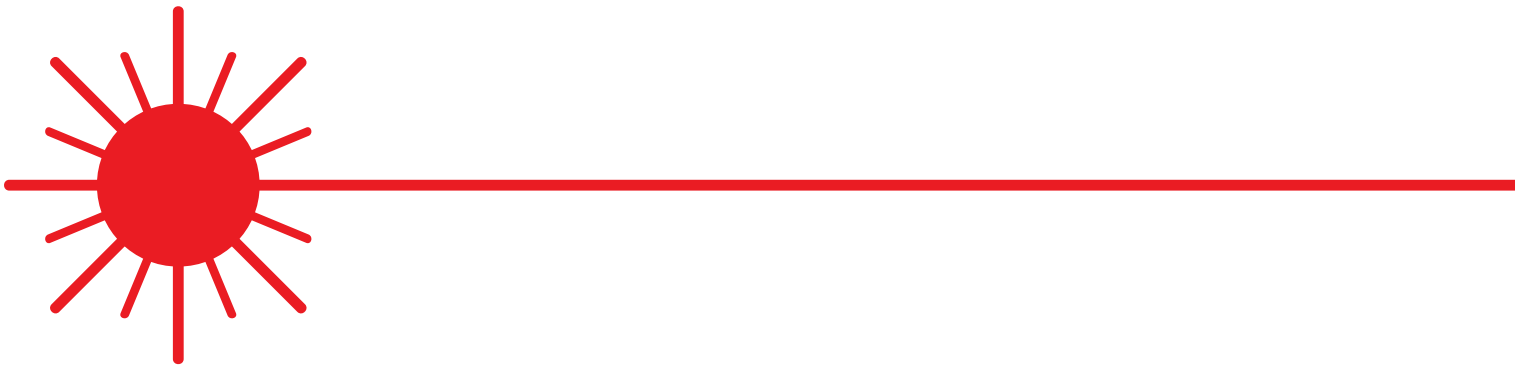
IOWA STATE UNIVERSITY

Laser Safety Manual



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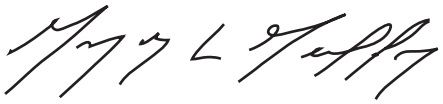
IOWA STATE UNIVERSITY
SAFETY POLICY

It is the policy of Iowa State University to provide and ensure a safe and healthful environment for employees, students and the general public.

Each person in a supervisory or management capacity is responsible for the provision and maintenance of safe working conditions in his or her respective area, and for proper adherence to all authorized and applicable environmental, health and safety policies, rules and regulations.

Each employee and student is responsible for complying with environmental, health and safety rules and for using any safety equipment that is provided or required. Each failure to comply with applicable rules, as well as environmental releases, safety hazards and accidents, shall be reported to supervisory personnel and, if necessary, referred to the proper environmental, health or safety authority.

It is the intent of this policy to promote environmental stewardship and prevent accidents and injuries to the Iowa State University community.



July 2001

Dr. Gregory L. Geoffroy
President
Iowa State University

A. INTRODUCTION

The Iowa State University Laser Safety Program is designed to ensure the safe use of lasers in research and the safety of all personnel and visitors who may be exposed to the radiation emitted by lasers.

The laser safety policy requires that all lasers and laser systems (whether purchased, borrowed, fabricated, or brought in for use by others) be operated in accordance with the requirements established by the latest American National Standards Institute (ANSI) Z136.1 document, *Standards for the Safe Use of Lasers.*

Most lasers are capable of causing eye injury to anyone who looks directly into the beam. In addition, reflections of high-power laser beams can produce permanent eye damage. High-power laser beams can also burn exposed skin and be the source of other potential dangers such as fire, electrical, and chemical hazards.

To properly implement this program and provide the greatest possible freedom to the laser user, laser operations at Iowa State University and Ames Laboratory are reviewed by the Department of Environmental Health and Safety (EH&S) or Environmental, Safety, Health, and Assurance (ESH&A), respectively. Also, copies of the ANSI Z136.1 and ANSI Z136.5 *Standards for the Safe Use of Lasers in Educational Institutions* can be reviewed at these safety offices.

B. RESPONSIBILITIES

EH&S and Ames Laboratory ESH&A

These safety departments will be responsible for:

- Maintaining inventory of all Class IIIb and Class IV lasers and verifying classification if necessary.
- Approving standard operating procedures, alignment procedures and other control measures before initial use.
- Ensuring that Class IIIb and Class IV lasers are inspected at least annually for compliance with safety requirements.
- Providing assistance in evaluating and controlling hazards.
- Updating the Laser Safety Manual.
- Maintaining records of Class IIIb and Class IV laser inspections.
- Participating in accident investigations involving lasers.
- Providing laser safety training.

Laser Operator

The laser operator is responsible for:

- Meeting all applicable requirements including training and medical surveillance before operating a laser.
- Operating lasers safely and in a manner consistent with this manual, applicable SOPs, and guidance from the Laser Safety Officer, or LSO (EH&S 4-7667 or ESH&A 4-4743).

Principal Investigator (PI)

The PI is responsible for:

- Assuming responsibility for ensuring each assigned laser is operated safely and in accordance with applicable requirements.
- Notifying his or her respective safety office of the intent to procure a laser, and providing required information for registration and safety reviews for lasers.
- Ensuring that each laser is stored securely and safely when not in use so that it is not usable by unauthorized personnel or under unauthorized conditions.
- Permitting only authorized laser operators to use the lasers.
- Providing an approved written SOP, if required, and ensuring that the laser is used only under conditions and in locations that meet the requirements of the SOP.
- Providing training specific to the laser for operators, in consultation with the respective safety office.

- Designating the newly trained operator to be a laser operator.
- Maintaining records of Class IIIb and Class IV laser training.

Department Chairperson

The Department Chairperson is responsible for:

- Ensuring all employees under their direction follow the applicable requirements and safe practices of this laser safety program including those specified in applicable SOPs.
- Ensuring the LSO is notified prior to the acquisition or fabrication of a new laser so that a preliminary safety review can be completed.
- Ensuring the LSO is notified prior to the operation of a new laser so that a final safety review or analysis can be completed.
- Assigning each laser to an individual and designating the PI who will be responsible for the safe storage and use of each laser. The respective safety office must be notified by the Department Chairperson whenever the laser is reassigned to a new PI.
- Assuring a safety review or analysis is conducted by the LSO prior to use whenever there is a change in location or conditions (such as modifications) which may affect the safe use of the laser.
- Assuring all laser operators complete applicable laser safety training and medical surveillance requirements before they are authorized to operate Class IIIb or Class IV lasers.

C. BASIC LASER CHARACTERISTICS

Laser radiation or light is coherent electromagnetic radiation characterized by one or more specific wavelength(s), the values of which are determined by the composition of the lasing medium. Laser radiation may be emitted in the visible portion of the electromagnetic spectrum (wavelengths of 0.4 micrometer (μm) and 0.7 μm) or in the invisible infrared and ultraviolet regions.

Laser radiation transmits energy which, when a laser beam strikes matter, can be transmitted, absorbed or reflected. Materials that transmit a laser beam are said to be transparent, whereas, materials that do not transmit a laser beam are said to be opaque and the incident radiation is either absorbed or reflected.

Absorption

Absorbed laser energy appears in the target material as heat. Absorption and transmission are functions of the chemical and physical characteristics of the target material and the wavelength of the incident radiation. At visible wavelengths, laser radiation impinging on the eye is focused on the retina and, if sufficient energy is absorbed, can cause cell destruction. At longer and shorter wavelengths, such as the far infrared and the ultraviolet regions, radiation striking the eye is absorbed in the cornea and the lens rather than being focused on the retina. Although these structures are less easily damaged than the retina, excessive energy absorption can cause cell damage and impairment of vision.

Reflection

Reflection is primarily a function of the physical characteristics of the surface of the target material. A smooth, polished surface generally provides a high-quality or specular reflection, whereas rough uneven surfaces are usually poor reflectors and produce a diffuse reflection. A reflector such as a flat mirror changes the direction of an incident beam with little or no absorption. A curved mirror or surface will change the divergence angle of the impinging laser beam as well as its direction.

For a diffuse reflection, the reflected energy is scattered in all directions thereby reducing the energy or power density. Generally, diffusely reflective surfaces are favored when designing a laser experiment, since their use reduces the likelihood of a specular reflection and thus enhances the safety of the experiment.

D. CLASSES OF LASERS

To provide a basis for laser safety requirements, all lasers and laser systems in the United States are classified according to the ANSI Z136.1 Standard and the Federal Laser Products Performance Standard. This laser classification is most often supplied by the manufacturer. Custom-built and modified lasers must be classified by the builder and verified by the Laser Safety Officer (LSO) (EH&S at 4-7667 or Ames Lab ESH&A at 4-2153). The ANSI Z136.1 Standard is enforced by the Occupational Safety and Health Administration (OSHA). The Laser Products Performance Standard is enforced by the Centers for Devices and Radiological Health (CDRH), a division of the Food and Drug Administration (FDA).

The following section describes the classification for continuous-wave lasers. The same hazard levels also apply to pulsed lasers with pulse duration of less than 0.25 s (second) but classification is more complex. See ANSI Z136.1 for details of the classification.

Class I Laser

Class I lasers are low-powered, completely enclosed lasers that do not emit hazardous radiation under normal operating conditions. Class I lasers are exempt from any control measures. Equipment such as laser printers and laser disc players are examples of this class.

Class II Laser

Class II lasers emit accessible, visible laser light with power levels less than 1 mW (one milliwatt) radiant power and are capable of creating eye damage through chronic exposure. The human eye blink reflex, which occurs within 0.25 s of exposure to the Class II laser beam, provides adequate protection. However, it is possible to overcome the blink response and stare into the Class II laser long enough to damage the eye. Consequently, Class II equipment housing lasers/laser systems must bear a label warning against staring into the beam. Equipment such as some visible continuous wave Helium-Neon lasers and some laser pointers are examples of Class II lasers.

Class IIIa Laser

Class IIIa lasers have power levels of 1 to 5 mW that normally would not produce a hazard if viewed only momentarily with the unaided eye. However, they pose severe eye hazards when viewed through optical instruments (e.g., microscopes, binoculars, or other collecting optics). Therefore, Class IIIa lasers must bear a label warning against direct eye exposure or viewing directly with optical instruments. Equipment such as some visible continuous wave Helium-Neon lasers and some solid-state laser pointers are examples of Class IIIa lasers. Lasers used as pointers in classrooms and auditoria

at Iowa State University are restricted and must not be greater than Class IIIa.

Class IIIb Laser

Class IIIb continuous wave lasers are ultraviolet, infrared or visible systems with power levels of 5 mW to 500 mW but cannot emit an average radiant power greater than 500 mW for $\geq$ 0.25 s or cannot produce a radiant energy greater than 0.125 J (joule) for a < 0.25 s exposure. Class IIIb pulsed lasers are visible or near infrared systems with power levels of 5 mW to 500 mW but cannot emit an average radiant power greater than 500 mW for $\geq$ 0.25 s or cannot produce a radiant energy greater than 0.03 J per pulse. These lasers are hazardous to the eye if viewed directly. This includes intrabeam viewing or specular reflections. Higher power lasers in this class will also produce hazardous diffuse reflections. Therefore, these lasers bear a sign warning against direct exposure to the beam. Specific control measures covered in Class IIIb lasers shall be used in areas where entry by unauthorized personnel can be controlled. Entry into the area by personnel untrained in laser safety may be permitted by the laser operator if entrants are instructed in applicable safety requirements prior to entry and are provided with appropriate protective eye wear. See section H for laser use requirements.

Class IV Laser

Class IV lasers are systems with power levels greater than Class IIIb. These lasers will produce eye, skin and fire hazards. This includes intrabeam viewing, specular reflections or diffuse reflections. Consequently, these lasers/laser systems bear signs warning against eye and skin exposure from direct or scattered radiation. See section H for laser use requirements.

Embedded Laser

Embedded lasers are found in laser products with lower class ratings. However, laser printers, CD players, and laser welders may have Class IIIb or Class IV lasers in their protective and interlocked housings. When such a laser system is used as intended, the lower laser class applies. When such a system is opened (e.g., for service or alignment) and the embedded laser beam is accessible, the requirements for the higher class laser must be implemented.

E. BEAM HAZARDS

The nature of laser beam damage and the threshold levels at which each type of injury may occur depend on the laser beam parameters. These include wavelength of light, energy of the beam, divergence and exposure duration. Pulse length, pulse repetition frequency and pulse train characteristics are additional parameters for pulsed lasers. The ANSI Z136.1 Standard establishes Maximum Permissible Exposure (MPE) limits for laser radiation. Damage can occur to the skin, retina, lens, cornea and conjunctival tissue surrounding the eye. For lasers over 0.5 W, the beam can ignite flammable materials and initiate a fire.

Thermal burn, acoustic damage and photochemical damage to the retina may occur from laser light in the near ultraviolet (UV), visible and near infrared (IR) regions (below 400 nm - 1400 nm). Damage occurs as the laser light enters the eye and is focused on the retina (see Fig. 1). Normal focusing of the eye amplifies the irradiance by approximately 100,000; thus, a beam of 1 mW/cm² results in an exposure of 100 W/cm² to the retina. Energy from the laser beam is absorbed by tissue in the form of heat, which can cause localized intense heating of sensitive tissues. The most likely effect of excess exposure to the retina is thermal burn, which destroys retinal tissue. Since retinal tissue does not regenerate, the damage is permanent and may result in the loss of sight in the damaged area.

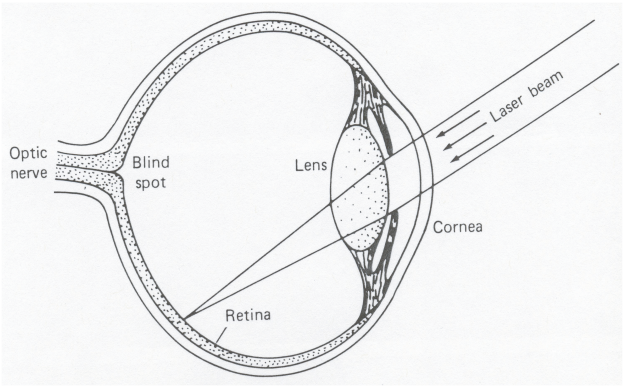


Fig. 1 Damage to the Retina Due to Laser Exposure

Intrabeam viewing of the direct beam and the specularly reflected beam are most hazardous when the secondary reflector is a flat and polished surface. Secondary reflections from rough uneven surfaces are usually less hazardous. Extended source viewing of normally diffuse reflections are usually not hazardous except for very high-powered lasers (Class IV). Extra care should be taken with IR lasers since diffuse reflectors in the visible spectrum may reflect IR radiation differently and produce greater exposures than anticipated.

F. ASSOCIATED HAZARDS

Beam hazards of a laser system are only one concern in using lasers. The other associated hazards described must be understood to ensure the safe use of a laser or laser system. Contact the LSO for specific training requirements associated with working around these hazards.

Electrical Hazards

The most lethal hazards associated with lasers are the high-voltage electrical systems required to power lasers. Several deaths have occurred when commonly accepted safety practices were not followed by those working with high-voltage sections of laser systems. The following is a list of recommended electrical safety practices.

- Do not wear rings, watches or other metallic apparel when working with electrical equipment.
- When working with high voltage, regard all floors as conductive and grounded.
- Do not handle electrical equipment when hands or feet are wet or when standing on a wet floor.
- Be familiar with electrocution rescue procedures and emergency first aid.
- Prior to working on electrical equipment, de-energize the power source. Lock out and tag out the disconnect switch.
- Check that each capacitor is discharged and grounded prior to working in the area of the capacitors.
- Use shock preventing shields, power supply enclosures and shielded leads in all experimental or temporary high-voltage circuits.

Chemical Hazards

Many dyes used as lasing media are toxic, carcinogenic, corrosive, or pose a fire hazard. All chemicals handled at Iowa State University must be accompanied by a material safety data sheet (MSDS). The MSDS will supply appropriate information pertaining to the toxicity, personal protective equipment and storage of chemicals.

Various gases might be exhausted by lasers or produced by targets. Proper ventilation is required to reduce exposure levels of the gas products to below acceptable limits. For further information contact your respective safety office.

Cryogenic fluids are used in the cooling systems of certain lasers. As these materials evaporate, they replace the oxygen in the air; thus, adequate ventilation must be ensured. Cryogenic fluids are potentially explosive when ice collects in valves or connectors that are not specifically designed for use with cryogenic fluids. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the

liquid oxygen comes in contact with any organic material. Although the quantities of liquid nitrogen used are small, protective clothing and face shields must be used to prevent freeze burns to the skin and eyes.

Compressed gases used in lasers also present potential health and safety hazards. Problems may arise when working with unsecured cylinders, cylinders of hazardous materials not maintained in ventilated enclosures, and when certain gases (toxins, corrosives, flammables and oxidizers) are stored together. For additional gas cylinder safety guidelines review the *EH&S Gas Cylinder Safety Guidelines*.

Collateral Radiation

Radiation other than that associated with the primary laser beam is called collateral radiation. Examples are x-rays, UV, plasma, radio frequency emissions, and ionizing radiation. X-rays could be produced from two main sources in the laser laboratories: electric-discharge lasers and high-voltage vacuum tubes of laser power supplies such as rectifiers, thyratrons and crowbars. Any power supplies that require more than 15 kilovolts (keV) may produce enough x-rays to cause a health hazard. Interaction between x-rays and human tissue may cause cancer, such as leukemia, or permanent genetic effects to future generations.

UV and Visible

Laser discharge tubes and pump lamps may generate UV and visible radiation. The levels produced may exceed the MPE limit and cause skin and eye damage.

Plasma Emissions

Interactions between very high-power laser beams and target materials may produce plasmas that may contain hazardous UV emissions.

Radio Frequency (RF)

Q switches and plasma tubes are RF excited components. Unshielded components may generate radio frequency fields that exceed federal guidelines.

Fire Hazards

Class IV lasers represent a potential fire hazard. Depending on the construction material, beam enclosures, barriers, stops and wiring are potentially flammable if exposed to high beam irradiance for more than a few seconds.

Explosion Hazards

High-pressure arc lamps, filament lamps and capacitors may explode violently if they fail during operation. These components are to be enclosed in a housing that will withstand the maximum explosive force that may be produced. Laser targets and some optical components also may shatter if heat cannot be dissipated quickly enough. Consequently, care must be used to provide adequate mechanical shielding when exposing brittle materials to high intensity lasers.

G. LASER SAFETY PRACTICES

The following measures are recommended as a guide to safe laser use. Some additional measures may be required for specific laser classes and lasers that emit invisible radiation. See ANSI Z136.1 for more details. Contact the LSO for specific requirements.

Work Area Safety Practices

- A laser should be isolated from areas where the uninformed or curious may be attracted by its operation. Doors should be closed or locked to keep out unqualified personnel.
- The illumination in the room should be as bright as possible in order to constrict the eye pupils of users.
- The laser should be set up so that the beam path is above or below normal eye level (below 4.5 ft or above 6.5 ft).
- Where practical, the laser system or beam should be enclosed to prevent accidental exposure to the beam.
- The potential for specular reflections should be minimized with shielding and by removal of all unnecessary shiny surfaces.
- Windows to hallways or other outside areas should have adequate shades or covers.
- The main beams and reflected beams should be terminated or dumped. This is required for any accessible laser for which the maximum permissible exposure (MPE) limit could be exceeded.
- Electrical installation must meet electrical safety standards. The active laser should never be left unattended, unless it is a part of a controlled environment.
- Good housekeeping should be practiced to ensure that no specular reflector is left near the beam.
- Warning devices should be installed for lasers with invisible beams to warn of operation.

Laser Use Safety Practices

- Avoid looking into the primary beam at all times.
- Do not aim the laser with the eye; direct reflections could cause retinal damage.
- Avoid looking at the pump source.
- Clear all personnel from the anticipated path of the beam.
- Before operating the laser, warn all personnel and visitors of the potential hazard, and ensure all safety measures are satisfied.
- Be very cautious around lasers that operate at frequencies not visible to the human eye.
- Do not wear bright, reflective jewelry or other objects.

- Use proper eye protection when working with a Class IIIb or Class IV laser. Remember, safety glasses provide no protection unless they are worn. Safety glass lenses may shatter or melt when the lens specifications are exceeded. Scratched or pitted lenses may afford no protection. Eye protection is specific for the type of laser and may not protect at different frequencies or powers. See Section H for more details on required personal protective equipment (PPE).

H. REQUIREMENTS FOR LASER OPERATIONS

The following measures are required prior to safe laser use. Additional requirements may be needed for specific lasers at Iowa State University or Ames Laboratory. Contact the LSO for specific requirements.

General Requirements

- Class I lasers may be used for the intended purposes of their manufacturer without restrictions. However, any direct exposure to Class I and Class II laser radiation should be avoided.
- Class II, Class IIIb and Class IV lasers shall bear a warning label containing the laser classification, type and other warnings required by ANSI Z136.1. These requirements also apply to homemade lasers that are used on the Iowa State University campus.
- Class IIIb and Class IV lasers shall be registered with the LSO.
- Each laser and laser application shall meet the safety standards of ANSI Z136.1 or receive equivalent approval from the LSO.
- Each Class IIIb and Class IV laser must be assigned to a PI who is responsible for safe storage and use of that laser. The Department Chairperson assigns each laser to the PI in consultation with the LSO. The LSO must be consulted whenever a laser is reassigned to a new PI.
- All laser operators must complete training requirements for the class of laser they operate. See Section L for training details.
- All lasers must operate in accordance with applicable ANSI Z136.1 safety standards and in a manner consistent with safe laser practices. These practices should be in written Laser Safety Standard Operating Procedures (SOPs) for Class IIIb and Class IV lasers.
- Each Class IIIb and Class IV laser shall be used in a controlled area that restricts access to unauthorized personnel. The controlled laser areas shall be posted with appropriate warning signs.
- Each operator of a Class IIIb or Class IV laser shall meet medical surveillance requirements as applicable. See Section M for medical surveillance details.
- Class IIIb and Class IV lasers should receive a preliminary safety review by the LSO prior to acquisition or fabrication of the laser. These lasers also should receive a final safety review by the LSO prior to initial use of the laser. The final review should cover user qualifications, safe operation practices, electrical safety, area controls, and written SOPs.
- Purchase order for Class IIIb or Class IV lasers should be reviewed by the LSO before the order is placed.
- Each operator of a Class IIIb or Class IV laser shall wear appropriately rated protective equipment (e.g., eye wear) as required.

Engineering Controls

- All lasers require a protective housing.
- All Class IIIb and Class IV lasers must be equipped with the following CDRH mandated engineered safety features:
  - ✓ Protective housing interlock systems must prevent emission of laser radiation when the housing is open .
  - ✓ Viewing portals in the protective housing must be equipped with filters and attenuators that keep escaping light below the MPE limit .
  - ✓ Optical instruments for viewing the laser system must be equipped with filters, attenuators, and interlocks to keep exposures below the MPE limit for all conditions of operation and maintenance .
  - ✓ Class IIIb and Class IV lasers must be equipped with a removable master key switch and must not be operable when the key is removed. Also, the lasers must be equipped with electrical connections that allow them to be controlled by an area interlock system and remote shut-off devices. When the terminals are open-circuited, lasers must not emit any radiation in excess of the MPE. Class IV laser systems must have an integral and permanently attached beam stop or attenuator capable of preventing the emission of laser light in excess of the MPE limit when the laser system output is not required such as during warm-up procedures.

These features are standard for purchased lasers and must be designed and incorporated into locally built lasers. Exceptions must be approved by the LSO.

Laser Control Areas

- Class IIIb and Class IV lasers may only be operated in laser control areas approved by the LSO. Laser control areas confine laser hazards to well-defined spaces that are entirely under the control of the laser user. The control areas must be equipped with the prescribed safety features. Operations must meet the following ANSI Z136.1 safe operating standards:
  - ✓ The Class IIIb laser control area must be posted with appropriate warning signs that indicate the nature of the hazard.
  - ✓ Only authorized personnel who have received training are allowed to operate the laser systems.
  - ✓ Spectator access is controlled by the laser user. Access should only be permitted in the area after appropriate instruction has been provided to the spectators by the laser operator and protective measures are taken.
  - ✓ The laser beam must be terminated within the control area by appropriate beam stop devices. Light levels in excess of the MPE limit must not pass the boundary of the control area.
  - ✓ All openings through which laser light might escape the control area (doorways, windows, and other open portals) must be shielded in a manner to preclude the transmission of laser light through the openings to below the MPE limit.
  - ✓ Personnel must be provided with with appropriate eye protection within the controlled area.
  - ✓ Special rules apply to outdoor use and areas that do not provide complete laser light containment. The Federal Aviation Administration has strict rules governing these types of laser uses. Contact the LSO for further information on these rules.
- Class IIIb infrared and ultraviolet lasers require additional controls since the beam is invisible. Highly absorbent, non-specular stops should terminate the beam. Signs and a light should warn those in the area when the laser is being operated. Special attention should be given to the production of ozone, skin sensitizing agents and other hazardous products when ultravio-

let lasers are used.

- Class IV lasers require additional controls. Contact the LSO for details about these controls and how to ensure compliance.

Temporary Laser Control Areas

For servicing of embedded lasers, and in special cases where permanent laser control areas cannot be provided (i.e., lecture demonstrations, displays, etc.), temporary laser control areas can be created. Contact the LSO for details.

I. PERSONAL PROTECTIVE EQUIPMENT

Despite the application of all practicable engineering and administrative controls, there are occasions when it is necessary to work near a Class IIIb or Class IV laser. On these occasions it is required to use personal protective equipment (PPE) for eye and skin protection.

Eye Protection

Eye protection suitable to the laser must be provided and worn within the laser control area if there is a potential for exceeding the MPE limit. Protective eyewear may include goggles, face shields, spectacles or prescription eyewear using special filter materials or reflective coatings. Exceptions may be approved in the written SOPs or by the LSO if the eyewear produces a greater hazard than when eye protection is not worn.

No single type of eyewear will provide protection against all wavelengths of laser radiation; therefore, eye protection should:

- Provide enough visibility to move about safely.
- Be able to withstand the maximum power of laser radiation likely to be encountered.
- Be able to absorb the specific wavelength of radiation that is being used.
- Be clearly labeled with their designed wavelength, the optical density at that wavelength, and the maximum power rating.
- Be inspected periodically by the laser operator to ensure that pitting, cracking and other damage will not endanger the wearer.

Lasers that can be tuned through a range of wavelengths present special problems. Broadband laser goggles may provide the level of protection required but they must be chosen with great care. If there is any doubt regarding the suitability of a particular type of eye protection, contact the LSO for guidance.

Because various wavelengths of laser radiation require different eyewear, more than one type of laser should not be run simultaneously in the same laboratory unless they are under the control of the same person. The only eye protection present in the laboratory will be that suitable for the laser in use.

Skin Protection

Clothing such as gloves and covers for the forearms may be required to protect the skin if laser intensity and wavelength warrant such protection. This is most important if the laser is running in the ultraviolet region. Very large peak powers with pulsed ultraviolet lasers may be particularly dangerous. The LSO can assist in identifying protection equipment that is appropriate for the intended use. This equipment should be addressed in the written SOP.

J. WARNING LABELS AND SIGNS

ANSI Z136.1 requires that lasers and laser systems have appropriate warning labels and that the rooms in which they operate bear appropriate warning signs. On the warning sign or equipment label, the following information should be included:

- The signal word “Caution” shall be used with all signs and labels associated with all Class II and Class IIIa lasers that do not exceed the appropriate MPE for irradiance (Fig. 2).
- The signal word “Danger” shall be used with all signs and labels associated with all other Class IIIa lasers that exceed the MPE for irradiance and for all Class IIIb and Class IV lasers (Fig. 3).
- The signal word “Notice” shall be used on signs posted outside a temporary laser-controlled area such as during periods of service.
- At position 1, above the tail of the sunburst, special precautionary instructions or protective actions required by the reader such as:
  - ✓ For Class II lasers/laser systems: “Laser Radiation - Do Not Stare into Beam.”
  - ✓ For Class IIIa lasers/laser systems where the accessible irradiance does not exceed the appropriate MPE limit based upon 0.25 s exposure for wavelengths 0.4 to 0.7 μm (micrometer): “Laser Radiation - Do Not Stare into Beam or View Directly with Optical Instruments.”
  - ✓ For all other Class IIIa lasers/laser systems: “Laser Radiation - Avoid Direct Eye Exposure.”
  - ✓ For all Class IIIb lasers/laser systems: “Laser Radiation - Avoid Direct Exposure to Beam.”
  - ✓ For Class IV lasers/laser systems: “Laser Radiation - Avoid Eye or Skin Exposure to Direct or Scattered Radiation.”
- Additionally at position 1, above the tail of the sunburst, special precautionary instructions or protective action that may be applicable include: Laser Protective Eyewear Required, Invisible Laser Radiation, Knock Before Entering, Do Not Enter when Light is On, and Restricted Area.
- At position 2, below the tail of the sunburst, the type of laser (Ruby, Helium-Neon, etc.) or the emitted wavelength, pulse duration (if appropriate) and maximum output.
- At position 3, the class of the laser or laser system.

Signs for laser laboratory doors are provided by the LSO.

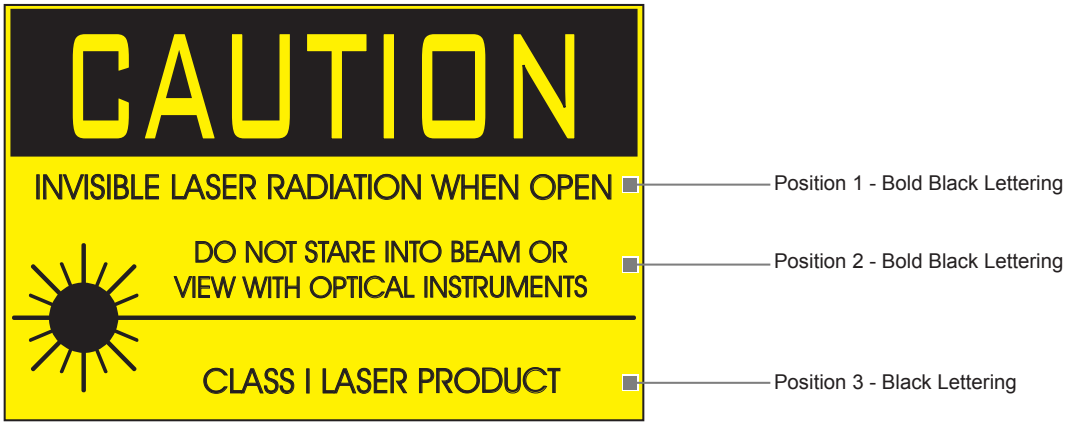


Fig. 2 Sample Warning Sign for Class II and Certain Class IIIa Lasers

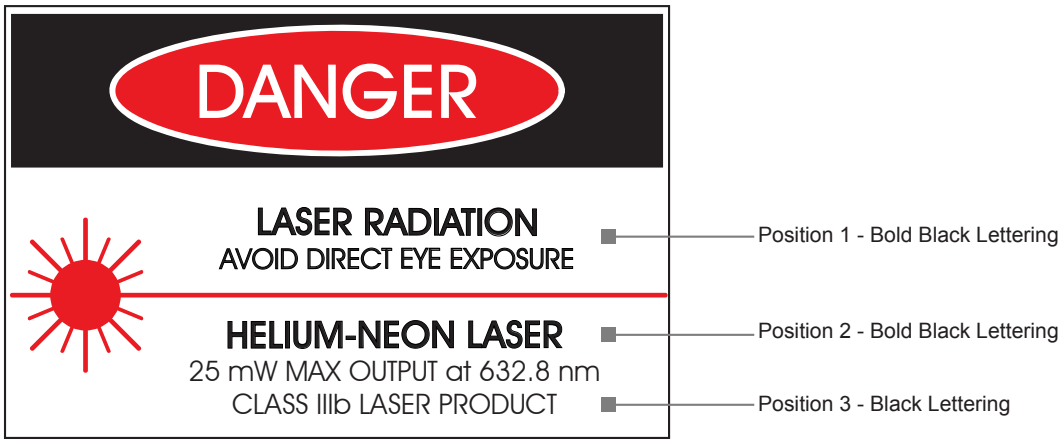


Fig. 3 Sample Warning Sign for Certain Class IIIa Lasers and for Class IIIb and Class IV Lasers

K. LASER SAFETY STANDARD OPERATING PROCEDURES

An approved, written SOP is required for certain lasers (see Section K) that are high powered or that emit invisible radiation. However, the LSO may recommend or require a written procedure for any laser or laser application where it is deemed necessary to ensure adequate safety controls.

- Class IIIb lasers and laser systems require an approved, written procedure if:
  - ✓ The laser beam produced is a wavelength invisible to the eye; or,
  - ✓ The laser produces a continuous wave visible beam of more than 15 mW.
- Helium-Neon lasers with 15 mW or less normally do not require a written procedure, however, all other safety requirements for this class of laser apply.
- All Class IV lasers and laser systems require a written SOP.

The Principal Investigator normally prepares the required written SOP. The LSO must review the SOP before the laser is operated.

L. LASER SAFETY TRAINING

Only a qualified and authorized person is permitted to operate a laser system. Therefore, all Class IIIb and Class IV laser users are required to complete Laser Safety Training, participate in a baseline eye exam (see Section M) and complete all required departmental job activity training prior to performing this activity. In addition, laser users will need retraining every five years.

Laser Safety Training (Initial)

All Iowa State University and Ames Laboratory laser users must complete Laser Safety Training prior to performing laser work. All laser users need to call Ames Laboratory's Training Office (4-9972) located at 125 Spedding Hall to schedule a Laser Safety Training appointment. The computer-based training course includes a video and a final examination. The participant must achieve at least an 80% score on the examination. Training typically takes 11/2 to 2 hours to complete.

Additionally, the laser user is provided with an informational packet and will be required to sign a *Laser User Authorization Form*, which acknowledges their responsibility for completing job activity training prior to operating a laser.

The laser user will then be directed to the Occupational Medicine Department, G11 TASF to schedule a baseline eye exam. Training authorization will **not** be granted until the baseline eye exam has been completed.

Note: *Iowa State University employees need to bring a completed Intramural Form to the Ames Laboratory Training Office in order for Occupational Medicine to schedule a baseline eye exam. The Intramural Form needs be made out to Ames Laboratory, 224 TASF. The item description on the Intramural Form should state " for baseline eye exam". The cost will be $105 (subject to change), and the laser user's supervisor must sign the Intramural Form. Ames Laboratory employees will not need to prepare a purchase order form as their program will be directly charged by Occupational Medicine.*

Retraining Iowa State University Employees

Iowa State University employees are responsible for retraining every five years by logging onto the EH&S Online Training Center and completing the Laser Safety Refresher Online Training. Participants should be able to complete retraining within an hour. The completion date will be recorded on the EH&S online training system.

Retraining Ames Laboratory/ Institute for Physical Research and Technology (IPRT) Employees

Ames Laboratory/IPRT employees will receive a *Training Announcement* indicating that they

are due for their five year Laser Safety Retraining. Laser users will be instructed to contact the Ames Laboratory Training Office at (4-9972) to schedule an appointment to complete this retraining requirement. The completion of this half-hour training will be recorded on each individual's *Employee Training Profile*.

M. MEDICAL SURVEILLANCE & EXPOSURE INCIDENTS

Employees who are routinely engaged in work where they may be exposed to laser radiation from Class IIIb and Class IV lasers must be included in a laser medical surveillance program. Before laser operation, users should schedule an appointment for a preliminary baseline eye exam with Occupational Medicine (4-2056) located at G11 TASF. Users should then complete a Hazard Inventory Form, have it signed by their supervisor and bring the form to Occupational Medicine prior to the time of their scheduled exam. This medical surveillance program will establish a baseline of ocular conditions before exposure to laser radiation. It will also detect and document, as early as possible, ocular damage in the event of a suspected exposure incident. Both serve to assess the effectiveness of control measures and institute appropriate therapeutic measures.

Laser users shall be subject to the following baseline eye examination

- Ocular medical history, including hyperphotosensitive conditions
- Visual acuity 20/20 (6/6 each eye far, Jaeger 1+ near with corrections)
- Macular function (Amsler grid or similar pattern)
- Color vision (Ishihara or similar test)

If abnormalities are found, the Occupational Medicine physician may examine ocular fundus with an ophthalmoscope or other appropriate examinations.

Additional eye exams may be required in the event of exposure or suspected exposure to laser radiation above the MPE limit. An eye exam is also required upon termination of laser work or upon termination of employment involving laser work. Other routine eye examinations are not required. Medical records are kept at the Occupational Medicine office.

If an exposure incident occurs, your respective safety office must be notified as soon as possible. If the incident causes an injury or could potentially have caused an injury, the person or persons who have received an exposure should inform their supervisor and be seen immediately by the Occupational Health Works at McFarland Clinic. Your supervisor will call (239-4496) to arrange medical care for you and complete a First Report of Injury form. The First Report of Injury form will be FAXed (294-1621) or mailed to the Office of Risk Management, 1350 Beardshear within 24 hours of the incident reporting. Occupational Health Works will coordinate treatment and refer you to an appropriate specialist for additional care if neccessary. After-hour treatment or emergencies will be seen at the Mary Greeley Medical Emergency Department. Please notify medical staff that treatment is needed due to a workplace injury or illness so that they can initiate the proper paperwork. Remember, all accidents and injuries at work or in the course of employment must be reported to your supervisor and a First Report of Injury completed, even if no medical attention is required. In addition, your respective safety office will conduct an investigation, and an incident report will be written.

N. GLOSSARY OF TERMS

Absorption – Transformation of radiant energy to a different form of energy by interaction with matter.

Beam – A collection of rays characterized by direction, dimensions and divergence (or convergence).

Blink Reflex or Aversion Response - The closure of the eyelid or movement of the head to avoid exposure to a noxious stimulant or bright light. It often occurs within 0.25 seconds which includes the blink reflex time.

Continuous Wave (CW) - The output of a laser operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser that is operated with a continuous output for a period of $\geq$ 0.25 seconds is regarded as a CW laser.

Controlled Area - An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from radiation hazards.

Diffuse Reflection - Change of spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Enclosure – A barrier used to enclose the laser beam.

Energy - The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers and is generally expressed in Joules (J).

Environmental Health and Safety Department (EH&S) - The department at Iowa State University which has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Environmental, Safety, Health, and Assurance Department (ESH&A) - The department at Ames Laboratory which has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Fail-Safe Interlock - An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into or remain in a safe mode.

Housing – The metal case that contains the laser. In the case of Class IIIb and Class IV lasers, this case is required to be interlocked.

Infrared Radiation - Electromagnetic radiation with wavelengths that lie within a range of 700 nm to 1 mm.

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

Irradiance – Radiant power incident per unit area upon a surface, expressed in W/cm².

Laser - A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally or spatially or both. An acronym for Light Amplification by Stimulated Emission of Radiation.

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

Laser Safety Officer - The individual who has authority to monitor and enforce the safe use of lasers and laser systems.

Maximum Permissible Exposure (MPE) - The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure (J/cm²) or irradiance (W/cm²). The criteria for MPE are detailed in Section 8 of ANSI Z136.1.

Nominal Hazard Zone (NHZ) - A zone that describes the space within which the level of the direct, reflected or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

Optical Density (D_λ) - Logarithm to the base ten of the reciprocal of the transmittance:

$$D_\lambda = -\log_{10} \tau_\lambda, \text{ where } \tau_\lambda \text{ is the transmittance.}$$

Power - The rate at which energy is emitted, transferred, or received in W or J/s.

Principal Investigator (PI) - The authorized laser user who assumes responsibility for the control and safe use of a laser or laser system. The Principal Investigator is appointed by the Department Chairperson.

Pulsed Laser - A laser that delivers its energy in the form of a single pulse or a series of pulses. The duration of a pulse is regarded to be < 0.25 s.

Q-Switched Laser - A laser that emits short (~10-250 ns), high-power pulses by means of a Q-switch.

Radiant Exposure - Surface density of the radiant energy received in units of J/cm².

Radiant Flux - Power emitted, transferred, or received in the form of radiation in units of W.

Repetitive Pulse Laser - A laser with multiple pulses of radiant energy occurring in sequence.

Specular Reflection - A mirror-like reflection.

Standard Operating Procedure (SOP) - A set of operating instructions for a particular laser or laser system. The procedure specifies measures which, if followed, will ensure safe and correct use of the laser or laser system.

Transmittance - The ratio of transmitted power to incident power.

Ultraviolet Radiation (Light) - Electromagnetic radiation with wavelengths shorter than those of visible radiation; for the purpose of this laser safety manual, 180 nm to 400 nm.

Visible Radiation (Light) - Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths of 400 nm to 700 nm.

Wavelength - The distance between two successive points on a periodic wave that have the same phase.