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.

Engineering Controls

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.

<u>Administrative and Procedural Controls</u>

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.

<u>Recommended Work Area Controls</u>

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.