BINGHAMTON UNIVERSITY | DIVISION OF OPERATIONS

Binghamton University Laboratory Laser Safety Program

2026

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1. Program Purpose and Scope

This program establishes requirements to protect students and employees from the potential hazards associated with laser devices and systems used to conduct laboratory, educational or research activities at Binghamton University. This program delineates the responsibilities for students and employees using lasers, describes the methods used to audit lasers, identifies laser hazard control strategies, describes required laser medical monitoring, and outlines the training requirements for this program.

This program incorporates the regulations outlined in the federal Food and Drug Administration, Center for Devices of Radiological Health (20 CFR Part 1040 and 21 CFR Part 1040), that requires labeling and engineering controls for lasers manufactured after 1976. This program also incorporates elements of the American National Standards Institute standard (ANSI Z136.1-2014) for the safe use of lasers, which establishes the minimum requirements for the control of laser hazards based upon the actual conditions of use.

2. Laser Safety Program Personnel and Responsibilities

In order to implement an effective laser safety program that minimizes potential exposures and prevents accidents, the Binghamton University Laboratory Laser Safety Program requires participation by all laser users, including students and employees. The overall responsibility for implementing and complying with this program is shared between the Authorized Laser Supervisors, the Authorized Laser Operators, and the Laser Safety Officer. The following defines the participants and their responsibilities:

a. Authorized Laser Supervisor

A faculty or staff member that has been approved by the Laser Safety Officer to operate specific laser devices or systems.

Responsibilities:

- Ensure compliance with all elements of the Laser Safety Program
- Provide adequate supervision and training to their operators of approved laser devices or systems
- Initiate corrective actions to address potential hazards associated with equipment, experiments, and procedures proposed by their authorized laser operators
- Request hazards reassessments from the Laser Safety Officer prior to modifications or procedural changes proposed for approved laser devices or systems
- Attend all required training sessions, ensure authorized laser operators attend all required training sessions, and implement elements of the training program in their laser operations,

- Implement appropriate engineering controls, write and enforce laser standard operating procedures as directed by the Laser Safety Officer,
- Ensure appropriate personal protective equipment is available and worn when laser systems and devices are operating,
- Report all laser accidents and incidents immediately to the Laser Safety Officer for appropriate investigation, and
- Ensure all laser injuries are evaluated and treated as appropriate.
- Submit names of individuals authorized to work with the Laser to the LSO to maintain a roster

b. Authorized Laser Operator

A student, faculty, or staff member that operates laser devices or systems controlled by an authorized laser supervisor.

Responsibilities

- Comply with all elements of the BU Laboratory Laser Safety Program and Guide,
- Attend all required training sessions specified in the BU Laboratory Laser Guide and implement training elements in their laser operations,
- Request prior approval and review of proposed experiments by their authorized laser supervisor to identify potential hazards and recommend corrective actions,
- Immediately report any equipment malfunction or potentially hazardous condition to the authorized laser supervisor for corrective action.
- Wear appropriate personal protective equipment for the lasers that they operate as directed by the authorized laser supervisor or Laser Safety Officer.
- Seek medical evaluation and treatment for all laser injuries.

c. Laser Safety Officer

The LSO is an individual designated by the Office of Environmental Health and Safety to administer and manage the Laser Safety Program. The LSO shall have the authority and responsibility to monitor and enforce the control of laser hazards, to effect training of individuals who are involved with the use of laser technology and applications, and to enforce the knowledgeable evaluation and control of laser hazards.

Responsibilities

- Audit all laser devices and systems operated at the University to ensure compliance with appropriate government regulations and professional standards.
- Provide laser safety training to all University employees that work with class 3B and 4 laser systems.
- Provide technical expertise and recommendations to authorized laser supervisors and authorized laser operators to protect employee health and safety, and to

maintain compliance with applicable regulatory requirements and recognized professional standards.

- Maintain laser safety audit documentation and report audit results to authorized laser supervisors for corrective action.
- Develop, implement, audit, and enforce the BU Laboratory Laser Safety Program to ensure compliance with applicable regulations and recognized professional standards.

d. High Powered Lasers Definition and Inventory

Lasers and laser systems are classified by their potential hazard in ANSI Z136.1 by using a scheme of class 1-4. The scheme is based on the laser beam's ability to cause biological damage to the eye and skin, and pose a fire hazard.

EHS maintains an inventory of High-Powered Lasers and is available upon request by calling 607-777-2211 or emailing ehs@binghamton.edu

i. Laser Fundamentals

Laser light differs from normal light in that it is monochromatic, directional, and coherent. These properties can cause the light to be extremely energetic and focused, causing physical and biological damage. The levels of hazard are organized into 4 classes that are described below.

ii. Laser Classes

Laser are classified according to the level of laser radiation that is accessible during normal operation, not maintenance or service. The ANSI laser classes are described below:

Class 1 Lasers

Class 1 Lasers are generally not capable of causing harm. Low power lasers with an open beam path or high power, enclosed beam lasers may be designated as a Class 1 laser system by the LSO. This classification is based on normal use, not maintenance or special service. A class 4 laser must have interlocks, laser shielding viewing windows of proper filtering and be fully enclosed/incapable of hurting anyone to qualify as a Class 1 laser. An example of a class 1 laser is a simple laser pointer used for presentations

Class 2 Lasers

Class 2 Lasers have an output power below 1mW and are considered to be not capable of causing harm unless abused.

Class 3b and 3r Lasers

Class 3B laser control area must be posted with a "Warning" sign and accessed by trained personnel only. The beam path must be well defined, meaning it must be well below or well above eye level. All diffuse and specular reflections must be controlled. Eyewear must be worn if beam is open.

Class 4 Lasers

Class 4 laser control area must have the same characteristics as Class 3b, with the addition of an emergency stop button and rapid egress under emergency conditions. For an open beam path, entryway controls must be used.

Class 4 Entryway Controls (ANSI 4.4.2.10.3) may be any combination of the following, with the goal in mind that no user, authorized or otherwise, may enter a laser control area and unknowingly subject themselves to a hazardous exposure.

- Non-defeatable: Doorway interlock that shuts down laser when door is opened. Not popular on card access control doors
- Defeatable entryway controls: used when access is controllable with card access, but is on a timer. Users may enter the room and have 30s to close the door before the laser interlock is activated and shuts down the laser. A barrier and appropriate eyewear must be at the door for this type of control.
- Procedural Entryway controls may be best to avoid door interlocks, especially in laser control areas with card access. All personnel with access must be trained, there must be a barrier and eyewear at the door, and a visible or audible signal at the door indicating the laser is on.

e. Beam Characteristics

The output beam has 3 important characteristics, listed below:

- **Spectral:** What is the wavelength? Retinal Hazard Region is 400-1400nm
- **Temporal**: How is laser presented in time? Continuous or pulsed?
- **Spatial:** How the beam propagates in distance and how is energy distributed across the beam. Example a high divergence beam

Continuous wave lasers MPE is presented in W/cm^2

Pulsed Lasers MPE is presented in J/cm^2

f. Eye Anatomy and Laser Injuries

i. Anatomy of the Eye

- **Cornea**- The clear front window of the eye which transmits and focuses (i.e., sharpness or clarity) light into the eye. Corrective laser surgery reshapes the cornea, changing the focus.
- **Fovea**- The center of the macula which provides the sharp vision.
- **Iris**- The colored part of the eye which helps regulate the amount of light entering the eye. When there is bright light, the iris closes the pupil to let in less light. And when there is low light, the iris opens up the pupil to let in more light.
- **Lens**- Focuses light rays onto the retina. The lens is transparent, and can be replaced if necessary. Our lens deteriorates as we age, resulting in the need for

reading glasses. Intraocular lenses are used to replace lenses clouded by cataracts.
- **Macula**- The area in the retina that contains special light-sensitive cells. In the macula these light-sensitive cells allow us to see fine details clearly in the center of our visual field. The deterioration of the macula is a common condition as we get older (age related macular degeneration or ARMD).
- **Optic Nerve-** A bundle of more than a million nerve fibers carrying visual messages from the retina to the brain. (In order to see, we must have light and our eyes must be connected to the brain.) Your brain actually controls what you see, since it combines images. The retina sees images upside down but the brain turns images right side up. This reversal of the images that we see is much like a mirror in a camera. Glaucoma is one of the most common eye conditions related to optic nerve damage.
- **Pupil-** The dark center opening in the middle of the iris. The pupil changes size to adjust for the amount of light available (smaller for bright light and larger for low light). This opening and closing of light into the eye is much like the aperture in most 35 mm cameras which lets in more or less light depending upon the conditions.
- **Retina**- The nerve layer lining the back of the eye. The retina senses light and creates electrical impulses that are sent through the optic nerve to the brain.
- **Sclera**- The white outer coat of the eye, surrounding the iris.
- **Vitreous Humor**- The, clear, gelatinous substance filling the central cavity of the eye.

ii. Type of Injury

Thermal burn is caused by elevated temperatures after absorption of laser energy and can occur in both skin and eyes at all wavelength. It is also the dominant injury for CW and long pulse lasers. Deeper penetration can occur at 1micron wavelength in lower layers of skin and may not show any surface level burn. A retinal burn, a type of thermal burn, is very common and can be sustained in a short amount of time.

Retinal Explosion (Micro-cavitation)- explosive effect when dealing with short pulses (< 5us for visible, <13us for NIR). Usually results in severe loss of vision. Basically a steam explosion from boiling water.

Photochemical Injuries are caused by chemical reactions in tissue after absorption of high energy photons. Can occur in both eyes and skin but only with wavelengths less than 600nm. This is the dominant effect for blue and UV wavelengths for exposures greater than 10s. Photochemical skin injuries can be similar to sunburn from scattered UV. Possibility of skin cancer from long term UV exposure.

3. Laser Hazards

a. Beam Hazards

Laser beams are capable of causing personal injury to the eye and/or skin as a result of direct or indirect contact with the laser beam. The following laser safety controls, listed in order from the most effective to less effective, are used to control beam hazards.

i. Open Beam Control Measures

Any time there is an exposed 3B or 4 beam, these control measure musts be followed:

- Laser Control Area: This is the lab or room area defined by the LSO
- Laser Eye Protection
- Beam Control
- Administrative and Beam Controls
- Education and Training

ii. Non-Beam Hazards

Non-beam hazards are capable of causing personal injury through contact with laser components or with materials used to support laser experiments and equipment. Some examples of non-beam hazards include electric shock, chemical contact and/or inhalation of laser gases or dyes, air contaminants generated by beam-target interactions, and fire.

Non-beam hazard controls are achieved by following existing university programs such as Lockout/Tagout (for electrical energy), and by modifying the BU Chemical Hygiene Plan to provide standard operating procedures to minimize chemical exposure issues associated with the laser. Specific non-beam hazards are identified during the initial laser safety audit, and recommended control measures are provided in the initial audit report to address the conditions of use in each lab. A detailed description of specific non-beam hazards and recommended control measures are contained in the BU Laboratory Laser Safety Guide.

b. Control Measures

Authorized laser supervisors shall provide and implement control measures to minimize the potential hazards associated with laser devices and systems. In some cases, more than one control measure may be specified. In such cases, more than one control measure which accomplishes the same purpose *shall not* be required. Specific control measures in the ANSI standard may be replaced by the following measures that provide equivalent protection, as outlined in section 4.2 of the ANSI standard.

4. Engineering controls

Engineering controls are devices used to prevent or minimize beam exposures below the maximum permissible exposure limit. Typically, these controls are incorporated in both the laser and in the lab. Laser engineering controls consist of protective housings, interlocks, beam shutters, activation switches, and an emergency shut-off. The engineering controls required for a particular laser depends upon the assigned hazard class, and are established by the Food and Drug Administration as 20 CFR Part 1040 and 21 CFR Part 1040.

Laboratory engineering controls consist of devices, interlocks, and barriers installed to protect spectators or other authorized lab personnel from exposure to laser radiation above the maximum permissible exposure limit. Typically, these engineering controls are only required for open beam class 3b or 4 laser systems, but they may be required when protective housings or enclosures on embedded laser devices are opened for service or repair work.

5. Administrative Controls

Administrative controls consist of warning labels, signs, training, access restrictions, and work practices that inform laser operators of potential hazards associated with laser devices and systems. Administrative controls supplement engineering controls and personal protective equipment. The administrative controls required for a particular laser device or system depends upon the hazard classification as well as the intended use of the laser. If standard operating procedures (SOP's) are required as an administrative control, the SOP must be written by the laser users and approved by the LSO.

6. Personal Protective Equipment

a. Laser Eyewear

Laser safety glasses and skin covering provide supplemental protection to laser operators when used in conjunction with engineering and administrative controls. However, for protective equipment to be effective, it must be properly selected to protect users from beam hazards, periodically inspected for damage that compromises its effectiveness, and worn by laser operators.

All laser eye protection is assigned an optical density (OD) value that refers to the attenuation provided at a specific wavelength or spectral range. Based upon the beam characteristics (diameter, output power, pulse width, frequency) and maximum permissible exposure value, an appropriate optical density is selected for the wavelength used. The OD at each wavelength MUST be printed on the safety glasses somewhere, usually on the lens itself or frame. It cannot be on a separate manual or in the case. There are several lens materials, polycarbonate plastic and glass are the two most common. Glass lenses are great for allowing visible light in.

Skin protection is required to minimize ultraviolet radiation exposure, which lowers the threshold for biological effects and may cause photo dermatitis in conjunction with certain medications. The Laser Safety Officer shall assess and recommend appropriate eye or skin protection for each laser, and the authorized laser supervisor shall provide and ensure their operators wear this equipment whenever the laser is on.

b. Protective Clothing

When there is a possibility of exposure to laser radiation greater than the MPE for skin, users are required to use protective gloves, clothing, and shields. Skin protection can best be achieved through engineering controls. Minimize exposure to UV radiation by using beam shields and clothing (opaque gloves, tightly woven fabrics, laboratory jacket or coat) which attenuate the radiation to levels below the MPE for specific UV wavelengths. Use flame-retardant materials for Class 4 lasers. Special attention must be given to the possibility of producing undesirable reactions in the presence of UV radiation (formation of skin sensitizing agents, ozone, etc.).

c. Laser Function Categories

i. Operation

Laser systems in normal operation must have all safety features functional and all required Engineering and Administrative controls in place.

ii. Maintenance and Service

Routine tasks for assuring performance must be performed following written procedures with no access to the beam. Maintenance SOPs should include lockout/Tagout, de-energization, and procedures for returning the laser to service. Vary rarely, users may wish to service the laser without removing it from operation. Service procedures may require access to the beam and thus great care must be taken to protect the users and environment. A temporary control area may be created during this service time. The LSO should be notified and consulted before work is started to ensure proper control measures are in place, as they may be different from normal operation.

iii. Employee Medical Monitoring

ANSI Z136.1-2000 requires eye examinations for all employees that use or may be exposed to class 3b and 4 laser radiation to:

- Establish a baseline for comparison in case of an accidental or chronic injury,

- Identify employees that may be at special risk from chronic exposure to selected continuous wave (CW) lasers,
- Assess the ability of an employee to safely perform their assigned duties, and
- Identify employees that may be at increased risk for eye injury.

ANSI Z136.1-2014 also recommends skin examinations for employees that use or may be exposed to class3b and 4 lasers ultraviolet radiation. These employees are at an increased risk of biological effects due to exposure to direct or diffuse beam reflections, and photo dermatitis in conjunction with certain medications and diffuse beam exposures.

All authorized laser supervisors, operators, and other university employees that may be exposed to class 3b or 4 laser radiation shall receive appropriate baseline eye and or skin examinations. The laser supervisor shall ensure that all their operators have received their examinations. The laser safety officer will identify any other university employees with incidental exposure to class 3b or 4 lasers that require baseline eye examinations. The laser safety officer shall report all laser eye and skin injuries to University Police to ensure employees receive appropriate medical treatment. Injured employees shall report to appropriate medical provider to ensure follow-up examinations, referrals, and assessments are performed and completed.

d. Training

All authorized laser supervisors and operators using class 3b and 4 open beam lasers are required to attend laser safety training sessions. The purpose of this training is to review laser safety concepts and topics, and to facilitate the safe use of laser devices and systems used in their laboratories. The laser safety officer shall provide the authorized laser supervisors with the appropriate training to comply with this requirement, and the authorized laser supervisor shall ensure that their operators attend the required training sessions. The following briefly summarizes the laser safety training provided by the laser safety officer.

e. Initial Orientation

Initial orientation sessions cover laser safety concepts and requirements outlined in the guide.

i. Refresher Training

Annual refresher laser safety training sessions review pertinent safety information and changes to applicable standards and University policies.

ii. Site-Specific Training

All authorized laser supervisors with open beam class 3b or 4 lasers must provide and document specific hands-on training to their operators for the lasers used in their labs:

- Prior to use by new students, technicians, or visiting faculty,
- Whenever modifications to a laser system results in changes to the output power, hazard controls, or existing standard operating procedures, or

- Immediately following an incident or accident that results or could have resulted in personal injury or property damage. In this case, the training shall review the incident, focus on the root cause and contributing factors, and identify the preventative measures implemented to prevent recurrence of that incident.

The scope and duration of site-specific training will vary depending upon the lasers and their associated hazards, however this training must review:

- The existing laser and laboratory engineering controls and their proper use,
- The administrative controls (SOP) developed for each laser system in use, that includes normal operations as well as alignment procedures, and
- The required personal protective equipment for each laser system present in the lab, as well as the proper storage, inspection, and use for each.

f. Laser Safety Audits and Investigations

All authorized laser supervisors and operators are expected to review their open beam laser system(s) and experimental layout(s) before each use to verify all safety controls, components, and equipment works properly, and to confirm the equipment and components have not been modified. All malfunctioning equipment shall be repaired and laser system modifications corrected before energizing the laser.

The laser safety officer conducts formal laser safety audits with the authorized laser supervisor or one of their designated operators to assess compliance with hazard control strategies described in the Laser Safety Guide. The Laser Safety Officer issues a written report to the authorized laser supervisor and provides 30 days to correct the deficiencies noted during the audit, unless the deficiency is serious enough to warrant immediate action. The following provides a brief overview of the formal laser safety audits conducted by the laser safety officer; details for each audit are provided in the Laser Safety Guide.

i. Initial Audits

Initial Audits are performed for all newly acquired lasers, new laser laboratories, or other lasers that have not been evaluated by the Laser Safety Officer. These initial laser safety audits collect information about the faculty supervisor and laser units; evaluate administrative, engineering, and non-beam hazard controls; and assess available and required personal protective equipment. The audit scope varies with the hazard class assigned to the laser. The audit scope for class 3b and 4 open-beam systems, which have a greater potential for injury, is greater than an audit of an embedded laser device.

ii. Periodic Audits

Periodic laser safety audits are performed annually to ensure compliance with the BU Laboratory Laser Safety Guide requirements. These audits are specific to each laser, based upon the conditions of use observed during the previous audit, and limited to class 3b and 4 open beam systems.

g. Incident and Accident Investigations

Authorized laser supervisors and operators must report all laser incidents or accidents to the Laser Safety Officer immediately. An investigation will be made to identify the root cause and contributing factors for the incident or accident, to estimate employee exposure, and to identify corrective actions to prevent recurrence of the incident. These investigations will be conducted immediately; the Laser Safety Officer, the authorized laser supervisor, the employee involved in the incident, and any witnesses shall participate in the investigation. The Laser Safety Officer will send the authorized laser supervisor a written incident or accident summary that identifies necessary corrective actions. The authorized laser supervisor shall initiate and complete all corrective actions identified by the Laser Safety Officer; when the Laser Safety Officer confirms successful completion of all corrective actions, laser operations can resume.
All laser related injuries shall be evaluated immediately. Students, faculty, and staff shall report for all follow-up treatment and referral services as directed by the physician.

7. Appendix A: Important Equations

Term and Symbol	Unit	Equation
MPE:		$\text{MPE: E}_{\text{Irradiance}} = \frac{MPE: H_{Radiant\ Exposure}}{t}$
Irradiance (E):	Watts/cm^2	(E) = $\Phi/A = \frac{Power}{Area} = \frac{Watts}{(\frac{\pi x D^2}{4})} = W/_{cm^2}$
Accessible Emission Limit:		$AEL = MPE \times Limiting\ Aperture\ Area$ 0.385 cm^2 for pupil area
Pulse Energy		$Joules = \frac{Avg. Power\ (W)}{Repetition\ Rate\ (Hz)}$
Radiant Energy (Q)	Joule	$Q = \Phi \times \text{T}$
Radiant Power (Φ)	Watt	$\Phi = \frac{Q}{\text{T}}$
Radiant Exposure (H)	Joules/cm^2	$H = Q/A$
Pulse Repetition Time (PRT) & Frequency (PRF)		$PRF = \frac{1}{PRT}$ $\frac{t}{PRT} = \frac{\Phi_{\text{avg}}}{\Phi_{\text{max}}}$

8. Appendix B: ANSI Z136.1-2014 References

Table 10a. Control Measures for the Seven Laser Classes

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.4.2.1)	X	X	X	X	X	X	X
Without Protective Housing (4.4.2.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.4.2.1.3)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.4.2.1.4)	∇	∇	∇	∇	∇	X	X
Key Control (4.4.2.2)	—	—	—	—	—	•	•
Viewing Windows, Display Screens and Diffuse Display Screens (4.4.2.3)	Ensure viewing limited < MPE						
Collecting Optics (4.4.2.6)	X	X	X	X	X	X	X
Fully Open Beam Path (4.4.2.7.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.4.2.7.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.4.2.7.3)	Further controls not required if 4.4.2.1 and 4.4.2.1.3 fulfilled						
Area Warning Device (4.4.2.8)	—	—	—	—	—	•	X
Laser Radiation Emission Warning (4.4.2.9)	—	—	—	—	—	•	X
Class 4 Laser Controlled Area (4.4.2.10 and 4.4.3.5)	—	—	—	—	—	—	X
Entryway Controls (4.4.2.10.3)	—	—	—	—	—	—	X
Protective Barriers and Curtains (4.4.2.5)	—	—	—	—	—	•	•

LEGEND:
- X Shall
- • Should
- — No requirement
- ∇ Shall if enclosed Class 3B or Class 4
- NHZ Nominal Hazard Zone analysis required

Table 10b. Control Measures for the Seven Laser Classes (cont.)

Administrative (and Procedural) Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.3.1)	—	—	—	—	—	•	X
Output Emission Limitations (4.4.3.2)	—	—	—	—	LSO Determination		
Education and Training (4.4.3.3)	—	•	•	•	•	X	X
Authorized Personnel (4.4.3.4)	—	—	—	—	—	X	X
Indoor Laser Controlled Area (4.4.3.5)	—	◦	—	◦	—	X NHZ	X NHZ
Class 4 Laser Controlled Area (4.4.2.9 and 4.4.3.5)	—	—	—	—	—	—	X
Temporary Laser Controlled Area (4.4.3.5)	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	—	—
Controlled Operation (4.4.3.5.2.1)	—	—	—	—	—	—	•
Outdoor Control Measures (4.4.3.6)	X	◦ NHZ	X NHZ	◦ NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.4.3.6.2)	•	•	•	•	•	•	•
Alignment Procedures (4.4.3.8)	∇	X	X	X	X	X	X
Spectators (4.4.3.7)	—	◦	—	◦	—	•	X
Service Personnel (4.4.3.9)	LSO Determination						

LEGEND:
- X Shall
- • Should
- — No requirement
- ∇ Shall if enclosed Class 3B or Class 4
- MPE Shall if MPE is exceeded
- NHZ Nominal Hazard Zone analysis required
- ◦ May apply with use of optical aids

Table 10c. Control Measures for the Seven Laser Classes (cont.)

Personal Protective Equipment PPE	Classification						
	1	1M	2	2M	3R	3B	4
Laser Eye Protection (4.4.4.1)	—	—	—	—	—	X	X
Skin Protection (4.4.4.3)	—	—	—	—	—	•	•
Protective Clothing (4.4.4.1 and 4.4.4.3.1)	—	—	—	—	—	•	•

LEGEND:
- X Shall
- • Should
- — No requirement

Table 10d. Control Measures for the Seven Laser Classes (cont.)

Control Measures: Special Considerations and Warning Signs	**Classification**						
	1	1M	2	2M	3R	3B	4
Laser Optical Fiber Transmission Systems (4.5.2)	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Automated Installations (4.5.3)	—	—	—	—	—	X NHZ	X NHZ
Laser Controlled Area Warning Signs (4.6)	—	—	—	—	—	X	X

LEGEND:
- X Shall
- — No requirement
- MPE Shall if MPE is exceeded
- NHZ Nominal Hazard Zone analysis required

9. Appendix C: Definitions

Accessible Emission Limit (AEL)	The maximum accessible emission level permitted within a particular class. The AEL is determined as a product of the maximum permissible exposure (MPE) times an area factor called the limiting aperture (LA). The LA is dependent on laser wavelength pupil size. AEL=MPE *area of LA.
Authorized Laser Supervisor	A faculty or staff member that has been approved by the Laser Safety Officer to operate specific laser devices or systems.
Authorized Laser Operator	A student, faculty, or staff member that operates laser devices or systems controlled by an authorized laser supervisor.
Average Power	The power of a pulsed laser in watts, averaged over a period of several seconds. A laser's average power output is the product of the energy/pulse and the repetition rate
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 hazards.
Collimating Lens	Narrows a beam of particles or waves, causing a high divergence beam to become low divergence (more concentrated)
Duty Cycle	Ratio of on time to the off time. Pulse duration (length of pulse) divided by pulse period (time from beginning of one pulse to the beginning of the next)
Exposure Duration	Visible Lasers: 0.25s (aversion response) Infrared Lasers: 10s (natural eye movement) Ultraviolet Lasers: 100s (accumulated exposure)
Extended Source	Having an apparent source size with angular subtense of greater than 1.5 mrad

Harmonic Generator	Combines photons of the same frequency to a new wavelength
Irradiance	Power averaged over the area of the laser beam (W/cm^2)
Interlocks	An electrical or mechanical device designed to prevent access to laser radiation above the maximum permissible exposure level. Often, interlocks are connected to a shutter that interrupts the beam when the device is in the open position.
Laser	A device that produces an intense, coherent, directional beam of non-ionizing radiation by stimulating electronic or molecular transitions to lower energy levels. Also an acronym for Light Amplification by the Stimulated Emission of Radiation.
Laser Device	An enclosed laser, assigned a higher classification number than the equipment in which it is incorporated, which uses engineering controls to limit accessible radiation emissions.
Laser Hazard Class	A classification scheme used to evaluate the laser system's capability of injuring people that ranges from class 1 (lowest) to class 4 (highest).
Laser Incident	An unplanned, undesired event or human activity that adversely affects or interrupts the completion of a specific activity or task. These include property damage or events that could have resulted in personal injury.
Laser Safety Officer	An Environmental Health and Safety employee that develops, implements, and enforces the Laser Safety Program.

Laser System	An assembly of electrical, mechanical, and optical components that includes a laser. For the purposes of this program document, this term refers to open beam laser systems.
Limiting Aperture (LA)	The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation and classification. Symbol: D_f.
Maximum Permissible Exposure (MPE)	The level of radiation which persons may be exposed to without suffering adverse effects. Dependent upon exposure duration, wavelength, viewing conditions, and tissue type affected
Nominal Hazard Zone	The space within which the level of direct, reflected, or scattered radiation during operation exceeds the applicable maximum permissible exposure level.
Nominal Ocular Hazard Zone	The distance at which the MPE value equals the irradiance of the laser beam. Hazard Distance is an equivalent term for skin exposure.
Optical Density	A method to describe the level of attenuation of a given material as a means of determining eye protection. $OD = \log10 [\Phi i/\Phi t]$ Where: Φi = power incident on the eye protector Φt = power transmitted through the eye protector For example: eye protection rated at OD 4 has an attenuation factor of 104 = 10,000. This rating would allow 1/10,000 (0.01%) of the beam through the eyewear
Point Source	Having an apparent source size with angular subtense of less than 1.5 mrad
Peak Power	The instantaneous power output during a laser pulse. It is calculated by dividing the energy in joules by the pulse duration in milliseconds. The resulting peak power will be in kilowatts (kW)

Protective Housing	An enclosure that surrounds the laser or laser system that prevents access to laser radiation above the applicable maximum permissible exposure level. A protective housing may also enclose associated optics and a workstation, and limit access to other associated energy emissions and to electrical hazards associated with components and terminals.