Boston College
Environmental Health and Safety

LASER SAFETY PROGRAM

I. PURPOSE:

The purpose of this guideline is to:

• identify potential hazards to health and safety associated with lasers, laser systems, and laser operations and to prescribe suitable means for the evaluation and control of these hazards

• provide guidance for compliance with applicable State and federal regulations and other applicable technical standards,
and to

• indicate specific responsibilities and activities for laser safety, training, medical evaluation, and job assessment.

The hazards associated with the use of lasers can range from minimal to extreme depending on the operating parameters and power levels. It is very important that each laser system is thoroughly evaluated by trained professionals before they are placed in use, that operators are trained regarding laser hazards and safe practices, and that engineered and administrative controls for the safe use of the individual systems are in place before any system is operated.

II. REGULATORY FRAMEWORK

Although few federal regulations have been written for the use of lasers there have been several lengthy and detailed standards governing their safe use. The primary standards include those published by the American National Standards Institute, the Commonwealth of Massachusetts, and the Federal Government. Other standards include those issued by such agencies as the Food and Drug Administration and the World Health Organization. The most comprehensive standard in use is the American National Standards Institute Z136.1 for the safe use of lasers. This document provides a basis for definitions regarding laser terminology, methods of hazard evaluation, control measures, medical surveillance, criteria for eye and skin exposure, and guidelines for conducting laser measurements.

The Massachusetts Department of Public Health has promulgated regulations for the safe use of laser in 105 CMR 121.000 "The Use of Laser Systems, Devices or Equipment to Control the Hazard of Laser Rays or Beams. This document has set requirements for registration of lasers within the State and for training of laser workers, and medical eye examinations.

The federal document 21 CFR 1040 sets requirements for the manufacture of lasers. Performance requirements are written for protective clothing, safety interlocks, remote controls, key control, emission indicators, beam attenuators, control locations, viewing optics, labeling, and product information. Typically these regulations apply primarily to the manufacture of lasers. However, the laser standards provide a solid basis for a laser safety program and provide goals for laser equipment being used in the field.
This program complies with:
• 21 CFR Subchapter J Part 1040, "Performance Standards for Light-Emitting Products"

• 105 CMR 121.000, "The Use of Laser Systems, Devices or Equipment to Control the Hazard of Laser Rays or Beams", and

• ANSI Z-136.1, "ANSI Standard for the Safe Use of Lasers".

• 29 CFR 1926.54 "Nomionizing Radiation".

BACK TO TOP OF PAGE

III. RESPONSIBILITIES

A. Laser Safety Committee

The Boston College Radiation Safety Committee is responsible for the establishment and continuing review of an adequate radiation protection program at the College. The Committee is also responsible for the College's compliance with radiation protection regulations promulgated by the state , Federal, and local agencies for both ionizing and nonionizing radiation.

A Laser Safety Subcommittee of the Radiation Safety Committee has been designed to ensure adequate protection and controls for Laser hazards at the College. This committee is comprised of the Radiation Safety Officer, Associate Radiation Safety Officer, Director of Environmental Health and Safety, and appointed members from various B.C. departments.

B. Environmental Health and Safety

Environmental Health and Safety (EH&S) is responsible for developing and maintaining a comprehensive laser safety program. These activities include the following items:

1. Identification and dissemination of program requirements

2. Registration of lasers and laser workers to include suspension, restriction, or termination of laser operations if a laser hazard exists

3. Evaluation of laser system hazards

4. Recommendations for laser safety including administrative controls, engineered devices, and personnel protective equipment.

5. Laser safety training

6. Coordination of baseline medical eye examinations

7. Designation of a qualified Laser Safety Officer to implement the Laser Safety Program as stipulated by the Laser Safety Committee

8. Maintenance of laser safety records

9. Investigation of laser safety accidents

10. Review and approval of laser operational procedures, and

11. Ongoing surveillance and inspection of laser installations to ensure compliance with program requirements.

C. Project Departments

Each department with lasers is responsible for complying with this laser safety program to include the following items:

1. Registering of all lasers with EH&S

2. Scheduling laser system evaluations with EH&S

3. Informing EH&S of any major changes in the operating conditions of a registered laser system or purchase of any new laser systems

4. Maintaining an up-to-date list of all laser workers in the department

5. Ensuring that all department laser workers attend EH&S laser safety training

6. Providing "hands on" training to department laser workers

7. Ensuring that all laser operators obtain medical eye examinations,

8. Purchasing and providing all engineered, administered, and personnel protective devices recommended by the EH&S safety evaluation, and

9. Developing and posting Standard Operating Procedures for the safe use of Department laser systems.

D. Laser Workers

Any individual associated with the operation, administration, or maintenance of lasers or laser systems is responsible for complying with relevant portions of this laser safety program. Specific requirements are categorized into the following two job functions:

Laser Operators - Personnel who are directly involved with the operation of lasers or associated systems. This may include normal operations when the beam may be totally enclosed, performance of engineering analyses, and laser system administration or supervision. Particular emphasis is placed upon those laser operators who are involved with beam alignment and use of open beam systems.

Laser Operators are responsible for complying with all aspects of this laser safety program to include the following activities:

1. Attendance at EH&S laser safety training

2. Obtaining a Medical laser eye examination

3. Development of laser safety protocols for the laser systems that they are responsible for

4. Compliance with all laser safety controls recommended by EH&S
Laser Maintenance Laser maintenance personnel are those individuals that are involved in the maintenance of laser systems that do not work with the systems in an energized state. These may include electricians, mechanics, hydraulics engineers, plumbers, etc.

Boston College personnel who perform maintenance on B.C. laser systems are responsible for the following safety related activities:

1. Attendance at EH&S laser safety training

2. Compliance with EH&S laser safety program requirements and other applicable safety requirements for associated hazards such as; chemical, fire, and radiation.

E. Health Services

Health Services is responsible for providing baseline medical eye examinations for all Laser Operators prior to their assignment to a laser laboratory and upon termination of employment or study at BC. "The

BC Policy for Laser Eye Exams" is provided in Appendix B. Eye examination protocols shall include evaluation of ocular history, visual acuity, macular function, contrast sensitivity, and ocular fundus. Periodic eye examinations are not required however, examinations shall be conducted immediately after any suspected overexposure to laser radiation or eye injury.

BACK TO TOP OF PAGE

IV. LASER OPERATIONS

The term LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. This is a process whereby some type of active medium such as a gas, solid state semiconductor, or a liquid is enclosed in a vessel. When some form of excitation mechanism or energy source is applied, such as light, electric current, or chemical reaction, some of the orbital electrons of the active medium inside the vessel become excited and move to a higher energy state. At some point the lasing medium absorbs so much energy and so many electrons are in the excited state that a population inversion occurs. This means that some of the high energy electrons decay back down to the lower energy state through a stimulated emission of a visible or invisible photon. The wavelength, frequency, and energy of this photon will depend upon the types of gases used in the active medium, the power level and the pulse duration. A diagram representing the processes of stimulated emission or radiation is shown on Figure 1:

Figure 1.
Three Level energy diagram - one of the many possible sets of energy level transitions that can result in laser action. An absorbed photon (pumping energy) results first in an electron in an excited state at e1. However, the emitted laser photon energy corresponds to e2 -e0 since e2 is the longer-lived (metastable) level.

Once the population inversion is achieved, the spontaneous decay of a few electrons from the energy level to a lower energy level starts a chain reaction via a feedback mechanism. The photons emitted spontaneously hit other atoms without being absorbed and stimulate their electrons to make the transition from the metastable energy level to the lower energy levels, emitting photons with precisely the same wavelength, phase and direction.

When this reaction is produced in an optical cavity with high reflectance mirrors on each end, the chain reaction continues and the number of photons emitted tends to continue to increase. When one of the mirrors has a small point where the mirror is only partially reflective then a laser beam will emerge. This beam then passes through an output coupler which focuses and aligns the beam as it emerges from the laser. A diagram of a laser optical cavity is shown on Figure 2:

Figure 2.
Diagram of Laser Optical Cavity

BACK TO TOP OF PAGE

V. LASER CHARACTERISTICS

The emerging laser beam takes on some special properties because of the way it is produced. Besides being very powerful, the beam is also monochromatic, directional, and coherent. By monochromatic we mean that the light emitted tends to be one color. In actuality it is one wavelength specific to the active medium and the stimulated emission photon so it may also be invisible and not really a visible color. But this phenomenon is special in that the light is not white, or polychromatic as would be emitted from an incandescent bulb.

Another special characteristic of the laser beam is that it is directional. As the beam is emitted from the output coupler it is moving in one direction and it tends to stay in this mode as it moves through most mediums with very little divergence of the emitted beam.

The last attribute of the laser is that the beam is coherent. This means that the photon waves tend to be in phase. This is one reason that so much energy and power can be condensed into one a powerful beam.

As can be seen by the electromagnetic spectrum the visible range of possible laser emissions is somewhat narrow when compared with other possibilities in the infrared and ultraviolet ranges of laser emission wavelengths. Laser emissions can be extremely hazardous even if they can not be seen. Lasers that are not visible to the naked eye can be even more dangerous than those in the visible ranges.

BACK TO TOP OF PAGE

VI. TYPES OF LASERS

There are two general types of lasers. One is the type of laser that generates a continuous wave of light which is emitted as a steady beam. This type of laser has a peak power equal to the average power output and the beam irradiance is constant with time. The second type of laser is the pulsed laser. The pulsed laser has a mode of operation which consists of a series of laser pulses with pulse periods ranging from a few picoseconds to seconds.

For each type of laser the hazards are different depending upon the wavelength, the output power, and the pulse duration and frequency. The wavelength is an important consideration because this is the property affecting the lasers ability to penetrate materials and it determines with which part of the eye it is most likely to interact. The wavelength will also determine if the beam is visible or invisible to the naked human eye. Protective eyewear or barriers need to specifically address the wavelength or wavelengths of interest. For example, a protective goggle that provides adequate protection for a helium neon (HeNe) laser with a wavelength of 632 nm may not be effective for a Nd:YAG laser with a wavelength of 1064 nm.

For continuous lasers and repetitively pulsed lasers the average power and exposure duration are the primary factors in determining the laser hazard level. To effectively evaluate pulsed laser safety the following items must also be considered; Total Energy per Pulse, Peak Power, Pulse Duration, Pulse Repetition Frequency, and Radiant Exposure.

BACK TO TOP OF PAGE

VII. LASER HAZARDS

The output power is directly related to the hazard classification of the laser in that it provides an indication of the radiant energy and radiant power that may be transferred from the laser to the eye. To a lesser extent the Irradiance (radiant energy incident on the point element of a surface), and Radiant Exposure (time integral of the irradiance) are also useful in determining laser hazards.

Depending on the combination of the factors mentioned here a Laser is classified according to its potential hazard. Hazard classifications include Class I, Class II, Class IIIa or IIIb, and Class IV. Class I lasers in general, are lasers that emit very low laser power levels and have not been shown to be capable of causing any biological damage. Class II lasers also emit very low power levels, typically less than a milliwatt of continuous power, but they could cause eye damage after direct long term exposure. Momentary exposure to a Class II laser beam is not hazardous to the eye. Class IIIa lasers, may cause eye damage if the beam is viewed directly or with optical instruments for even a short time. Class IIIb lasers can produce radiation powerful enough to injure human tissue with just one short exposure to the direct beam or even to a reflection of the beam off a shiny surface (Specular Reflection). Class IV lasers are the most hazardous and can cause injury to the eye or skin with momentary intrabeam exposure or even to diffuse reflections from rough surfaces or smoke screens.

Eye: Corneal or retinal burns are possible from acute exposure. The location and extent of injury is dependent upon the classification of the laser based upon a number of parameters to include; power, wavelength, beam diameter, frequency, etc. Corneal opacities (cataracts) or retinal injury may also be possible from chronic exposures to excessive levels.

Skin: Skin burns are possible from acute exposure to high levels of laser radiation in the infrared spectral region. Erythema (skin reddening), skin cancer, and accelerated skin aging are possible in the ultraviolet wavelength range.

Laser characteristics and capabilities to injure personnel

The assigned laser classification is the primary means of determining its capability of causing personnel injury. Manufacturers are required to provide a laser classification for commercial lasers and laser systems manufactured after August, 1976. In all other cases EH&S will provide laser classifications for lasers manufactured in house for internal use.

In addition to the laser classification, engineering, administrative, and personnel protective devices to minimize hazards will be evaluated and identified by EH&S. Hazards evaluations require availability of all pertinent data from the manufacture to include a minimum of the following information:

1. power or energy output
2. beam diameter
3. beam divergence
4. pulse duration
5. pulse frequency- repetition rate
6. wavelength
7. beam profile, and
8. maximum anticipated exposure duration.

HARMFUL EFFECTS OF LASER EXPOSURE

Based upon the type of laser and the mode of operation including the power, there are several different damaging effects that they may cause. Possible laser exposure damage includes thermal, photochemical, acoustic, and chronic effects. Specific areas affected are the eye and the skin. Laser affects on tissue are dependent on the power density of the incident beam, the tissues ability to absorb the laser wavelength, the amount of time the beam is incident on any one spot, and the effects of circulation and conduction. Ocular hazards can be the result of three different types of exposures, these are direct, diffuse, and specular (see Figure 3). Direct exposures are those in which the beam hits the eye directly. Diffuse exposures are the result of the initial beam being reflected by some surface that is rough and tends to scatter the incident beam in several directions resulting in a general reduction in the power intensity of the beam in any one direction. Diffuse reflections may also include the reflection of a laser beam as it traverses through an area of smoke or steam. Specular reflections on the other hand are those reflections in which the power tends to be affected minimally, but the direction may change. These surfaces are highly reflective and absorb little of the beam.

Direct Intrabeam exposure.

Diffuse reflections.

Specular Reflections

Figure 3.
Types of Laser Reflections and Exposures
Injury to the eye is highly specific to the wavelength of the laser beam. The eye (as shown on Figure 4) is a complex organ which collects light and receives a visual image to send to the brain for processing. The cornea is the part of living tissue that is exposed to the environment and is the first part of the eye that is exposed to an incident laser beam. Between the cornea and the lens is the aqueous. This material seems to absorb some wavelengths of ultraviolet and infrared radiation and is used to help maintain constant temperature and pressure levels in the eye. The iris is a heavily pigmented layer of muscle tissue in the eye which adjusts the size of the pupil from approximately 2 mm to 7 mm depending on the level of brightness being viewed by the subject. Upon exposure to a very bright light a dilated pupil will constrict in about 20 ms. The lens is a relatively clear and crystalline substance which focuses incident light and transmits it back to the retina for processing. The light is transmitted through the vitreous, a gel-like fluid, to the retinas' photoreceptor cells, the rods and cones. The fovea is a location on the retina that has an unusually high number of receptors. Images are sent to the brain via the optic nerve.

Figure 4
The general structure of the eye showing the principal structures referred to in this text. This cross-section is for a horizontal section as seen from above for a standard left eye. The physical dimension and optical parameters based upon the Gullstrand normal eye are given in Appendix B.

The laser radiation wavelength determines where the beam will interact with the eye anatomy. The anatomy of the eye affected by laser light incident on the eye depends upon the wavelength. For example, Far Ultraviolet and Far Infrared wavelengths each tend to be absorbed by the initial layers of the eye, either in the cornea or aqueous. Visible light and near ultraviolet and near infrared wavelengths, on the other hand, pass through the cornea and lens to directly impact with the retina.

Another phenomena associated with laser light is that the eye tends to condense the already intense light as it focuses it onto the retina. Incandescent light from
an extended light source tends to be somewhat more diffuse as it hits the back of the eye and the retina. Eye damage occurs where the incident light is absorbed (see Figure 5). For ultraviolet light in the wavelength ranges from 315 to 400 nm the prevalent effects are cataracts and presbyopia (farsightedness). For accidental exposure to UV light in the range from 100 to 315 nm the significant effects are keratoconjunctivitis and milky cornea. In the retinal hazard zone from 400 to 1400 nm eye injury can be in the form of either retinal damage with the negative impact on vision or on the fovea with an impact on acuity. Some of the visible affects of damaging laser light on the retina are seen by broken blood vessels in the retina and blood floating in the aqueous. In some cases the retina explodes and separates from the back of the eye. In extreme cases, and dependent to some extent upon probability, the area of the retina that is impacted with the laser light could be close enough to the fovea or optic nerve to cause serious or permanent damage and blindness.

Figure 5

Absorption and Transmission of Laser Light by Components of the Ocular System

Eye damage from an overexposure to laser light includes burns and often times the breaking of capillaries or other blood vessels. Damage may be visible on the outside of the eye or it may only be seen by an ophthamologist on the inside of the eye in the form of retinal damage. Depending on the extent of the injury and exact locations of interaction, the eye can make repairs to this type of damage. Potential long term affects include loss of visual acuity, and possible loss of sight in the eye.

Skin exposures to laser light may lead to either acute or chronic skin injury. Acute injury is probably the easiest type to understand. The effects are either thermal, leading to localized burns or photochemical contributing to erythema which is localized skin reddening much the same as sunburn. Both of these types of over exposures can be extremely painful and hazardous. Chronic skin injuries can result from prolonged skin exposure over long periods of time at exposure levels that are to low to induce an acute response. Chronic exposures can lead to increased incidence of photochemical responses that lead to early aging, or in the case of ultraviolet light exposures, can cause skin cancer.

OTHER SAFETY CONCERNS

Other safety considerations that may go into the assessment and evaluation of laser hazards include the following items; electrical hazards, skin exposure hazards, chemical and associated gas hazards. Some other special considerations include whether the laser is enclosed in an engineered system of protection, if the beam is invisible, if maintenance repair and modifications will be necessary on a routine basis, and whether there is a potential for explosion, fire, or hazardous fumes.
Of all the ancillary hazards mentioned here, the electrical are the most significant. There have been several electrocutions in the U.S. from laser related electrical accidents. General guidelines to prevent electrical shock include; not wearing metal jewelry when working with lasers, using only one hand to work on circuits, assuming that all floors are conductive when working with high voltage, checking that capacitors are discharged, shorted and grounded before allowing access to the capacitor area, periodically checking containers for deformities and leaks, using rubber gloves and insulating floor mats when available, not working alone, and having easy access to main power shutoff. It is also good practice to have at least a few personnel in the work are that are trained and certified in cardiopulmonary resuscitation (CPR) in the event that this form of first aid is needed.

Some chemicals used in laser systems may be hazardous or toxic substances. Also, laser induced reactions may produce hazardous particles or gases that need to be vented out of the work area. Fire hazards may be presented by flammable solvents used in dye lasers. Ignition may occur via high voltage pulses or flash lamps. Direct beams and unforeseen specular reflections of high-powered CW infrared lasers are capable of igniting flammable materials. Other potential fire hazards include electrical components and Class IV laser beam enclosures.

The basic hazards associated with the operation of lasers are provided in the following categories:

Solvents used in dye lasers are extremely flammable. Ignition may occur via high voltage pulses or flash lamps. Direct beams and unforeseen specular reflections of high-powered CW infrared lasers are capable of igniting flammable materials. Other fire hazards are associated with electrical components and the flammability of Class IV laser beam enclosures.

Ionizing radiation may also be a concern with laser safety. X-rays may be generated from high voltage power supplies and transformers associated with laser systems.

Other hazards which may be associated with the operation of high power laser systems include cryogenic coolant hazards or excessive noise from high powered systems.

As lasers are registered with EH&S hazard evaluations and inspections will be performed to identify appropriate safety controls. Aspects of a laser system that influence the hazard evaluation include but are not limited to the following items:

BACK TO TOP OF PAGE

VIII. LASER CLASSIFICATION

In accordance with the ANSI Standard Z136.1 laser hazard classifications have been developed in order to standardize evaluations and associated safety controls. The following list is a summary of hazard capabilities and the laser class:

LASER Class Hazard Capabilities

Class I Cannot produce hazardous levels of radiation.

Class II Continuous intrabeam exposure damages the eye. Momentary intrabeam exposure (= 0.25 seconds) is not damaging to the eye. Visible radiation wavelengths only.

Class IIa Continuous intrabeam exposure damages the eye. The accessible radiation shall not exceed Class I AEL for and exposure duration = 103 seconds.

Class IIIa Eye damage may occur if the beam is viewed directly or with optical instruments.

Class IIIb Eye and skin damage will occur for direct, momentary intrabeam exposure.

Class IV Produces hazardous direct or specularly reflected beams, may be a fire hazard or produce a hazardous diffuse reflection.

Certified laser manufacturers are required to label their products as to the Class type as of September 19, 1985 (10 CFR Part 1040).

BACK TO TOP OF PAGE

IX. CONTROL MEASURES

A. General

Based upon laser hazard evaluations performed by EH&S additional safety controls may be warranted. It will be the responsibility of the project departments to implement all of the proposed control features for each laser or laser system to the satisfaction of the EH&S.
Control measures or systems will be used to reduce the possibility of eye and skin exposures to hazardous amounts of laser radiation and to other hazards associated with laser operations. The required safety features will apply to both normal operating conditions, alignments, and to maintenance activities.

Laser control measures include the following items and activities; Engineering Controls, Administrative and Procedural Controls, Personnel Protective Equipment, Warning Signs and Labels, and special considerations. Engineering controls are the most important because they remain constant or fixed in place and ideally can not be bypassed. Laser operations should always be enclosed to the greatest extent possible. Accessways or enclosures should be interlocked whenever practical so that the emission will be shut down whenever the access is opened. Other laser engineering controls include beam enclosures, panic buttons, key switches, and beam stops. Administrative and procedural controls are the next most important safety controls. Administrative controls include the development of policy and procedures to ensure that entry to laser work areas is controlled, safe practices and protocols are developed and implemented, personnel are trained in general laser safety and receive hands-on training from project supervisors, and that all laser regulations and standards are being met in the laser safety program.

Given the laser classifications, there are specific laser hazard controls for each of the categories according to their hazard significance. Class I lasers require no controls and no user safety rules are necessary. Class II laser safety controls require that a person never stare into the laser beam. Only prolonged exposure to the beam presents a potential for damage. Class IIIa lasers require basic engineering controls to enclose as much of the beam as possible and prevent any inadvertent exposure to the beam by unauthorized users. Additional controls for Class III lasers may include caution labels and warning signs for laser work areas. Class III lasers also require the development of administrative procedures regarding the safe operation of the system. Class IIIb lasers require danger warning labels and more stringent engineering controls such as safety system interlocks to prevent operation of the laser in the event that engineering enclosures are breached. Additionally, Class IIIb lasers require the consideration and use of personnel safety devices such as safety goggles or protective clothing. Any direct exposure to the Class IIIb laser beam is to be avoided. Class IV lasers present the most serious safety hazards and the engineering controls should ensure that they are only operated within a localized enclosure or in a controlled workplace. Eye and skin protection should be provided to all personnel working in the laser area. Remote firing and viewing techniques should be utilized whenever possible.

Laser hazard control measures can be designed and incorporated to address the most significant hazards. Control measures are designed to reduce the possibility of exposure to the eye and skin to hazardous levels of radiant laser energy and to the other hazards associated with the operation of the laser devices. One of the most important aspects of laser safety and control is to limit the laser power to the minimum level necessary to perform the intended task. ANSI standard Z136.1- 1993 Table 10, "Control Measures for the Four Laser Classes," should be used as a guideline in the development of safety controls (See Attachment D).

B. Engineering Controls

Engineering controls are the priority means of minimizing the possibility of accidental exposures to laser hazards. If engineering controls are impractical or inadequate, then safety should be supported through the use of administrative procedures and personnel protective equipment. Engineering controls that may prove useful and effective in improving the safety of a laser or laser system are provided in the following list:

1. Protective housings with interlocks and labels
2. Barriers, shrouds, and absorbent beam stops
3. Fail-safe interlock systems
4. System control master switches
5. Permanently attached beam stops and attenuators
6. Laser system status indicators and warning lights
7. Laser control area warning lights
8. Equipment labels and area warning signs and lights
9. Equipment grounding methods
10. Viewing portals, collecting optics, and display screens
11. Enclosed beam paths

12. Emission delays

Sample Laser Safety Warning Signs are provided in Figure 6.

Sample Warning Sign for Class 2 and Certain Class 3a Lasers

Figure 6
Laser Safety Warning Signs (continued on next page)

Sample Warning Sign for Certain Class 3a Lasers and for Class 3b and Class 4 Lasers

Figure 6
Laser Safety Warning Signs

C. Administrative and Procedural Controls

Administrative and procedural controls are methods and instructions which specify safety rules or work practices and which implement or supplement engineering controls and which may specify the use of personnel protective equipment. Administrative controls may include but are not limited to the following items:

1. Laser safe operating procedures
2. Maintenance and safety inspection programs
3. Laser registration and hazard evaluation

The operating conditions and alignment procedures must be clearly identified and described in procedures. These procedures must include safety controls and precautions to address this laser safety program. Safety controls must address the most significant hazards even if those conditions are only evident for a fraction of operating time. Description and analysis of the work environment submitted in Attachment A, "Application for Requisition of Laser Systems," must consider a minimum of the following items:

1. methods to limit access
2. the number of lasers and laser systems in one general work area
3. the degree of system isolation
4. the availability of engineered controls to restrict untrained personnel
5. variations in beam paths and power levels
6. the proximity of specularly reflective objects
7. the use of optics and lenses which could easily alter beam paths, wavelengths or beam diameter.
8. specific requirements for visitors

D. Personnel Protective Equipment

All personnel who work in areas where there is the is a possibility of being exposed to hazardous level of laser radiation are required to wear approved laser eyewear. Exceptions may be made in special cases if wearing protective eyewear produces a greater safety hazard than when it is not worn. Exceptions shall be noted in written procedures approved by EH&S. Laser eyewear requirements will be indicated by EH&S in the applicable laser hazard evaluation which coincides with each laser registration. EH&S will review and approve the use of all protective eyewear.

Flame resistant clothing may be appropriate for some laser installations where there is a possibility of either chronic or acute skin exposure. Loose-fitting clothing and long, loose hair could also be a hazard in a laser laboratory. Jewelry, including watches, should never be worn when working with lasers to minimize both the possibility of beam reflections and electrocution.

Personnel protective equipment includes eyewear, clothing, and gloves. The eye may be protected against harmful laser radiation by the use of protective eyewear that attenuates the intensity of laser light while transmitting enough ambient light for safe visibility (luminous transmission). The ideal eyewear provides maximum attenuation of the laser radiation while transmitting the maximum amount of ambient light. No single lens material is useful for all wavelengths or for all radiation exposures.

In choosing protective eyewear, careful consideration must be given to the operating parameters, Maximum Permissible Exposure, and wavelength. ANSI Z136.1 requires that protective eyewear be available and worn whenever hazardous conditions may result from laser radiation or laser related operations.

Eyewear is generally selected based upon the Optical Density O.D. for the given wavelength and power level and the degree of luminous transmission of the lens. Eyewear manufacturers include such companies as American Optical Company, UVEX, and the Kentek Corporation along with several others. Eyewear should always be labeled with information regarding the wavelengths for which they provide protection and what the optical density is for each wavelength. A reference on the label as to whether the eyewear meets the ANSI standards is also advisable.

Protective clothing can be used to reduce the level of chronic exposure to the skin from ongoing laser operations. More importantly, protective clothing and gloves that are flame resistant can be used to prevent an acute exposure to the skin and subsequent burns. Laser burns to the skin are similar to thermal or radiant (sun) burns. Jewelry should never be worn when working with lasers both because it presents a reflective hazard and an electrical hazard.

BACK TO TOP OF PAGE

X. LASER REGISTRATIONS

All class III and IV lasers shall be registered with EH&S on the Boston College Radiation Safety Office Attachment A, "Application for Registration of Laser Systems." This form shall be completed with all the required information and submitted to EH&S. The registration should include copies of the systems standard operating procedures including necessary safety requirements. After this form is received, the LSO will perform a laser hazard analysis, inspect the laser system and work area and complete the BC RSO Laser Radiation Survey Form, Attachment B. All laser systems must be registered and approved before purchase and instillation at BC.

XI. LASER SAFETY TRAINING AND WORKER REGISTRATION

A laser safety training program is developed and implemented by EH&S. The program is required for all laser workers and is also provided to personnel who may work around or near the lasers even though they may not work on operational lasers. Topics in the laser safety training program include the following categories:

1. Fundamentals of laser operation (physical principles, construction, etc.)

2. Bioeffects of laser radiation on the eye and skin,

3. Relations of specular and diffuse reflections,

4. Nonradiation hazards of lasers (electrical, chemical, etc.)

5. Laser and laser system classifications,

6. Control measures

7. Overall management and employee responsibilities, and

8. Medical surveillance practices. Training attendance will be documented on training sign-in forms and on the BC RSO Laser Worker Registration Form, Attachment C. Additional hands-on training will be provided by project supervisors in each of the specific laboratories. This training shall be documented by the project supervisor and records shall be maintained.

BACK TO TOP OF PAGE

XII. LASER PROTECTIVE EQUIPMENT MANUFACTURERS

American Optical Company
Safety Products Group
14 Mechanic St.
Southbridge, MA 01550
(617) 765-9711

Ealing Electro-Optics, Inc.
New Englander Industrial Park
Holliston, MA 01746
(508) 429-8370

Edmund Scientific Co.
101 E. Glouster Pike
Barrington, NJ 08007-1380
(609) 547-3488

Energy Technology, Inc.
PO Box 1038
San Luis Obispo, CA 93406
(805) 544-7770

Engineering Technology Institute
601 Lake Air Drive, Suite 1
Waco, TX 76710
(800) 367-4238
Fish-Schurman Corp.
PO Box 319
New Rochelle, NY 10802
(914) 636-1300

General Scientific Equipment Co.

525 Spring Garden
Philadelphia, PA 19123
(215) 922-5710

MWK Industries
198 Lewis Court
Corona, CA 91720
(800) 356-7714

Omicron Eye Safety Corp.
73 Main Street
Brattleboro, VT 05301
(802) 257-7363

Optical Coating Laboratory, Inc.
2789 Northpoint Parkway
Santa Rosa, CA 95407-7397
(707) 525-7709

Phase-R Co.
Box G-2
New Durham, NH 03855
(603) 869-3800

Rockwell Laser Industries
7754 Camargo Road
Cincinnati, OH 45243
(513) 271-1568

U.S. Laser Corp.
PO Box 609
825 Windham CT. N.
Wychoff, NJ 07481
(201) 848-9200

U.V.P., Inc.
PO Box 1501
San Gabriel, CA 91778
(818) 285-3123

UVEX Safety, Inc.
10 Thurber Blvd.
Smithfield, RI 02917
(800) 343-3411

Wilson Industries
South El Monte, CA
(818) 444-7781

BACK TO TOP OF PAGE