that may store lethal amounts of electrical energy. **Most of the fatalities that have occurred during laser use are due to contact with laser energized conductors.** Electrical shock can occur during laser installation, maintenance, modification, and service where protective covers are removed to allow access to active components as required for those activities.

Electrical safety practices include:

- Obtaining the permission of the Laser Supervisor before attempting service or repairs of laser high voltage electrical components.
- Making sure another lab staff member (a "buddy") is present while working on electrical components.
- Being well trained in the potential electrical hazards and methods to prevent injury and death.
- Ensuring that fabricated (homemade) lasers have no exposed energized electrical components that a laser operator may accidentally touch.
- Replacing illegible or missing electrical hazard warning labels.
- Following the measures below when protective housings or covers are removed to access exposed energized components:
    - Adhere to Lock Out/Tag Out (LOTO) procedures to prevent unexpected re-energizing of equipment.
        - Contact EHS for more information on LOTO.
    - Enclose high voltage sources and terminals whenever possible.
    - Turn off power and ground all high voltage points before working on power supplies.
    - Check that each capacitor is discharged and grounded prior to working near the capacitor.
    - Do not wear rings, watches or other jewelry when working with or near energized equipment.

Laser-Generated Air Contaminants (LGAC)

Air contaminants may be generated when Class 4 and some Class 3B laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend on the target material, cover gas and beam irradiance. Laser-irradiated materials such as plastics, composites, metals and tissues may release carcinogenic, toxic and noxious air contaminants. Lasers emitting ultra-violet radiation may generate ozone as the beam interacts with air molecules.

Concentrations of LGAC must be maintained below the exposure limits specified by OSHA, NIOSH or ACGIH. There are three major control measures to reduce the concentration of LGAC to acceptable levels:

- Use enclosing exhaust hoods or local exhaust ventilation to remove the LGAC at the point of generation and vent to the building exterior.
- Isolate the process by using physical barriers.
- Wear respiratory protection when engineering controls are not feasible. (Note: Respirators may not be used without first contacting EHS for fit testing.)

EHS can assist laser operators determine if their laser operation generates harmful levels of LGAC and recommend the most appropriate control measures.

Collateral and Plasma Radiation

Collateral radiation (radiation not associated with the primary laser beam) may be produced by system components such as power supplies, discharge lamps and plasma tubes. Radiation may be in the form of X-rays, UV, visible, IR, microwave and radiofrequency (RF). When high power pulsed laser beams (peak irradiance of 1012 W/cm2 or greater) are focused on a target, plasma is generated that may also emit collateral radiation. Contact the LSO for evaluation of these hazards. The Radiation Safety Officer can help evaluate hazards associated with ionizing radiation.

Fire Hazards

Class 4 laser beams can ignite flammable solvents, gases and combustible materials. Fire safety practices include:

- Terminating laser beams with non-combustible materials.
- Storing only necessary materials in the vicinity of the laser beam path.
- Storing flammable and combustible solvents and materials properly and away from the laser beam.
- In the event of a fire:
    - dial 856-256-4911 or 9-1-1
    - Be aware of the location of the closest fire alarm pull station and fire extinguisher.

Compressed Gases

There exist certain risks associated with the use of high pressure gas cylinders. Safe practices when working with such cylinders include:

- Securely strapping or chaining cylinders to a wall, heavy bench, etc. High pressure compressed gas cylinders can become “missiles” in the lab should the cylinder valve shear off as the cylinder falls.
- Refraining from storing cylinders near doorways and emergency exits.
- Storing cylinders containing hazardous gases (e.g. chlorine, fluorine, hydrogen chloride and hydrogen fluoride) in ventilated gas cabinets or enclosures.

- Using tubing and connectors that are compatible with the gas being delivered to the laser system.

Laser Dyes, Solvents, and Chemicals

Laser dyes are complex fluorescent organic compounds that are dissolved in a solvent to form a lasing medium. Some dyes are highly toxic or carcinogenic. Most solvents suitable for dye solutions are flammable and toxic by inhalation and/or skin absorption. Hazardous chemicals are sometimes used to clean optics and for other laser-related activities.

The use of hazardous chemicals generates hazardous waste which must be managed correctly to protect workers and the environment and to prevent regulatory non-compliance and potential costly fines.

Safe use and management of chemicals in laser facilities include:

- Obtaining chemical hygiene and chemical waste training each year from The CITI Program.
- Storing in BioRAFT an accurate Chemical Inventory which will provide appropriate Safety Data Sheets.
- Preparing and handling dye solutions in a fume hood.
- Wearing a lab coat, safety glasses and gloves. EHS can be contacted for assistance with glove selection.
- Installing spill pans under dye pumps and reservoirs.
- Knowing and following the correct disposal method for chemical wastes. Contact EHS with any questions on correct disposal.
- Knowing the location of the closest eyewash and safety shower.
- Reporting chemical spills and personal chemical exposures immediately to Public Safety (856-256-4911) and EHS (856-256-5105 or ehs@rowan.edu). Also, fill out an Incident Report Form.

Laser Optical Tables

Laser optical tables often weigh in excess of 3000 pounds and the legs of the table are often unattached to the table top. Forcibly pushing against the table may cause the table to topple resulting in considerable table and facility damage and possibly serious personal injuries as well. Lifting of the tabletop may result in the falling of heavy unsupported leg supports also potentially injuring individuals. When planning the relocation of laser optical tables, individuals should always first seek approval of the Laser Supervisor. Proper lifting and moving equipment should be used. Refer to manufacturer's installation recommendations for information on handling equipment.

XVII. Laser Safety Assessments and Audits

Pre-Construction Assessment

Prior to construction or renovation of a laser facility containing Class 3B and/or Class 4 lasers, the Laser Supervisor should consult with the LSO to discuss the proposed laser operation and to determine the facility requirements necessary to comply with the Rowan University Laser Safety Program.

Pre-Operational Assessment

Prior to placing a new Class 3B or Class 4 laser into routine operation, the Laser Supervisor (or his/her qualified designee) shall inform the LSO and schedule a pre-operational laser safety assessment to determine whether all the requirements of the Rowan University Laser Safety Program have been met. The LSO shall promptly communicate to the Laser Supervisor, in writing, any changes that must be made to the laser facility or operation before routine laser activities can begin.

Safety Audits

Laser safety staff shall conduct safety audits of each laser facility annually. The audit is designed to determine whether the facility is successfully meeting the requirements of the laser safety program as defined in the Rowan University Laser Safety Manual. A report of the findings of the audit shall be located in the inspection module within BioRAFT. The Laser Supervisor is expected to correct any deficiencies within the time frame noted in the audit report and provide documentation within the audit generated. The LSO is committed to assisting laser personnel, when they request help, to achieve compliance.

A copy of the Laser Safety Audit can be found in BioRAFT.

XVIII. Imminent Laser Hazards

The LSO is empowered by Rowan University to order the immediate termination of any laser-related activity that he/she believes to be a serious and imminent health and/or safety hazard. An example would be the presence of a Class 4 laser specular reflection through a window into a public area.

When the LSO terminates an operation, he/she shall attempt to immediately inform the Laser Supervisor in-person of the reason for termination. The LSO shall also inform the Laser Supervisor, in writing, within 24 hours.

The LSO shall promptly report the circumstances of the termination to members of the Laser Safety Committee (LSC) and within 5 working days the Committee shall meet to consider whether to uphold the LSO's decision to terminate the operation. The affected Laser Supervisor shall be invited to attend the meeting to provide information for the Committee's consideration. In lieu of attendance, the Laser Supervisor may provide information in writing.

The Laser Supervisor may resume the terminated laser operation once he/she is provided with written notice from the LSO that the condition of concern has been satisfactorily rectified. The LSO shall also provide members of the LSC with a copy of this notice.

XIX. Servicing of Lasers

When on-site servicing or repair of lasers or laser systems is conducted by non-university personnel (e.g. laser manufacturer representative), such personnel are expected to perform their activities in compliance with the requirements of ANSI Z136.1. Depending on the type of service and the laser, this may include the establishment of a temporary laser-controlled area, the posting of a "NOTICE" warning sign and/or the erection of temporary barriers.

The Laser Supervisor shall be present whenever lasers are serviced or repaired.

The Laser Supervisor or his/her qualified designee shall confirm that, after servicing, all engineering controls that may have been bypassed or disconnected (e.g. protective housing interlock) have been returned to normal operation.

Example of “NOTICE” sign:

XX. Transfer and Disposal of Lasers

The Laser Supervisor shall inform the LSO when a laser has been transferred to another Rowan University Laser Supervisor or to an individual or entity off-campus.

When a Laser Supervisor terminates an affiliation with the University and lasers formerly under his/her supervision remain on campus, the departmental Chair or other pertinent authority shall promptly transfer control of those lasers to a Laser Supervisor who will take steps to prevent the unauthorized use until the lasers are permanently re-assigned or disposed.

Prior to the disposal of an unwanted laser, the Laser Supervisor shall ensure that the LSO has been informed. The LSO will help facilitate proper disposal of the laser.

APPENDIX A - Standard Operating Procedures

Class 3b or 4 Lasers

I. Scope

a. This document provides safety guidance for laser operators and spectators within the laser controlled area.
b. Procedures reflected herein are in accordance with applicable regulation parameters impacting the operation of the laser laboratory.
c. This document must be paired with a completed Registration Form.

II. Responsibilities

a. _____ (Laser Supervisor) is responsible for the safety of this laboratory operation in conformance with this Standard Operating Procedure (SOP). In the absence of _____, _____ shall assume these responsibilities.
b. Only trained Laser Operators listed on the SOP, and maintenance personnel from manufacturers, may energize the laser or laser system

III. Personal Protective Equipment

a. List all required PPE_____

IV. Beam Alignments

a. List personnel permitted to perform alignment
_____

A. Secure all entrances into the laser area.

B. Locate all equipment and materials needed prior starting alignment.

C. Use laser protective eyewear with proper OD and wavelength for alignment. Use skin covers (labcoat, gloves, and UV face shield) to protect users from UV laser beam scatter.

D. Intrabeam viewing must always be avoided. Whenever possible use a low power alignment laser (class 2 or 3a), if none is available, use the lowest beam power available.

E. If there are others in the room make sure they are aware of the alignment in progress and are wearing all required PPE.

F. Keep optical table(s) clear of objects which may cause unwanted reflections. Close laser shutter if entering the beam path is necessary.

G. Insure all beam blocks, enclosures, and beam barriers are replaced when the alignment is complete.

V. Laser Controlled Areas

a. The laser hazards associated with this laboratory have been analyzed, and the controls specified for these hazards will reduce the risk to employees and the environment to acceptable levels.

   A. All entries into the laser controlled area must be posted with the proper warning sign.

      1. Do not rely on closed doors as adequate security. Use key locks or activated interlocks on doorways into the laser area.
      2. When the laser is energized, all entrances into the laser controlled area must be secured to prevent unauthorized access. If there is a "laser on" indicator it must be used.

   B. This laser safety plan/standard operating procedures shall be stored near the laser or laser system. A copy shall also be uploaded into BioRAFT.

   C. The laser beam shall be contained in the immediate area using non-reflective and non-flammable beam blocks and/or partitions.

   D. It is the discretion of the laser operator to allow or deny entry into the laser area while the laser is energized.

   E. If there are windows in the laser area, they must be blocked with opaque material that is non-reflective and non-flammable.

   F. If possible position the laser so it is not at standing or sitting eye level.

   G. If the laser/laser system is key operated; do not leave the key in the laser when the experiment is finished.

VI. Non-beam Hazards

a. Laser dyes should be handled with care and proper protective equipment must be used (labcoat, safety glasses and gloves). If dyes are to be mixed, it must be done in a well ventilated fume hood. Dye pumps and storage must be in secondary containers.
b. When working with high voltage, the "buddy" system should always be used. Trained CPR laboratory personnel are highly recommended.
c. Compressed gas cylinders must be secured properly and staff should be trained with the proper hazards and handling of the various gases.
d. Attention should be given to protect against fire, especially with a class 4 laser/laser system. Flammable solvents may be used in laser dyes or to clean components. Fire extinguishers (charged properly) should be kept in the laser area and staff should know how to use them.
e. Good general housekeeping can greatly improve safety from physical hazards. Cables should be secured to keep trip hazards to a minimum.

VII. Laser Maintenance

a. Only properly trained PI's and approved personnel may service laser systems. List these people:_____

b. All enclosures, interlocks, and safety devices must be replaced and verified operational prior to returning the laser to regular use.

VIII. Training

a. Individuals who use these equipment are required to take the Rowan University Environmental Health and Safety (EHS) Laser Safety Training and shall be trained to recognize the intrinsic hazards, are aware of basic safety information that relates to their job duties, and know the safe operating requirement for this activity.
b. All operating personnel shall read and understand this Standard Operating Procedure (SOP) and all applicable references stated in this SOP. Signatures of all authorized operators are required at the end of this SOP.

IX. Emergency Procedures

a. In an event of a laser emergency, refer to this manual which should be posted in the laser controlled area.
b. In an event of fire or other emergency, evacuate and dial 9-1-1.

XI. Additional Safety Measures

_____

_____

_____

Standard Operating Procedure Signature Form

Laser Supervisor shall verify and document that personnel working under the direction of this SOP understand and agree to comply with the safety plan before beginning work.

All individuals listed below affirm that they have read and agreed to comply with the attached SOP.

Name	Signature	Date

APPENDIX B - Laser Device Registration Form

(required for class 3b and 4 lasers)

Principal Investigator:_____ Phone Number:_____

Department:_____ Building and Room Number:_____

Laser Supervisor:_____ Phone Number:_____

Manufacturer:_____ Model:_____ Serial Number:_____

Type of Laser (i.e.: Argon, HeNe):_____ Wavelength (nm):_____

Laser Classification: □Class 1 □Class 1M □Class 2 □Class 2M □Class 3R (3a) □Class 3b □Class 4

Beam diameter at aperture:_____ Beam divergence (in mrad):_____

Pulse or Continuous Wave:

□ Pulse	**□ Continuous Wave**
Pulse Duration (ns):	**Maximum power (watts):**
Pulse-repetition frequency (pulses per second):	**Avg. operating power (watts):**
Maximum energy (J/cm2):	
Avg. operating energy (J):	

Fiber Optic: Single Mode or Multi-mode:_____ Mode field:_____

Laser Application:

Please upload the completed document into BioRAFT under the Documents Tab.

APPENDIX C - Acronyms

TABLE OF SELECT ACRONYMS USED IN THIS DOCUMENT

ANSI	**American National Standard Institute**
LSO	**Laser Safety Officer**
LSC	**Laser Safety Committee**
MPE	**Maximum Permissible Exposure**
NHZ	**Nominal Hazard Zone**
SOP	**Standard Operating Procedure**
EHS	**Environmental Health and Safety**
LGAC	**Laser-Generated Air Contaminants**
CW	**Continuous Wave**
UV	**Ultraviolet**
IR	**Infrared**
LOTO	**Lockout Tagout**