Environmental Health & Safety

# Laser Safety - For Research Use of Lasers

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# 1.0 Introduction

The University of Iowa Laser Safety Program is designed to provide guidance for the safe use of lasers in research and to help provide for the safety of all personnel and visitors that may be exposed to the radiation emitted by lasers.

The laser safety policy is based on standards promulgated by ANSI Z136.1, and applies to all lasers and laser systems, whether purchased, borrowed, fabricated, or brought in for use by others.

Many lasers are capable of causing eye injury to anyone who looks directly into the beam. Reflections alone from high-power laser beams can produce permanent eye damage. High-power laser beams can also burn exposed skin. Laser operators must be aware of other potential dangers such as fire, electrical, biological and chemical hazards.

This manual will provide basic information on laser operation and safety practices, as well as University policy regarding the safe use of lasers and laser systems. Beam hazards are discussed in the body of the text and non-beam or associated hazards are discussed in Appendix 1.

# 1.1 Registration

All Class 3B and Class 4 lasers at the University of Iowa must be registered with the Environmental Health & Safety (EHS). Please contact Environmental Health & Safety at 335-8501 prior to receiving a laser so that the unit can be registered and the work area, procedures, and safety-related equipment can be evaluated prior to use of the laser.

# 1.2 Responsible Parties

## 1.2 .1 Laser Safety Officer

The Laser Safety Officer will be responsible for:

- Maintaining inventory of all Class 3B and Class 4 lasers and verifying classification if necessary.
- Reviewing standard operating procedures, alignment procedures and other control measures, before initial use.
- Periodically inspect Class 3B and Class 4 lasers to assess compliance with safety requirements.
- Providing assistance in evaluating and controlling hazards.
- Maintaining records of Class 3B and Class 4 laser inspections.
- Participating in accident investigations involving lasers.
- Suspending, restricting or terminating the operation of a laser or laser system without adequate hazard controls.

### 1.2.2 Laser Operator

The laser operator is responsible for:

- Completing all applicable requirements including training and medical surveillance, as applicable, before operating a laser.
- Operating lasers safely and in a manner consistent with safe laser practices, requirements and standard operating procedures. This includes the use of personal protective equipment as applicable.
- Maintaining a safe environment/area during the operation of a laser.

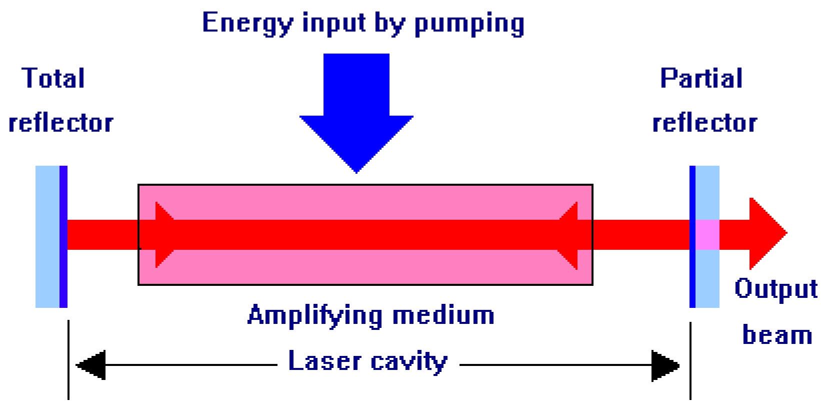
### 1.2.3 Principal Investigator

The Principal Investigator is responsible for:

- Notifying EHS of the intent to procure a laser, and providing required information for registration and safety reviews for lasers.
- Providing laser specific training for all operators.
- Ensuring each assigned laser is operated safely and in accordance with applicable requirements.
- Providing medical surveillance for laser operators and ancillary personnel as described in Medical Surveillance and Exposure Incidents, as applicable.
- 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.
- Maintaining written SOPs for Class 3B (if required) and all Class 4 lasers and ensuring laser use is commensurate with the requirements of the SOP.
- Informing EHS prior to receiving a laser, transferring a laser to another user, sending a laser to another site off-campus, or disposal of a laser or laser system.
- Reporting any known or suspected accidents to the Laser Safety Officer.
- Ensuring that a hazard assessment for personal protective equipment (PPE) use and specific PPE training is provided for all laser users for whom PPE will be required.

# 2.0 Laser Characteristics

The term LASER is an acronym for Light Amplification by the Stimulated Emission of Radiation. The figure below is a simplified diagram of a laser:




Lasers operate by the excitation of a medium through the introduction of energy. As electrons in this medium return to their ground state, they stimulate the release of light of a certain wavelength. This chain reaction continues until a certain number of photons reach the totally reflective mirror. This reverses the direction of the beam and the beam continues to intensify until it passes through the partially transmissive mirror, constituting the laser beam. Laser radiation will continue to be produced as long as energy is applied to the lasing medium. Laser radiation differs from normal light in that it is coherent, electromagnetic radiation characterized by one or more specific wavelength(s). The wavelengths are determined primarily by the composition of the lasing medium, which can be a solid, liquid, or gas. Laser radiation may be emitted in the visible portion of the electromagnetic spectrum (wavelengths of 400 – 700 nm) or in the invisible infrared (700-3E6 nm) and ultraviolet (180-400 nm) regions.

Laser radiation transmits energy which, when a laser beam strikes matter, can be transmitted, absorbed, or reflected. If a material transmits a laser beam it is said to be transparent. If the beam is not transmitted, the material is said to be opaque and the incident radiation is absorbed or reflected.

## 2.1 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, 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.

## 2.2 Reflection

Reflection is a function of the physical character of the surface of the target material. A smooth polished surface is generally a good, or specular, reflector; a rough uneven surface usually is a poor reflector producing 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 reflecting surfaces are favored when designing a laser experiment since their use reduces the likelihood of a specular reflection and hence enhances the safety of the experiment.

## 2.3 Transmission

Most visible light laser beams, such as those generated by HeNe, Nd:Yag, and Krypton lasers are transmitted through clear objects, such as a room window or water. Use of these types of lasers often requires the use of window coverings that absorbs the beam and prevents the laser hazard from existing outside of the immediate work area. It is important to note that these coverings will need to be fire resistant for use with higher-powered lasers. Some lasers, such as CO2, are not transmitted through glass, and therefore do not require the use of window coverings.

# 3.0 Laser Classification

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 (FLPPS). The manufacturer is responsible for determining the laser classification. The builder must classify custom-built and modified lasers. EHS can assist with the classification of such lasers. 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 part 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 seconds but classification is more complex. See ANSI Z136.1 for details of the classification. Copies of ANSI Z136.1 can be purchased from the Laser Institute of America.

## 3.1 Class 1 Lasers

Class 1 lasers include any laser of laser system containing a laser that cannot emit laser radiation at levels that are known to cause eye or skin injury during normal operation. This does not apply to service periods requiring access to Class 1 enclosures containing higher class lasers. (See Embedded Lasers). Equipment, such as laser printers and laser disc players, are examples of this class. These lasers may present hazards if the housing is breached for maintenance

## 3.2 Class 2 Lasers

Class 2 lasers are visible continuous wave (CW) and repetitive-pulse lasers or laser systems which can emit accessible radiant energy exceeding the appropriate Class 1 AEL but less than 1 mW. The human eye blink reflex, which occurs within 0.25 seconds, provides adequate protection for Class 2 lasers. However, it is possible to overcome the blink response and stare into the Class 2 laser long enough to damage the eye. Class 2 lasers are typically exempt from control measures other than having a protective housing and label. Equipment such as some visible continuous wave Helium-Neon lasers and some laser pointers are examples of Class 2 lasers.

## 3.3 Class 3R Lasers

Class 3R lasers are defined as laser systems that are potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable. They can pose severe eye hazards when viewed through optical instruments (e.g., microscopes, binoculars, or other collecting optics). Class 3a lasers must be labeled. A warning label shall be placed on or near the laser in a conspicuous location and caution users to avoid staring into the beam or directing the beam toward the eye of individuals. Equipment, such as some visible continuous wave Helium-Neon lasers and some solid state laser pointers, are examples of Class 3a lasers. It is recommended that no pointers over Class 3a be used at the University of Iowa.

## 3.4 Class 3B Lasers

Class 3B lasers are medium powered lasers (visible and invisible regions) that present a potential eye hazard for intrabeam (direct) specular conditions. Class 3B lasers do not present a diffuse hazards or significant skin hazard except for higher powered 3B lasers operating at See Laser Usage Requirements for specific usage requirements for Class 3B lasers.

## 3.5 Class 4 Lasers

Class 4 lasers are high-powered lasers (visible or invisible) considered to present potential acute hazard to the eye or skin for both direct and scatter conditions. They also present potential hazard conditions for fire and by-product emissions from target or process materials. See Laser Usage Requirements for specific usage requirements for Class 4 lasers.

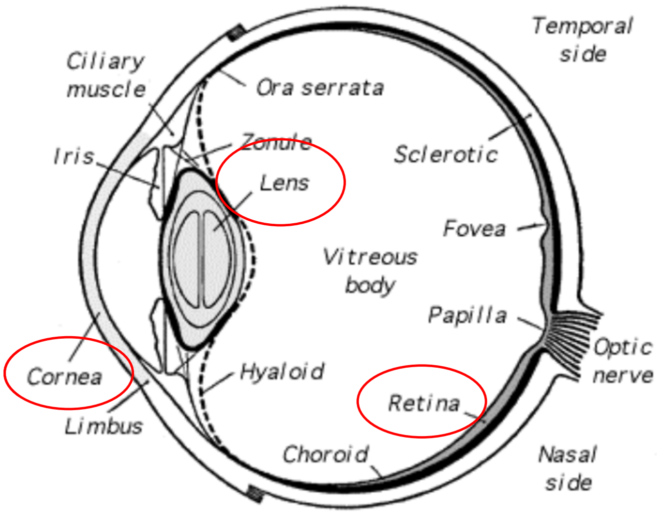
## 3.6 Embedded Laser

Embedded lasers are found in laser products with lower class ratings. Laser printers, CD players, and laser welders may have Class 3B or Class 4 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 of the embedded laser must be implemented.

# 4.0 Laser Safety Hazards

## 4.1 Beam Hazards

The nature of laser beam damage and the threshold levels at which each type of injury may occur depends on several parameters. These include wavelength of light, energy of the beam, beam divergence and exposure duration. For pulsed lasers, parameters also include the pulse length, pulse repetition frequency and pulse train characteristics. The ANSI Z136.1 standard establishes Maximum Permissible Exposure (MPE) limits for laser radiation. MPE's need to be determined for each specific laser so that a Nominal Hazard Zone (NHZ) can be established. The Nominal Hazard Zone is the area around a laser in which the applicable MPE is exceeded. The EHS can assist in determining MPEs and NHZs, however in most cases, the NHZ is considered the whole room in which the laser is housed. When an MPE is exceeded, damage can occur to the skin, retina, lens, cornea, and conjunctival tissue surrounding the eye (See figure below).

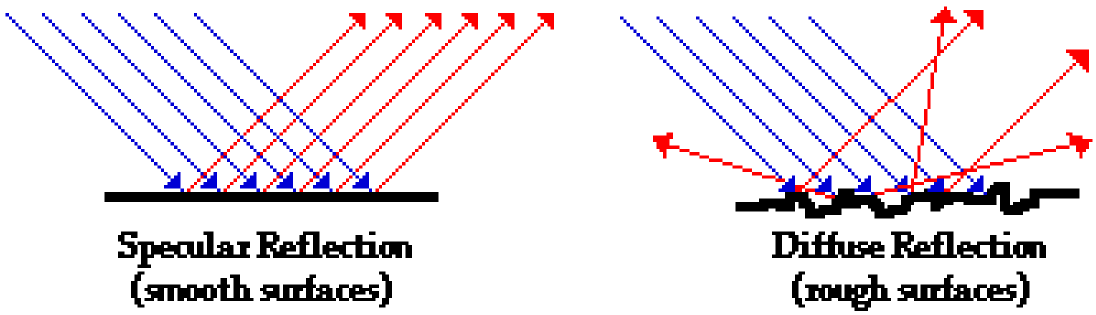



For lasers over 500 mW, the beam can ignite flammable materials and initiate a fire.

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. 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 that destroys retinal tissue. Since retinal tissue does not regenerate, the damage is permanent, which may result in the loss of sight in the damaged area.

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 produce more diffuse reflections and are usually less hazardous. Extended source viewing of normally diffuse reflections are not normally hazardous except for very high power lasers (Class 4 lasers). 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.

The figure below represents the two types of laser light reflection:




Risk of skin injury can also be significant when working with high power infrared lasers or lasers which emit in the ultraviolet spectral region. Risks from infrared lasers include thermal burns and blistering or charring of the skin. Risks from UV lasers include sunburn, skin cancer, skin aging and photosensitization.

## 4.2 Laser Generated Airborne Contaminants (LGAC)

LGACs are airborne contaminants associated with the use of Class 3B and Class 4 lasers. LGACs result from the interaction of the laser beam with target or other materials and can include metallic fumes and dust, chemical fumes and aerosols containing biological contaminants. LGACs are generally only formed when target irradiance reaches 10E7 W/cm2. Local or area ventilation must be adequate to keep airborne contaminant levels below worker exposure limits.

# 5.0 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, or contact EHS at 5-8501 for additional information.

## Work Area Safety Practices

- A laser should be isolated from public areas. Doors should be closed or locked to keep out unauthorized personnel. The proper warning signs should be posted.
- The illumination in the area should be as bright as practicable 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 by shields and by removal of all unnecessary shiny surfaces.
- Windows to hallways or other outside areas must be provided with adequate shades or covers when necessary to keep the Nominal Hazard Zone (NHZ) within the room.
- The main beams and reflected beams should be terminated or dumped. This is required for any accessible laser for which the MPE limit could be exceeded.
- Electrical installation must meet electrical safety standards. The active laser never should be left unattended unless it is a part of the controlled environment.
- Warning devices must be installed for lasers with invisible beams to warn of operation.
- The laser work area should be maintained as free of clutter as possible, to minimize the chance of accidentally igniting something.
- Ensuring that lasers are well secured to the work surface helps prevent a stray beam.

## 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 3B or Class 4 laser. Remember that 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. Frequent inspection of protective eyewear is recommended. Eye protection is specific for the type of laser and may not protect at different frequencies or powers. See* *Personal Protective Equipment* *for more details.*

# 6.0 Laser Usage Requirements

## 6.1 General Requirements

- Class 1, Class 2, lasers may be used for the intended purposes of their manufacturer without restrictions. Any direct eye exposure to these types of lasers should be avoided.
- Class 3a, Class 3B, and Class 4 shall carry a warning label containing the laser classification, type, and other warnings required by ANSI Z136.1 or assigned an equivalent level by the manufacturer. These requirements also apply to non-commercially built lasers that are used on the University of Iowa campus.
- Class 3B and Class 4 lasers must be registered with the Environmental Health & Safety.
- Each Class 3B and Class 4 laser must be assigned to a Principal Investigator who is responsible for safe storage and use of that laser. EHS must be consulted whenever a laser is acquired, reassigned to a new Principal Investigator, transferred off-campus, or disposed. Please contact the University's Laser Safety Officer at 335-8501 prior to initiating any of these activities.
- All laser operators must complete training specific to the type of laser they operate. See Laser Safety Training. Compliance with this requirement will be reviewed during EHS audits.
- All lasers must be operated according to the applicable ANSI Z136.1 safety standards and in a manner consistent with safe laser practices. Laser Safety Standard Operating Procedures (SOPs) are required for certain Class 3B lasers and for all Class 4 lasers. (see Laser Safety Standard Operating Proceduresfor details).
- Each Class 3B and Class 4 laser shall be used in a controlled area that restricts access to unauthorized personnel. The controlled laser areas must be posted with appropriate warning signs.
- Each operator of a Class 3B or Class 4 laser must wear protective equipment (e.g., eye wear and clothing) as appropriate. (see Personal Protective Equipment).
- The EHS will perform periodic audits in order to assess the efficacy of the laser safety program. Any required corrective action resulting from the audit will be communicated to the Principal Investigator in a timely manner.

## 6.2 Engineering Controls

- All lasers require a protective housing.
- All Class 3B and Class 4 lasers must be equipped with the Center for Devices and Radiological Health (CDRH) mandated engineered safety features that follow:
  - Protective housing interlock system that 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 Maximum Permissible Exposure (MPE) limit.

- Optical instruments for viewing the laser system must be equipped with filters and attenuators and interlocks to keep exposures below the MPE limit for all conditions of operation and maintenance.

These features are standard for purchased lasers and should be designed and incorporated in custom built lasers.

- Class 4 lasers shall also be equipped with a removable master key switch if provided by the manufacturer. The laser shall not be operable when the key is removed.
- The lasers should be equipped with electrical connections that allow for an access control system and remote shut-off devices. When the terminals are open-circuited, the laser must not emit any radiation in excess of the MPE. Class 4 laser systems must be equipped with 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 beam is not required.

# 6.3 Laser Control Areas

## Class 3B Laser Controlled Area

The following items are required for Class 3B laser use in controlled areas:

- Posted with the appropriate warning sign(s).
- Operated by qualified and authorized personnel.
- Under the direct supervision of an individual knowledgeable in laser safety.
- Have any potentially hazardous beam terminated in a beam stop of an appropriate material.
- Have only diffuse reflective materials in or near the beam path, where feasible.
- Have personnel within the controlled area provided with the appropriate eye protection if there is any possibility of viewing the direct or reflected beams.
- Have the laser secured such that the beam path is above or below eye level of a person in any standing or seated position, except as required for medical use.
- Have all windows, doorways, open portals, etc. from an indoor facility be either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the appropriate ocular MPE.
- Require storage or disabling (for example, removal of the key) of the laser or laser system when not in use to prevent unauthorized use.

## Class 4 laser control area

Requires, in addition to the items listed for Class 3B areas, the following additional measures:

- Personnel who enter a Class 4 controlled area during laser operation shall be adequately trained, provided with appropriate protective equipment, and follow all applicable administrative and procedural controls.
- Class 4 area/entryway safety controls shall be designed to allow both rapid egress by laser personnel at all times and admittance to the laser controlled area under emergency conditions.
- For emergency conditions there shall be a clearly marked "Panic Button" (remote controlled connector or equivalent device) available for deactivating the laser or reducing the output to the appropriate MPE levels.
- Area or entryway safety controls to deactivate the laser or reduce the output to the appropriate MPE levels in the event of unexpected entry into the laser controlled area.
- These controls may be non-defeatable, defeatable or procedural as determined by the LSO.

### Temporary Laser Controlled Area

Where removal of panels or protective housings, over-riding of protective housing interlocks, or entry into the NHZ becomes necessary (such as for service), and the accessible laser radiation exceeds the applicable MPE, a temporary laser controlled area shall be set up. The temporary laser controlled area shall be posted on the outside with a Notice sign and with the appropriate warning sign (Class 3B or Class 4) inside the controlled area to warn of the potential hazard.

# 7.0 Personal Protective Equipment

In addition to engineering and administrative controls, personal protective equipment for skin and/or eyes is often necessary when working with Class 3B or Class 4 lasers.

## 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 if the beam is viewed. 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 if the eyewear produces a greater hazard than when the 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 the wavelength(s) they are designed for, and the optical density at each wavelength.
- 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. Broad band 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 Laser Safety Officer at 5-8501 for guidance.

## Skin Protection

Skin injuries from lasers primarily fall into two categories: thermal injury (burns) from acute exposure to high power laser beams and photo chemically induced injury from chronic exposure to scattered ultraviolet laser radiation.

Thermal injuries can result from direct contact with the beam or specular reflections. These injuries (although painful) are usually not serious and are normally easy to prevent through proper beam management and hazard awareness.

Photochemical injury may occur over time from ultraviolet exposure to the direct beam, specular reflections, or even diffuse reflections. The effect can be minor or severe sunburn, and prolonged exposure may promote the formation of skin cancer. Proper protective eyewear and clothing may be necessary to control UV skin and eye exposure.

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 ultra-violet. Very large peak powers with pulsed ultra-violet laser can be particularly dangerous. Contact the Laser Safety Officer at 5-8501 for specific information regarding protective clothing.

Other protective equipment includes window drapes designed to prevent the escape of the laser beam outside of the room in which it is used. The type of drape used must be appropriate to the laser. Some laser beams such as that from a $CO2$ laser do not penetrate glass and therefore do not require the use of window drapes.

**NOTE**: By OSHA regulation all laser users required to wear personal protective equipment must undergo a hazard assessment for PPE use and must receive specific PPE training. Forms for completing each are included as Appendix 3 to this manual. Completion of these two items for each laser user is the responsibility of the Principal Investigator.

# 8.0 Warning Labels and Signs

ANSI Z136.1 requires that lasers and laser systems have appropriate warning labels and that the areas in which they operate be posted with appropriate warning signs.

The figures below are examples of laser warning signs:
All lasers (except Class 1) shall have appropriate warning labels affixed to a conspicuous place on the laser housing or control panel.  Laser area warning signs and equipment labels are available from the EHS or a number of safety supply companies, including the Laser Institute of America.

# 9.0 Laser Safety Standard Operating Procedures

A written SOP is required for certain lasers that are high powered or that emit invisible radiation.

Class 3B lasers and laser systems require a 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 4 lasers and laser systems require a written SOP.

Laser usage SOPs should include the following information as a minimum:

- Laser operating procedures
- Laser maintenance procedures
- Service procedures
- Alignment procedures
- A description of the Nominal Hazard Zone for each procedure.
- The use of protective eyewear and other personal protective equipment as appropriate.

# 10.0 Laser Safety Training

All Class 3B or Class 4 laser users are required to take basic laser safety training.

The Environmental Health & Safety offers this training in classroom, self-study or on-line formats.

In addition, all laser operators must be trained on the usage of each specific laser to be used.  The Principal Investigator, vendor, or other qualified individual may provide this training. Records of this training must be maintained for review by EHS and/or regulatory agencies.

Before operating a Class 3B, Class 4 laser, or a Class 3B or Class 4 laser embedded in a Class 1 laser system when the protective housing is removed, a person must:

1. Review the Laser Safety Manual.
2. Receive from the Principal Investigator a thorough review of the laser equipment to be used and the administrative requirements, alignment procedures and applicable SOPs.
3. Review the operating and safety instructions furnished by the manufacturer.
4. Utilize appropriate personal protective equipment.

# 11.0 Medical Surveillance and Exposure Incidents

Baseline eye exams for Class 3B and Class 4 laser users are required by ANSI Standard Z-136.1-2000. However, it is the opinion of physicians at the University Employee Health Clinic (UEHC) and the UIHC Ophthalmology Dept. that the basic exams specified in the standard would not provide sufficient information to confirm or preclude a pre-existing condition with the eye. Therefore, medical surveillance for laser users will be performed on a post-incident basis only. Individuals who wish to have an eye exam are encouraged to contact the UEHC for recommendations prior to scheduling.

If an exposure incident occurs, the affected individual(s) should inform their supervisor and be referred immediately to the Worker's Health Clinic, located in Clinic A of Boyd Towers. The employee will be evaluated and/or referred for ophthalmologic assessment as appropriate. If the incident occurs outside of regular clinic hours, the employee(s) should be seen in the UIHC Emergency Treatment Center. In addition, the employee must complete a “Worker’s Compensation First Report of Injury or Illness” form.

EHS will conduct an investigation and an incident report will be written.

**REFERENCES**


1. American National Standard for the Safe Use of Lasers, ANSI Z136.1, 2000.
2. American National Standard for the Safe Use of Lasers in Educational Institutions, ANSI Z136.5, 2000.
3. University of Waterloo, Ontario, Laser Safety Manual, 2000
4. “OSHA Technical Manual – Section III, Ch. 6 Laser Hazards”, 2000
5. “UC Berkeley Laser Safety Manual”, 1998
6. “Iowa State University Laser Safety Manual,” Iowa State University, 1998.
7. “Laser and Eye Safety in the Laboratory.” Matthews, Larry. New York: IEEE Press; Bellingham, Washington. SPIE Optical Engineering Press, 1995.
8. “Safety with Lasers and Other Optical Sources”, Sliney and Wolbarscht, 1980
9. “Laser Safety and the Eye”, Lions Laser Skin Center, Vancouver, 1996
10. “Publication 3000 – Chapter 16 Lasers” Lawrence Berkeley National Lab, 1997

# Appendices

# Appendix 1 - Associated Hazards

**Electrical Hazards**

The most lethal hazard associated with lasers is the high voltage electrical system required to power lasers. Several deaths have occurred when commonly accepted safety practices were not followed by persons 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 voltages, 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. Lockout 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. A material safety data sheet (MSDS) must accompany all chemicals handled at the University of Iowa. 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 below acceptable limits.

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 materials.

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 gases of different categories (toxins, corrosives, flammables and oxidizers) are stored together.

**Collateral Radiation**
Radiation other than that associated with the primary laser beam is called collateral radiation. Examples are X rays, LTV, 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 (kV) may produce enough x-rays to cause a health hazard. Interaction between X rays and human tissue may cause a serious disease such as leukemia or other cancers, or permanent genetic effects that may show up in future generations.

**UV and Visible**
UV and visible radiation may be generated by laser discharge tubes and pump lamps. The levels produced may exceed the MPE limit and thus cause skin and eye damage.

**Plasma Emissions**
Interactions between very high power laser beams and target materials may in some instances produce plasmas. The plasma generated 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 4 lasers represent a fire hazard. Depending on the construction material, beam enclosures, barriers, stops and wiring are all 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.

**Laser Generated Airborne Contaminants (LGAC)**
Air contaminants associated with the use of Class 3B and Class 4 lasers. LGACs result from the interaction of the laser beam with target or other materials and can include metallic fumes and dust, chemical fumes and aerosols containing biological contaminants. LGACs are generally only formed when target irradiance reaches 10E7 W/cm2. Local or area ventilation must be adequate to keep airborne contaminant levels below worker exposure limits.

# Appendix 2 – Glossary of Terms

**Accessible Exposure Limit (AEL) –** The maximum accessible emission level permitted within a particular laser class.

**Blink Reflex or Aversion Response** - The closure of the eyelid or movement of the head to avoid exposure to a noxious stimulant of bright light. It generally 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 0.25 seconds or greater 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 laser radiation and related 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. Diffuse reflections are less hazardous than specular reflections for a given 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).

**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.

**Environmental Health & Safety** - The department charged with implementing and maintaining the laser safety program at the University of Iowa. The Laser Safety Officer is an EHS staff member and has the authority to enforce laser safety policies in order to effect the knowledgeable evaluation and control of laser hazards.

**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 (E)** – Radiant power incident per unit area upon a surface, expressed in watts per square centimeter (W/cm2).

**Laser** - A device that produces an intense, coherent, directional beam of light by stimulated emission of electronic or molecular transitions to lower energy levels. 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.

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

**Nominal Hazard Zone (NHZ)** - 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 (Di)** - Logarithm to the base ten of the reciprocal of the transmittance: Di = log T, where T is the transmittance.

**Power** - The rate at which energy is emitted, transformed, or received in Watts/second or Joule/second. Also called the radiant power.

**Principal Investigator** - The authorized laser user who assumes responsibility for the control and safe use of a laser or laser system.

**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 0.25 seconds.

**Q Switched Laser** - A laser that emits short (~30 nanoseconds), high-power pulses by means of a Q-switch. A Q-switch produces very short, intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

**Radiant Exposure (H)** - Surface density of the radiant energy received (Joules/cm2).

**Radiant Flux (F)** - Power emitted, transferred, or received in the form of radiation, expressed in Watts (also called radiant power).

**Repetitively Pulsed Laser** - A laser with multiple pulses of radiant energy occurring in sequence with a frequency of 1 Hz.

**Specular Reflection** - A mirror-like reflection typically resulting from a shiny, flat surface. Specular reflections are more hazardous than diffuse reflections for a given beam.

**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 total transmitted radiant power to the total incident radiant power.

**Ultraviolet Radiation (Light)** - Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of laser safety, 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 that lie in the range of 400 nm to 700 nm.

**Watt** – The unit of power or radiant flux. 1 watt = 1 Joule per second.

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

# Appendix 3 – Requirements for Personal Protective Equipment (PPE) Use

For all individuals using personal protective equipment, a Hazard Assessment Form for PPE Use must be completed. The purpose of the Hazard Assessment Form is to help ensure that the appropriate protective equipment is provided to each individual to protect him or her from each job related hazard.

The Hazard Assessment Form has three main sections to complete:
1. Identification of the source of the hazard.
2. Assessment of the specific hazard posed.
3. Assessment of the PPE required.

Once the hazard assessment has been completed, PPE training must be provided to each individual assigned to wear PPE. The training must be specific to the type(s) of PPE being worn and must cover the following topics:
1. When the PPE is necessary.
2. What PPE is required?
3. How to properly don, doff, adjust, and wear PPE.
4. The limitations of PPE.
5. The proper care, maintenance, useful life, and disposal of PPE.

Attached are copies of the "Certification of Hazard Assessment Form for PPE Use" and the "Certification for PPE Training" form for your use. These records must be maintained for the duration of your operation. These forms are often reviewed by OSHA during their inspections, and are invaluable in proving that proper instruction and equipment was provided to workers at risk.
For questions regarding personal protective equipment policy, contact the Environmental Health & Safety at 335-8501.

# Appendix 4 – Laser Registration Form for Class 3B and Class 4 Lasers

All users of Class 3B and Class 4 must complete a Laser Registration Form. The purpose of the form is to provide the EHS with an overview of each investigators laser use operation by listing the following information:

- Types and class of lasers used.
- A brief description of the procedure(s) for which each laser is used.
- List of staff members who use the laser equipment.
- List of protective equipment utilized.

The information on the form will be updated periodically during EHS audits of each investigators laser operation. This will enable us to ensure that training for all staff utilizing lasers has been completed, and that we are assessing the operation appropriately, in order to help provide as safe a work environment as possible.
If you have any questions regarding this form, please contact the Laser Safety Officer at 335-8503.