BOWDOIN COLLEGE
LASER SAFETY PROGRAM

Purpose and Authority
This document meets the requirements of OSHA 29 CFR 1910.1450 (*Laboratory Standard*) and ANSI Z136.1-2007/136.5-2000 (*American National Standard for the Safe Use of Lasers in Institutional Settings*) for the development, implementation and maintenance of a written laser safety program (LSP).

Scope
The provisions of the LSP apply to all faculty and staff of the College who engage in the use of institutional lasers for research purposes.

Program Components
The LSP consists of the following components:

1. **Responsibilities.** The following responsibilities are defined regarding the LSP:

   Laser Safety Officer (LSO). Unless otherwise designated, the Radiation Safety Officer is the default LSO. The LSO is responsible for managing the safe use of the College's Class 3A, 3B and 4 lasers, as defined below. This includes the authority to:

   - Implement, review, and enforce administrative and engineering controls
   - Evaluate and mitigate associated laser hazards
   - Modify laser safety policies and procedures as necessary
   - Maintain training, equipment inventory, and other documentation
   - Report findings to the Radiation Safety Committee

   Radiation Safety Committee. The Committee is responsible for the overall administration of the LSP, including the approval of authorized users and proposals involving Class 3B or 4 lasers.

   Authorized Users. Only qualified personnel who have received specific safety training will be authorized by the Committee to use lasers in College facilities, and will be responsible for enforcing the Laser Safe Operating Procedures (LSOP) as determined for a specific project or activity. Authorized users are also responsible for knowing the manufacturer's safe operating specifications, and arranging the maintenance and servicing, of their laser equipment and providing documentation of same to the LSO.

2. **Definitions.** The following terms are defined with respect to the use of institutional lasers:

   Accessible Emission Level. The magnitude of accessible laser (or collateral) radiation of a specific wavelength or emission duration at a particular point as measured by appropriate methods and devices. Also means radiation to which human access is possible in accordance with the definitions of the laser's hazard classification.

   Accessible Emission Limit (AEL). The maximum accessible emission level permitted within a particular laser class. In ANSI Z 136.1, AEL is determined as the product of accessible emission Maximum Permissible Exposure limit (MPE) and the area of the limiting aperture (7 mm for visible and near-infrared lasers).

   Controlled Area. Any locale where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

   Continuous Mode. The duration of laser exposure is controlled by the user (by foot or hand switch).

Continuous Wave (CW). Constant, steady-state delivery of laser power for greater than 0.25 seconds.

Diffuse Reflection Takes place when different parts of a beam incident on a surface are reflected over a wide range of angles in accordance with Lambert's Law. The intensity will fall off as the inverse of the square of the distance away from the surface and also obey a Cosine Law of reflection.

Embedded Laser. An enclosed laser device which does not permit hazardous optical radiation emission from the enclosure, with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate to the engineering features limiting accessible emission.

Fail-Safe 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). Invisible electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 µm. These wavelengths are often broken up into regions: IR-A (0.7-1.4 µm), IR-B (1.4-3.0 µm) and IR-C (3.0-1000 µm).

Intrabeam Viewing. The viewing condition whereby the eye is exposed to all or part of a direct laser beam or a specular reflection.

Laser. An acronym for light amplification by stimulated emission of radiation. A laser is a cavity with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. It produces an intense beam of non-ionizing radiation as light in continuous waves or as a pulse, with the unique properties of coherency, collimation, and monochromaticity. The range of commonly available lasers is 200 nm to 10.4 µm.

Limiting Aperture. The maximum circular area over which radiance and radiant exposure can be averaged when determining safety hazards.

Maximum Permissible Exposure (MPE). The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eyes or skin.

Nominal Hazard Zone (NHZ). The space within which the level of the direct, reflected or scattered radiation during normal operation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are by definition below the MPE level.

Ocular Radiation. Ultraviolet, visible, and infrared radiation (0.35-1.4 µm) that falls in the region of transmittance of the human eye.

Pulse. A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output. The pulse duration is the "on" time of a pulsed laser, which may be measured in terms of milliseconds, microseconds, or nanoseconds as defined by half-peak-power points on the leading and trailing edges of the pulse, but is generally less than 0.25 seconds.

Secured Enclosure. An enclosure to which casual access is impeded by an appropriate means (e.g., secured by lock, magnetically or electrically operated latch, or by screws).

Ultraviolet (UV) Radiation. Electromagnetic radiation with wavelengths between X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).

3. **Laser Classification.** Lasers are grouped into four classifications based on maximum power output (in mW), and their capacity for causing damage to eyes and skin, as follows:

   - **Class 1, 1A (I, Ia).** No damaging radiant energy is produced, and no special precautions are necessary. Class 1 lasers are generally exempt from radiation hazard controls, except during servicing. Class 1A lasers, while still considered non-hazardous, are designated as "not intended for viewing" and are typically 0.4 mW in strength or less. EXAMPLES: Laser pointers, disk players.

   - **Class 2, 2A (II, IIa).** Low power, emits a visible beam of light but less than 1 mW in strength; protective eyewear is required when looking at the beam, but normal aversion response (blinking) is sufficient protection for everyday use. EXAMPLES: Construction equipment, bar code scanners.

   - **Class 3A, 3B (IIIa, IIIb).** Moderate power, strength ranging from less than 5 mW (3A) to less than 500 mW (3B), light is hazardous when directly viewed or reflected off another surface; protective eyewear is required at all times for Class 3B. While both classifications can cause eye injury, difference is that 3A cannot cause skin injury. EXAMPLES: Medical and laboratory equipment.

   - **Class 4 (IV).** High power, strength in excess of 500 mW, light is hazardous under any conditions with the potential for serious eye/skin damage (from direct beam or diffuse reflection) and fire hazards; special precautions are required, as outlined in *Requirements by Class* below. EXAMPLES: Institutional and industrial lasers.

   Note that Class 2, 2A, and 3A lasers that are completely enclosed and thoroughly protected from access are considered Class 1 for safety purposes (i.e., surveying transits, laser levelers, laser printers, etc.). For the purposes of this policy, this exemption will also apply to all laser pointers, barcode readers, and similar commonplace devices.

4. **Health and Associated Hazards.** Primary hazards associated with the use of lasers include personal injury or exposure, specifically:

   - **Eye Injury**. A laser beam of sufficient power can produce retinal intensities at magnitudes greater than conventional light sources, and even larger than those produced when directly viewing the sun. Permanent blindness can be the result. Exposure may occur during laser alignment, due to misaligned optics or equipment malfunction, or an inadvertent beam discharge. Excessive UV and IR radiation, either direct or reflected, and high luminance radiation from unshielded pump lamps may also cause eye injury. Unintended reflections may also occur from jewelry and watches, worn by the user, so all should be removed prior to laser use. Use of protective eyewear appropriate to the class and specifications of the laser being used is always recommended, and in the case of Class 3B and 4 lasers is required.

   - **Thermal Injury**. The most common cause of laser-induced tissue damage is thermal in nature, where the tissue proteins are denatured due to the temperature rise following absorption of laser energy. The thermal damage process (burns) is generally associated with lasers operating at exposure times greater than 10 microseconds and in the wavelength region from the near ultraviolet to the far infrared (0.315 µm-103 µm). Tissue damage may also be caused by thermally induced acoustic waves following exposures to sub-microsecond laser exposures. Fully covering exposed skin with opaque materials such as a lab coat and nitrile gloves is always recommended.

   - **Electrical Shock.** All jewelry, watches, metal bracelets, etc. must be removed prior to laser use. All floor surfaces should be considered as conductive and grounded when working around high-voltage equipment, unless specific measures have been taken to provide an insulated surface. Avoid using both hands simultaneously on the same circuit or control device, to prevent a circuit completion. Avoid water, wet floors, and excessive perspiration. In addition, EM radiation exposure may occur from uncontrolled high voltage (greater than 15KV) power supply units.

- **Chemical Exposure.** Toxic dusts or fumes may be emitted as vaporized target materials. In addition, leakage of gases and dyes from those types of lasers, or vapors from cryogenic coolant if in use, may chemically expose the user. Gases and chemicals used in some laser operations may also be toxic or corrosive. Appropriate PPE and/or ventilation may be required.

- **Fire and Explosion.** Gases or dyes used in some lasers may themselves be flammable, and Class 4 lasers emit enough thermal energy to ignite target materials. Bottled gases used in some laser operations may provide fuel for a fire or explosion under certain circumstances. Capacitor banks and optical pump systems of some high-powered lasers have the potential to explode. Storage of combustibles in the work area should be kept at a minimum.

- **Excessive Noise.** Depending on the type of equipment being used, and the activities involved, hearing protection and noise mitigation may be required.

5. Requirements by Class. The required safety measures by laser class are outlined in detail in the sections below. At all times will the manufacturer's safety precautions and operating procedures be followed, and should be documented on the LSOP as necessary.

Safety Control Measures by Laser Class	1,1A	2,2A	3A	3B	4
Administrative Controls					
Equipment Labeling	X	X	X	X	X
Registration with Radiation Safety Committee		X	X	X	X
Equipment-Specific Alignment and Operating Procedures		X	X	X	X
Authorized User Training		R	R	X	X
Warning Signage		R	R	X	X
Initial and Annual Safety Reviews			R	X	X
Medical Surveillance				R	R
Engineering Controls					
Controlled Access			X	X	X
Reflection Minimization and Shielding			X	X	X
Personnel Instruction in Safety Precautions			X	X	X
Protective Eyewear and Skin Protection			R	X	X
Project-Specific Laser Safe Operating Procedures (LSOP)			R	X	X
Interlocks, Disconnects, and Attenuators				R	X
Activation Alarm and Key Control				R	X
Protective Barriers and Curtains				R	R
Remote Monitoring and Firing Capability					R

NOTES: X = required; R = recommended (ANSI)

6. Administrative Controls. Baseline management of the LSP includes the following safety measures:

Equipment Labeling. All lasers must be clearly labeled by the manufacturer for make, model, serial number, class, specifications (wavelength, medium, mode, and maximum power output), certification, and appropriate warnings.

Registration. The make, model, serial number, class, and specifications of each Class 2, 3, or 4 laser in use by the College must be registered with the Committee, and this inventory maintained by the LSO.

Operating Procedures. The authorized user must provide written safe operating instructions specific to the laser being used and the workspace, and post said instructions on or near the equipment. This posting must be updated as necessary to remain current with the proposed laser operations outlined in the submitted LSOP. A sample posting is attached as a guideline.

Signage. Warning signs specific to the class and specifications of the laser equipment in use must be posted at the entrance to the work area for Class 3B and 4 lasers, using the ANSI-specified laser DANGER sign format (samples attached). ANSI CAUTION signage is also recommended for fixed installations of Class 2, 2A and 3A lasers; manufacturer's labels are adequate for portable devices.

Training. Authorized users of Class 3B and 4 lasers must receive baseline safety training (summary attached) and hands-on instruction of the specific equipment to be used by competent personnel, prior to using the equipment. Training is also recommended for users of fixed installations of Class 2, 2A, and 3A lasers; reliance on the manufacturer's information is adequate for portable devices. A training record and a list of authorized users will be maintained by the LSO.

Reviews. The LSO will conduct an initial review of each active work area based on the LSOP developed for projects using Class 3B or 4 lasers, and conduct annual safety reviews of ongoing projects.

Medical Monitoring. It is recommended that authorized users of Class 3B and 4 lasers have baseline eye examinations, for comparison in the event of an exposure incident in excess of the MPE. For the purposes of this policy, all faculty and staff users of Class 4 lasers, and all new faculty and staff with prior laser use experience, will receive a baseline examination.

7. **Engineering Controls.** Active use of laser equipment requires the following safety measures:
   Controlled Access. Access to work areas using Class 3A, 3B and 4 lasers will be restricted to authorized users only. All work areas will be within localized enclosures, either a secured room or a barrier-defined space within a room (outlining the NHZ). With the exception of projects specifically requiring long-term unmanned operation as part of the process, the equipment will never be left unattended while in operation, and must be discharged and/or powered down before being left unattended.
   Reflection Minimization and Shielding. Use of covers, shields, or other means to mitigate the access to any reflective surface in the NHZ is required for the use of Class 3A, 3B and 4 lasers. Materials used to prevent the reflection or escape of laser light must be designed and manufactured for this purpose; materials used for Class 4 applications must also be fireproof.
   Safety Instructions. Instructions specific to the equipment, project, and work area will be provided to all authorized users involved prior to using Class 3A, 3B and 4 lasers. These instructions will include at a minimum:

   - The hazard assessment and protective measures outlined in the LSOP
   - Personal restrictions (i.e., clothing, jewelry, etc.)
   - Housekeeping, work procedures, and schedules
   - Emergency procedures for that space

Laser Safe Operations Procedures (LSOP). Prior to the use of Class 3B and 4 lasers, a *Laser Safe Operations Procedure* form (attached) specific to the equipment being used and the project being conducted must be completed, approved by the Radiation Safety Committee, and reviewed onsite by the LSO. An LSOP is also recommended for fixed installations of Class 3A lasers.

Protective Eyewear. Safety glasses of appropriate optical density (OD) and type for the class and specifications of the Class 3B or 4 laser being used will be worn AT ALL TIMES by students, as well as spectators present in the work area with the opportunity for exposure. Faculty and staff users may remove their protective eyewear at their discretion when the laser is NOT in operation. The LSO can provide guidance on types of available eyewear. Note that the use of protective eyewear is recommended for ALL laser use.

Interlocks, Disconnects, and Attenuators. Automatic mechanical interlocks, remote interlock connectors, electrical disconnects ("master switch"), and beam attenuators are required when using Class 4 lasers (recommended for Class 3B), to interrupt the beam in the event of the housing being opened or an electrical or other fault occurring.

Alarm and Key Control. Some form of audiovisual activation notice – lit sign, flashing light, verbal countdown, etc. – will be provided at the entrance of the controlled access area, and activated when Class 4 lasers are in use (recommended for Class 3B). There must be sufficient emission delay in the warning to allow persons to react to the alarm before the laser fires. Class 4 lasers also require a locked-out key control (mechanical or electronic) to prevent unauthorized firing (recommended for Class 3B).

Barriers and Curtains. The use of non-reflective and fireproof barriers and curtains designed and manufactured for the purpose are recommended for Class 3B and 4 lasers, in addition to reflection minimization and shielding.

Remote Monitoring and Firing. Some form of remote operations monitoring, either electronic or visual, is recommended for the use of Class 4 lasers.

In addition, the following safety controls apply to ALL classes of lasers:

- Avoid looking into the beam or at the pump source at any time, and do not aim the laser by eye.
- A protective housing, OR enclosure of the laser equipment or beam path, must be provided either by the manufacturer or the authorized user.
- Lasers with viewing portals should have a means (i.e., interlock, attenuator, or filter) to maintain radiation levels below the MPE.
- Equipment must be set up so that the beam path is not at standing eye level (<4.5 ft or >6.5 ft).
- Beams must be terminated by materials appropriate for the Class of Laser.
- Collecting optics intended for viewing must incorporate a means to maintain transmitted radiation levels below the MPE.
- Lighting in work area should be as bright as practicable to constrict the pupils of users.
- Windows to hallways or outside areas must be provided with shades or covers.
- Warning should be given to all affected persons present before activating the laser.

8. **Emergency Procedures.** Response to any laboratory emergency will be as outlined in the *Radiation Safety Program* and *Chemical Hygiene Plan*. Emergency information and contact numbers are posted in every laboratory. Exposure incidents must also be reported to the LSO and EHS Manager for accident investigation purposes.

9. **Recordkeeping.** The list of authorized users, training logs, equipment inventory, maintenance and service records, medical monitoring results, and other documentation associated with laser use will be maintained by the LSO for a period of at least 3 years, and reviewed annually with the Committee.

10. Program Review. The LSP will be reviewed at least annually by the Committee and the LSO, and updated as necessary to reflect current operations.

Attachments

LSOP Form
Workplace Posting
Warning Signs
Training Summary

LASER SAFE OPERATING PROCEDURES (LSOP)
Project Proposal Form

Name _____ Department _____

Telephone _____ Date _____

Project Proposal:

Laser Location (Building, Room, Site) _____

Make, Model, Serial Number _____

Specifications (Class, Wavelength, Maximum Power Output, Medium, Mode) _____

_____

Check All Safety Control Measures That Apply:		**Specify:**
Administrative Controls		
Equipment Labeled	_____	_____
Registered with Radiation Safety Committee	_____	_____
Alignment and Operating Procedures Present	_____	_____
Required Warning Signage Posted	_____	_____
Authorized User Training Completed	_____	_____
Initial Safety Review Conducted	_____	_____
Baseline Medical Surveillance Conducted	_____	_____
Engineering Controls		
Access to Work Area Controlled	_____	_____
Reflection Minimization/Shielding Completed	_____	_____
Personnel Instructed in Safety Precautions	_____	_____
Laser Safe Operating Procedures (LSOP) Approved	_____	_____
Protective Eyewear and Clothing in Use	_____	_____
Interlocks, Disconnects, and Attenuators in Place	_____	_____
Activation Alarm and Firing Procedures Confirmed	_____	_____
Protective Barriers and Curtains in Place	_____	_____
Remote Monitoring and Firing Capability Confirmed	_____	_____

Specific Precautions:

LSO Approval

Signature _____ Date _____

LASER SAFE OPERATING PROCEDURES (LSOP)
Workplace Posting

Responsible Person _____ Department _____

Telephone _____ Date _____

Laser Location (Building, Room, Site) _____

Make, Model, Serial Number _____

Specifications (Class, Wavelength, Maximum Power Output, Medium, Mode) _____

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Manufacturer's Operating Instructions:

Instructions Specific to This Laboratory:

IN THE EVENT OF AN EMERGENCY, CONTACT SECURITY AT x3500 IMMEDIATELY