8.1 RADIATION SAFETY

At this time, radioactive materials are not to be used in the Cole Science Center.

8.2 LASERS

This Section describes requirements for personnel protection from laser radiation and other associated hazards. These requirements are designed to comply with the Massachusetts Department of Public Health (DPH) Code 105 CMR 121.000, "Rules and Regulations Relative to the Use of Laser Devices or Equipment to Control the Hazards of Laser Rays and Beams". A copy of these regulations is available at:

http://www.mass.gov/Eeohhs2/docs/dph/regs/105cmr121.pdf

This document delineates the requirements for registration and safe use of high power lasers and laser systems. All operations or research involving the use of lasers must be conducted in such a manner as to ensure that personnel exposure to laser radiation is below the maximum levels specified in 105 CMR 121.600. Further, all operations involving the use of high power lasers shall be planned and executed using the recommendations of the American National Standards Institute Z136.1 - 2000, "Standard for the Safe Use of Lasers". Many of those recommendations are incorporated into this document. ANSI Z136.1 is available from the Lab Manager.

The following is a summary of requirements for laser use.

LASER REQUIREMENT SUMMARY

Requirement	Laser Class				
Warning label	1	2	3a	3b	4
Warning sign		2	3a	3b	4
Registered with RSO		2	3a	3b	4
Laser safety training			3a	3b	4
Laser Safe Operating Protocol				3b*	4
Medical Surveillance				3b*	4

* If invisible to the eye, and if a cw laser, with visible beams > 15mW of power.

8.2.1 Laser Classification

Lasers are classified according to the definitions of Section 3.3 of ANSI Z136.1. Classification and labeling of commercially purchased lasers is the responsibility of the manufacturer. In addition to meeting the general requirements of this Chapter, lasers must meet specific requirements based on laser class. Only lasers fabricated on-site would require classification by the Investigator, which requires approval of the Radiation Safety Officer.

Laser classification and entry controls are summarized below.

Class 1 denotes exempt lasers or laser systems that cannot, under normal operating conditions, produce a hazard. Equipment such as laser printers that completely enclose the laser and laser beam are normally specified as Class 1.

Class 1 lasers must be labeled, but are exempt from other requirements.

Class 2 denotes low power visible-radiation lasers or laser systems. Visible cw HeNe lasers above Class 1, but not exceeding 1 mW (milliwatt) radiant power, are common examples of this class. Because of the normal human aversion or blink response, these lasers normally do not present a hazard. Class 2 lasers may present a hazard if viewed directly for extended periods of time (like many conventional light sources).

Class 2 lasers must be labeled and registered with the Radiation Safety Officer, but are exempt from other requirements. The warning label or sign shall caution users to avoid staring into the beam or directing the beam toward the eye of individuals, and shall be placed on or near the laser in a conspicuous location.

Class 3a denotes lasers or laser systems that normally would not produce a hazard if viewed for only momentary periods with the unaided eye. They may present a hazard if viewed using collecting optics. Visible cw HeNe lasers above 1 mW but not exceeding 5 mW radiant power are examples of this class.

Class 3a lasers must be operated in a location where access to the beam can be controlled. The potential for viewing of the direct or specularly reflected beam must be minimized. The operator of the laser shall inform personnel entering the area of the presence of the laser beam and the precautions they need to follow.

Class 3b denotes lasers or laser systems that can produce a hazard if viewed directly. This includes intrabeam viewing or specular reflections. Except for the higher power Class 3b lasers, this class laser will not produce hazardous diffuse reflections. Visible cw HeNe lasers above 5 mW but not exceeding 500 mW radiant power are examples of this class.

Class 3b lasers must be used in areas where entry by unauthorized personnel can be controlled. Entry into the area of personnel untrained in laser safety may be permitted by the laser operator if they are instructed as to safety requirements and are provided with protective eyewear, if required.

Class 4 denotes lasers or laser systems that can produce a hazard not only from direct or specular reflections, but also from a diffuse reflection. In addition, such lasers may produce fire and skin hazards.

Class 4 lasers must be operated by authorized users in areas dedicated to their use. Failsafe interlocks must be used to prevent unexpected entry into the controlled area, and access shall be limited by the laser operator to persons who have been instructed as to safety procedures and who are wearing proper laser protection eyewear (if required by written procedures) when the laser is capable of emission. Authorized operators are responsible for providing information and safety protection to untrained personnel who may enter the laser controlled area as visitors.

For pulsed systems, interlocks shall be designed so as to prevent firing of the laser, by dumping the stored energy into a dummy load. For continuous wave lasers, the interlocks shall turn off the power supply or interrupt the beam by means of shutters.

Manufacturer classifications are based on the level of laser radiation accessible during intended operation of the laser. The hazard may be greater, and therefore require additional controls, when maintenance or service is being performed.

8.2.2 Responsibilities

8.2.2.1 Responsibilities of Laser Investigators

Investigators using lasers are responsible for assuring their safe use in their area or lab. Specific responsibilities include:

- Complying with and enforcing the safety requirements prescribed in this Section.
- Reporting all proposed purchases of Class 2, 3a, 3b, and 4 lasers to the Safety Committee by submitting a registration form (Appendix 8-A) at least one month prior to proposed purchase.
- Registering all existing Class 2, 3a, 3b, and 4 lasers by submitting a registration form (Appendix 8-A) to the Lab Manager.
- Providing a Laser Safe Operating Protocol (see Appendix 8-B) to the Safety Committee for approval for all Class 3b and 4 lasers at least three weeks prior to proposed use.
- Assuring that all users are properly instructed in safe procedures for working with all lasers (see Appendix 8-C) and submitting "Authorized Laser User Certification" forms (Appendix 8-D) to the Lab Manager.
- Assuring that all required protective equipment is used during laser work.
- Reviewing in advance all lab procedures to be used by laser users in carrying out research work involving laser radiation for possibility of laser exposure, and associated non-beam hazards.
- Assuring the integrity of associated equipment such as vacuum systems, cryogenic systems, pressure vessels or other similar equipment to be used in conjunction with a laser.
- Assure that all laser system safety interlocks, warning lights, etc. are functioning.
- Posting warning signs and otherwise controlling laser hazards for which the Investigator is responsible.

- Maintaining control of visitors.

8.2.2.2 Responsibilities of Laser Users

The individual user is responsible for:

- Using only Investigator approved techniques and procedures in operations involving the use of lasers.
- Wearing prescribed protective glasses and any other required protective clothing or equipment.
- Meeting all applicable requirements of this Section including training, and medical surveillance if required, before operating any laser.
- Maintaining a current "Authorized Laser User Certification" for Class 2, 3a, 3b and 4 laser use (Appendix 8-D).

8.2.2.3 Responsibilities of the Laboratory Manager

- Maintaining a current laser inventory to comply with the DPH registration requirement.
- Maintaining all required records for DPH inspection.
- Assisting in the investigation of all accidents or incidents involving laser radiation to determine the cause(s) and to report to the Laboratory Safety Committee.

8.2.2.4 Responsibilities of the Safety Committee

- Reviewing registration forms to determine if a Protocol is necessary.
- Reviewing and approving Laser Safe Operation Protocols.
- Establishing policies and procedures on the safe use of lasers.
- Review reports of accidents or incidents involving lasers and assure that appropriate corrective action is taken to prevent re-occurrence.

8.2.3 Laser Registration

Prior to purchase of a Class 2, 3a, 3b, or Class 4 laser, and for existing lasers, a registration form (Appendix 8-A) must be submitted.

8.2.4 Laser Safe Operation Protocol

A Safety Committee approved Laser Safe Operating Protocol (LSOP) is required for all Class 3b and 4 lasers. However, the Committee may recommend or require a LSOP for any laser or laser application where it is deemed necessary for ensuring adequate safety controls.

The Investigator prepares the LSOP. The LSOP shall include all information outlined in Appendix 8-B and shall receive Safety Committee approval before the laser is operated.

8.2.5 General Safety Requirements

1. Each class 3b and 4 laser shall receive a preliminary safety review and approval by the Lab Manager prior to acquisition or fabrication of the laser. These lasers also shall receive a final safety review and approval by the Laboratory Manager prior to initial use of the laser. The final review shall cover user qualifications, safe operations including electrical safety, area controls, and written procedures if required.

2. Each laser and laser application shall meet the safety standards of ANSI Z136.1 or an equivalent level of safety approved by the Safety Committee.

3. Each Class 3a, 3b, and 4 lasers shall be used in a controlled area in order to restrict access of unauthorized personnel. The level of control depends on the laser class.

8.2.6 Laser Safety Training

All users of Class 2, 3a, 3b, and 4 lasers shall receive training by the Investigator and read "Laser Safety Training" (see Appendix 14). All users of Classes 3b and 4 lasers shall be re-certified in Laser Safety at intervals not to exceed two years.

Upon completion of training, the Investigator and User must complete an "Authorized Laser User Certification" form (Appendix 8-D).

8.2.7 Laser Medical Surveillance

All Investigators and Users who are routinely engaged in work where they may be exposed to laser radiation from a class 3b or 4 laser must participate in the laser medical surveillance program.

The purpose of laser medical surveillance is twofold. The first purpose is to establish a baseline of ocular conditions before exposure to laser radiation. The second purpose is to detect and document, as early as possible, ocular damage in the event of a suspected exposure incident. Both purposes serve to assess the effectiveness of control measures and to promptly institute appropriate therapeutic measures.

Laser medical surveillance includes a preliminary baseline eye exam. Additional eye exams are required immediately in the event of exposure or suspected exposure to laser radiation above the Maximum Permissible Exposure (MPE) established in 105 CMR 121.600 (pulse and wavelength dependent). An eye exam may be required upon termination of laser work or upon termination of employment at the College.

Investigators should contact the Environmental Health and Safety Office to schedule baseline eye exams and to report suspected exposures above the MPE.

8.2.8 Laser Warning Signs

Laser warning signs must meet the standards of ANSI Z136.1. Class 1 lasers do not require a sign. The word CAUTION shall be used with all Class 2 and Class 3a lasers. The word DANGER shall be used with all Class 3b and Class 4 lasers. Signs, including the appropriate precautionary statements detailed in ANSI Z136.1, must be described in the LSOP.

All warning signs and labels shall be displayed conspicuously in locations where they best serve to warn individuals of potential safety hazards. Normally, warning signs are posted at entryways (e.g., on doors) to laser controlled areas.

Warning labels are affixed to the lasers in a conspicuous location. The laser Investigator should remove laser warning signs if the laser has been removed from the room or area.

8.2.9 Safe Laser Practices

The following control measures are recommended as a guide to safe laser use. If any of these control measures cannot be accomplished, the LSOP must describe alternative controls to provide comparable protection. These practices are taken from ANSI Z136.1. Refer to that document for additional details.

The purpose of controls is to reduce the possibility of exposure to the eye and skin to hazardous laser radiation and to control other hazards associated with operation and maintenance of laser devices.

Engineering controls (physical features incorporated into the design or installation of the laser system) are the preferred method of control. If engineering controls are not feasible, then administrative and procedural controls and personal protective equipment should be used.

<u>Engineering Controls</u>

1. Protective housings should be provided for all classes of lasers.

2. Protective housings that enclose Class 3b or 4 lasers should have an interlock system that is activated when the protective housing is opened.

3. Enclosure of the laser equipment or beam path is the preferred method of control.

4. Service access panels intended to be removed by service personnel only and which permit direct access to laser radiation associated with Class 3b or 4 lasers should either be interlocked or require a tool for removal and have an appropriate warning sign.

5. Class 3b lasers should be provided with a master switch. Class 4 lasers must have a master switch. The master switch should be operated with a key or coded access (e.g., computer authorization password).

6. Lasers with viewing portals should have means, (e.g., interlock, filter, attenuators), to maintain laser radiation below the MPE.

7. The laser should be set up so that the beam path is not at normal eye level, i.e., so it is below 4.5 feet and above 6.5 feet.

8. All collecting optics intended for viewing use should incorporated means to maintain laser radiation transmitted through the collecting options to levels below the MPE.

9. Class 3b lasers should be provided with a remote interlock connector. Class 4 lasers must be provided with a remote interlock connector. The interlock connector provides electrical connection to an emergency master disconnect or to a room, or area interlock.

10. Class 3b lasers should be provided with a permanently attached beam stop attenuator. A Class 4 laser must be provided with such an attenuator.

11. An alarm, warning light, or verbal countdown command should be used with a Class 3 laser and must be used with a Class 4 laser to signal activation. For Class 4 lasers there must be an emission delay to allow action to be taken to avoid exposure.

12. When possible, Class 4 lasers should be fired and monitored from a remote position.

Administrative and Procedural Controls

1. In applications using Class 3b or 4 lasers with unenclosed beam paths, the Nominal Hazard Zone (NHZ: space within which the level of direct, reflected, or scattered radiation during operation exceeds the applicable MPE) must be established. A laser controlled area must be established in this zone, and appropriate control measures established.

2. Class 3a, 3b and 4 lasers must only be operated and maintained by authorized Investigators and Users. Student users must be directly supervised when working with Class 4 lasers.

3. LSOPs are required for all Class 3b and 4 lasers.

4. User Training is required for all Class 2, 3a, 3b, and 4 lasers.

Recommended Work Area Controls

1. Entry controls must prevent unauthorized people from being present when the laser is energized or about to be energized.

2. The illumination in the area should be as bright as practicable in order to constrict the eye pupils of users.

3. The potential for specular reflections should be minimized by shields and by removal of all unnecessary shiny surfaces.

4. Windows to hallways or other outside areas should be provided with adequate shades or covers.

5. The main beams and reflected beams should be terminated by material that is non-specular reflective and fireproof. This is required for any accessible laser for which the MPE could be exceeded.

6. An active laser should never be left unattended unless it is part of a controlled environment.

7. Good housekeeping should be practiced to ensure that no device, tool, or other reflective material is left in the beam.

Recommended Laser Use Controls

1. The manufacturer's recommendations for safe laser use must be followed unless alternative methods are described and approved in the LSOP.

2. Avoid looking into the primary beam at all times.

3. Do not aim the laser with the eye; direct reflections can cause retinal damage.
4. Avoid looking at the pump source.

5. Clear all personnel from the anticipated path of the beam.

6. Before operating the laser, warn all personnel and visitors of the potential hazard, and ensure all safety measures are satisfied.

7. Be especially cautious around lasers that operate at invisible light frequencies.

8. Do not wear bright, reflective jewelry or other objects.

Laser Protective Equipment

Normally, all persons who work in areas where there is radiation from Class 3b or Class 4 lasers must wear approved laser eyewear if the potential exists for exposure in excess of the MPE. Exceptions may be approved if wearing protective eyewear produces a greater safety hazard than when it is not worn. Exceptions shall be described in the LSOP.

The eyewear to be used will depend on the wavelength(s) and intensity of the accessible radiation. Keep in mind:

- No matter how good the glasses, no protection is provided unless worn.

- All safety glass may shatter, and all plastic lenses may melt when maximum irradiance or radiant exposure for the particular lens is exceeded.

- Laser safety glasses may not provide eye protection other than with the laser for which they are specified, unless the frequency produced is the same and power output is not greater.

In some cases, other protective equipment, such as clothing to protect the skin, may be required. Such requirements must be addressed in LSOP.

8.2.10 Associated (Non-Beam) Laser Hazards

Depending on the type of laser used, associated hazards other than those from beam radiation may be involved. Such hazards, if they exist, must be addressed in the LSOP.

Atmospheric Contamination

1. Vaporized target material: contaminants may include carbon monoxide, ozone, lead, mercury, and other metals.

2. Gases from flowing gas lasers or byproducts of laser reactions such as fluorine, hydrogen-cyanide, and many others.

3. Gases or vapors from cryogenic coolants.

Chemicals

Chemicals, including dyes and solvents, from certain dye lasers have been shown to be carcinogenic, toxic, or otherwise hazardous.

Cryogenic Coolants

Cryogenic liquids, such as liquid nitrogen or hydrogen, may cause burns.

Electrical Hazards

The potential for electrical shock is present in most laser systems. Pulsed lasers utilize capacitor banks for energy storage and cw lasers generally have high voltage DC or RF electrical power supplies.

Explosive Hazards

The potential exists for explosions at capacitor banks or optical pump systems during the operation of some high power lasers. Explosive reactions of chemical laser reactants or other gases used within the laser laboratory could cause damage to equipment or injury to personnel.

Jewelry

The use of jewelry (watches, rings etc.) is often an overlooked source of exposure to a beam reflected by a mirror-like surface.

Ultraviolet Radiation

Either direct or reflected UV radiation from flash lamps and cw laser discharge tubes may cause eye injury. Usually, UV radiation is a problem only when quartz tubing or windows are used.

Visible Radiation (non-laser)

High luminance radiation emitted from unshielded pump lamps may cause eye injury. Potentially hazardous X-rays may be generated from high voltage (over 15kV) power supply tubes.

8.2.11 Laser Accidents

As with driving a car, accidents with lasers can happen to anyone, despite their experience. Of course, adherence to safety precautions reduces the chance of an accident occurring. In most cases, accidents occur because proper eyewear was not worn. All suspected overexposure to laser radiation must be reported immediately to the Investigator, in most cases medical examination will be required. An accident report, available from the Lab Manager, must also be completed.

APPENDIX 8-A

Cole Science Center
Laser Registration Form

Investigator: Date:

Telephone #: Email Address:

Laser Location:

Manufacturer's Make and Model:

Lasing Medium:

Number of Devices:

Power/Energy Level Output:

Mode of Operation:

Brief Description of Experimental Use:

_____
Investigator Signature

_____
Date

APPENDIX 8-B

OUTLINE FOR LASER SAFE OPERATING PROCEDURES (LSOP)

The following outline is to be followed in preparing a Laser Safe Operating Procedures (LSOP). The LSOP is to include all lasers in a laser system, including alignment lasers. The LSOP must be reviewed annually.

I. INTRODUCTION

1. Location of laser or laser system (site, building, room).
2. Diagram of area layout (attachment).
3. Description of (each) laser, including classification, lasing medium, and beam characteristics.
4. Purpose/application of beam(s).

II. HAZARDS

1. Identification of the hazards (beams, electrical, chemical, etc.).
2. Analysis of hazards (target area, absorbing media, beam path, severity of potential accidents, etc.).
3. Identification of Nominal Hazard Zone (NHZ) of all beam paths if applicable (see Section M).
4. Identification of additional hazards during maintenance and service.
5. Laser warning sign description.

III. CONTROLS

1. Engineering Controls including:
   - Access controls (key-lock, enclosures, shutters, and stops)
   - Beam controls (door interlocks, signs, and signals)
   - Electrical controls (light on power supply, HV signs)
2. Administrative Control
3. Protective Equipment
4. Other Controls

IV. OPERATING PROCEDURES

1. Initial preparation of laboratory environment for normal operation (key position, warning lights on, interlock activated, and identification of personnel).
2. Personal protection requirements (eyewear, protective barriers).
3. Target area.
4. Countdown procedures.
5. Shutdown procedures.
6. Special procedures (alignment, safety tests, interlock bypass, emergency, etc.).

V. TRAINING

1. User training program.
2. Training for maintenance and repair personnel.

VI. RESPONSIBILITIES

1. Supervisory (include emergency contact).
2. Users and support personnel.

VII. MISCELLANEOUS

1. Rules for visitors during laser operation.
2. Procedures in case of accident.

APPENDIX 8-C

LASER SAFETY TRAINING

I. TRAINING REQUIREMENTS

The Investigator provides laser Safety Training to all Users of Class 2, 3a, 3b and 4 lasers. It covers both general laser safety concepts and laser-specific training. Basic concepts covered must include:

- Laser Classification
- Safety Requirements and Control Measures
- Biological Effects
- Protective Equipment
- Warning Signs and Labels
- Associated Non-Beam Hazards

The content of laser-specific training must be specified in the LSOP. Laser-specific safety training must include demonstration and observed practice of laser use including:

- operation and control measures
- special hazards and precautions
- safe practices specific to the laser(s)

Upon completion of Laser Safety Training, the Investigator will authorize the user for laser use, with or without restrictions. This authorization must be documented using the "Authorized Laser User Certification" form (Appendix 8-D).

II. DEFINITIONS

Authorized Laser User: An individual who has met all applicable laser safety training, medical surveillance, and approval requirements for operating a laser or laser system.

Aversion Response: Movement of the eyelid or the head to avoid an exposure to a noxious stimulant or bright light. It can occur within 0.25 sec, including the blink reflex time.

Continuous Wave (cw) Laser: 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 $\geq$ 0.25 sec is regarded as a cw laser.

Controlled area: An area where activity is controlled and supervised to protect from radiation hazards.

Diffraction: Deviation of part of a beam when the radiation passes the edge of an opaque obstacle.

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

Investigator: The faculty member who assumes responsibility for the control and safe use of a laser or laser system.

Laser: A device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. An acronym for Light Amplification by Stimulated Emission of Radiation.

Laser System: An assembly of electrical, mechanical, and optical components with includes a laser.

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

Nominal Hazard Zone (NHZ): The nominal hazard zone describes the space within which the level of the direct, reflected or scattered radiation during operation exceeds the applicable MPE.

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 less than or equal to 0.25 sec.

Specular Reflection: A mirror-like reflection.

III. LASER CLASSIFICATION

Each laser is classified according to the definitions of ANSI 136.1, Section 3.3. In addition to meeting the general requirements of 3.6.1, lasers must meet specific requirements based on laser class. Laser classifications are summarized descriptively below.

Class 1 denotes exempt lasers or laser systems that do not, under normal operating conditions, produce a hazard. Equipment such as laser printers that completely enclose the laser and laser beam is normally specified as Class 1.

Class 2 denotes low power visible-radiation lasers or laser systems. Visible cw HeNe lasers above Class 1, but not exceeding 1 mW radiant power, are common examples of this class. Because of the normal human aversion or blink response, which occurs in about 0.25 seconds, accidental injury is unlikely. Class 2 lasers may present a hazard if viewed directly for extended periods of time.

Class 3a denotes lasers or laser systems that normally do not produce a hazard if viewed for only momentary periods with the unaided eye. They may present a hazard if viewed using collection optics (e.g., telescope or binoculars). Visible cw HeNe lasers above 1 mW but not exceeding 5 mW radiant power are examples of this class. Class 3a lasers must be operated in a location where access to the beam can be controlled with the potential for viewing of the direct or specularly reflected beam minimized.

Class 3b denotes lasers or laser systems that can produce a hazard if viewed directly for less than 0.25 seconds. This includes intrabeam viewing or specular reflections. Except for the higher power Class 3b lasers, this class laser will not produce hazardous diffuse reflections. Visible cw HeNe lasers above 5 mW but not exceeding 500 mW radiant power are examples of this class. Class 3b lasers shall be used in areas where entry by unauthorized personnel can be controlled.

Class 4 denotes lasers or laser systems that can produce a hazard not only from direct or specular reflections, but also from a diffuse reflection. In addition, such lasers may produce fire and skin hazards. Class 4 lasers must be operated by authorized users in areas dedicated to their use.

Manufacturer classifications are based on the level of laser radiation accessible during intended operation of the laser. The hazard may be greater, and therefore require additional controls, when maintenance or service is being performed.

IV. LASER PROGRAM REQUIREMENTS

Section 8 of the Laboratory Safety Manual details requirements for use of lasers at the Science Center. Programmatic requirements include:

- registration with the Laboratory Safety Committee of all Class 3b and 4 lasers
- approval by the Laboratory Safety Committee of Laser Safe Operating Protocols (LSOPs) for all Class 3b and 4 lasers
- labeling all class lasers with the laser classification, type, and other information required by the American National Standards Institute (ANSI Z136.1)
- posting warning signs at use locations of Class 2, 3a, 3b, and 4 lasers as required by ANSI Z136.1

V. BIOLOGICAL EFFECTS OF LASER RADIATION

A. Eyes Effects

The brightness of a laser can exceed all other known natural and man-made light sources. The focusing effect of the cornea and lens of the eye can concentrate parallel rays from laser light by a factor of 100,000. Therefore, it is not surprising that the eyes are the most susceptible organ to laser light. Wavelengths in the infrared (IR) and ultraviolet (uv) range can cause corneal damage. Extremely low densities of pulsed lasers can cause retinal damage.

A continuous wave (cw) laser causes eye damage by thermal processes that overheat the absorbing tissue. The steady stream of photons is absorbed by tissue until the temperature rises above that of the eye's cooling capability. Eye surgeons use this thermal effect (under controlled conditions) when they "spot weld" detached retinas using argon or ruby lasers.

Pulsed lasers are more hazardous to the eye than cw, especially when the wavelength is in the ocular focus region. Pulsed lasers cause "blast (mechanical) damage" if the pulse duration is low. The pulse durations are so short that little or no thermal conduction occurs during the length of the pulse.

B. Skin Effects

Skin damage from laser radiation is not as significant a hazard as eye damage; skin injury can normally be treated similarly to treatment for a thermal burn or wound. Also, for those beams that the power or energy density is high enough to cause skin damage, the beam is usually enclosed, or some type of physical control is provided for personnel.

VI. SAFE LASER PRACTICES

The following control measures are recommended as a guide to safe laser use. If any of these control measures cannot be accomplished, the LSOP must describe alternative controls to provide comparable protection. These practices are taken from ANSI Z136.1. Refer to that document for additional details.

The purpose of controls is to reduce the possibility of exposure to the eye and skin to hazardous laser radiation and to control other hazards associated with operation and maintenance of laser devices.

Engineering controls (physical features incorporated into the design or installation of the laser system) are the preferred method of control. If engineering controls are not feasible, then administrative and procedural controls and personal protective equipment should be used.

<u>Engineering Controls</u>

1. Protective housings should be provided for all classes of lasers.

2. Protective housings that enclosed Class 3b or 4 lasers should have an interlock system that is activated when the protective housing is opened.

3. Enclosure of the laser equipment or beam path is the preferred method of control.

4. Service access panels intended to be removed by service personnel only and which permit direct access to laser radiation associated with Class 3b or 4 lasers should either be interlocked or require a tool for removal and have an appropriate warning sign.

5. Class 3b lasers should be provided with a master switch. Class 4 lasers must have a master switch. The master switch should be operated with a key or coded access (e.g., computer code).

6. Lasers with viewing portals should have means (interlock, filter, and attenuators) to maintain laser radiation below the MPE.

7. The laser should be set up so that the beam path is not at normal eye level, i.e., so it is below 4.5 feet and above 6.5 feet.

8. All collecting optics intended for viewing use should incorporate means to maintain laser radiation transmitted through the collecting options to levels below the MPE.

9. Class 3b lasers should be provided with a remote interlock connector. Class 4 lasers must be provided with a remote interlock connector. The interlock connector provides electrical connection to an emergency master disconnect or to a room, or area interlock.

10. Class 3b lasers should be provided with a permanently attached beam stop attenuator. A Class 4 laser must be provided with such an attenuator.

11. An alarm, warning light, or verbal countdown command should be used with a Class 3 laser and must be used with a Class 4 laser to signal activation. For Class 4 lasers there must be an emission delay to allow action to be taken to avoid exposure.

12. When possible, Class 4 lasers should be fired and monitored from a remote position.

Administrative and Procedural Controls

1. In applications using Class 3b or 4 lasers with unenclosed beam paths, the Nominal Hazard Zone (NHZ: space within which the level of direct, reflected, or scattered radiation during operation exceeds the applicable MPE) must be established. A laser controlled area must be established in this zone, and appropriate control measures established.

2. Class 3a, 3b and 4 lasers must only be operated and maintained by authorized Investigators and Users. Student users must be directly supervised when using Class 4 lasers.

3. LSOPs are required for all Class 3b, and 4 lasers.

4. User Training is required for all Class 2, 3a, 3b, and 4 lasers.

Recommended Work Area Controls

1. Entry controls must prevent unauthorized people from being present when the laser is energized or about to be energized.

2. The illumination in the area should be as bright as practicable in order to constrict the eye pupils of users.

3. The potential for specular reflections should be minimized by shields and by removal of all unnecessary shiny surfaces.

4. Windows to hallways or other outside areas should be provided with adequate shades or covers.

5. The main beams and reflected beams should be terminated by material that is non-specular reflective and fireproof. Note that this is required for any accessible laser for which the MPE could be exceeded.

6. The active laser never should be left unattended unless it is part of a controlled environment.

7. Good housekeeping should be practiced to ensure that no device, tool, or other reflective material is left in the beam.

Recommended Laser Use Controls

1. The manufacturer's recommendations for safer laser use must be followed unless alternative methods are described and approved in the LSOP.

2. Avoid looking into the primary beam at all times.

3. Do not aim the laser with the eye; direct reflections can cause retinal damage.

4. Avoid looking at the pump source.

5. Clear all personnel from the anticipated path of the beam.

6. Before operating the laser, warn all personnel and visitors of the potential hazard, and ensure all safety measures are satisfied.

7. Be especially cautious around lasers that operate at invisible light frequencies.

8. Do not wear bright, reflective jewelry or other objects.

Laser Protective Equipment

Normally, all persons who work in areas where there is radiation from Class 3b or Class 4 lasers shall wear approved laser eyewear if the potential exists for exposure in excess of the MPE. Exceptions may be approved if wearing protective eyewear produces a greater safety hazard than when it is not worn. Exceptions shall be described in the LSOP or and approved by Safety Committee. The eyewear to be used will depend on the wavelength(s) and intensity of the accessible radiation. Keep in mind:

- No matter how good the glasses, no protection is provided unless worn.

- All safety glass may shatter, and all plastic lenses may melt when maximum irradiance or radiant exposure for the particular lens is exceeded.

- Laser safety glasses may not provide eye protection with other than the laser for which they are specified, unless the frequency produced is the same and power output is not greater.

In some cases, other protective equipment, such as clothing to protect the skin, may be required. Such requirements are addressed in LSOP.

VII. LASER EYE PROTECTION

Engineering controls such as enclosed beam paths and enclosures are far more preferable than using filter goggles and spectacles for eye protection. However, safety goggles and spectacles are often an effective safety measure when engineering controls are not possible. It should be noted that the user must be careful that the filter material and the side shields can withstand the maximum irradiance encountered in the laser environment for at least 3 seconds, and filter is of required optical density.

VIII. NON-BEAM HAZARDS

Laser operators sometimes overlook non-beam hazards as a potential source of accidents. While the laser community has stressed ocular and skin hazards, the non-beam hazards have generally not been as thoroughly considered. Some of the more common non-beam hazards are the following:

Atmospheric Contamination

1. Vaporized target material: contaminants may include carbon monoxide, ozone, lead, mercury, and other metals.

2. Gases from flowing gas lasers or byproducts of laser reactions such as fluorine, hydrogen-cyanide, and many others.

3. Gases or vapors from cryogenic coolants.

Chemicals

Chemicals, including dyes and solvents, from certain dye lasers have been shown to be carcinogenic, toxic, or otherwise hazardous.

Cryogenic Coolants

Cryogenic liquids, such as liquid nitrogen or hydrogen, may cause burns.

Electrical Hazards

The potential for electrical shock is present in most laser systems. Pulsed lasers utilize capacitor banks for energy storage and cw lasers generally have high voltage DC or RF electrical power supplies.

Explosive Hazards

The potential exists for explosions at capacitor banks or optical pump systems during the operation of some high power lasers. Explosive reactions of chemical laser reactants or other gases used within the laser laboratory could cause damage to equipment or injury to personnel.

Jewelry

The use of jewelry (watches, rings etc.) is often an overlooked source of exposure to a beam reflected by a mirror-like surface.

Ultraviolet Radiation

Either direct or reflected from flash lamps and cw laser discharge tubes may cause eye injury. Usually, ultraviolet radiation is a problem only when quartz tubing or windows are used.

Visible Radiation (non-laser)

High luminance radiation emitted from unshielded pump lamps may cause eye injury. I. X-rays - Potentially hazardous X-rays may be generated from high voltage (over 15kV) power supply tubes.

IX. LASER ACCIDENTS

As with driving a car, accidents with lasers can happen to anyone, despite their experience. Of course, adherence to safety precautions reduced the chance of an accident occurring. In most cases, accidents occur because proper eyewear was not worn. All suspected overexposure to laser radiation must be reported immediately to the Investigator, in most cases medical examination will be required. An accident report, available from the Lab Manager, must also be completed.

APPENDIX 8-D

AUTHORIZED LASER USER CERTIFICATION

User Name: _____ Investigator Name:_____
(print) (print)

Date of Birth: _____

Description of Laser(s) on which User is certified, include Class and location:

TRAINING CERTIFICATION

I have received training in the use of the laser described above. This training included both general laser safety concepts, included the following topics, and laser-specific training.

* Laser Classification
* Biological Effects
* Medical Surveillance
* Associated Non-Beam Hazards
* Safety Requirements and Control Measures
* Protective Equipment
* Warning Signs and Labels

Laser-specific safety training included demonstration and observed practice of laser use including:

* operation and control measures
* special hazards and precautions
* safe practices specific to the laser(s)

User Signature: _____ Date of Training: _____

USER CERTIFICATION

_____ is certified to use the laser(s) described above in accordance with the Laser Safe Operating Protocol (if required) and Investigator established laser operating procedures. Laser use is subject to:

_____ no restrictions
_____ the following restrictions:

Investigator Signature: _____ User Signature:_____

Date of Certification: _____

Certification Expires: _____
(Class 3 and 4 laser users must be recertified every 2 years)

Give a Copy of this Certification to the Laboratory Manager