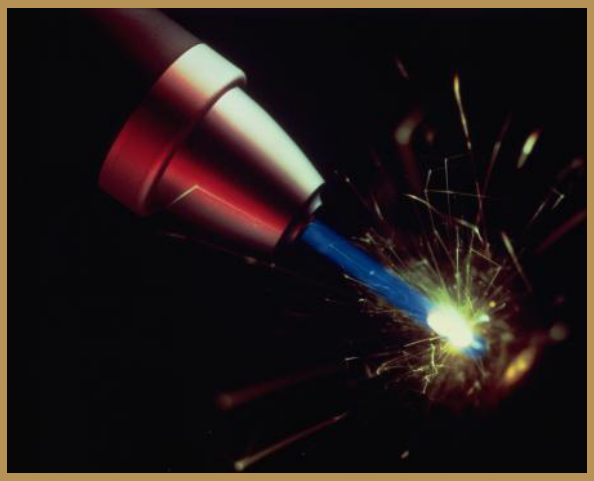
Laser Safety Manual



IOWA STATE UNIVERSITY

Environmental Health and Safety

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Ames, Iowa 50011-3602

(515) 294-5359 | www.ehs.iastate.edu

Reviewed 2019

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Protecting the Safety, Health, and Environment of the Iowa State Community

Iowa State University strives to be a model for safety, health, and environmental excellence in teaching, research, extension, and the management of its facilities. In pursuit of this goal, appropriate policies and procedures have been developed and must be followed to ensure the Iowa State community operates in an environment free from recognized hazards. Faculty, staff, and students are responsible for following established policies and are encouraged to adopt practices that ensure safety, protect health, and minimize the institution's impact on the environment.

As an institution of higher learning, Iowa State University

- fosters an understanding of and a responsibility for the environment,
- encourages individuals to be knowledgeable about safety, health and environmental issues that affect their discipline, and
- shares examples of superior safety, health and environmental performance with peer institutions, the State of Iowa and the local community.

As a responsible steward of facilities and the environment, Iowa State University

- strives to provide and maintain safe working environments that minimize the risk of injury or illness to faculty, staff, students, and the public,
- continuously improves operations, with the goal of meeting or exceeding safety, health and environmental regulations, rules, policies, or consensus standards, and
- employs innovative strategies of waste minimization and pollution prevention to reduce the use of toxic substances, promote reuse, and encourage the purchase of renewable, recyclable and recycled materials.

The intent of this statement is to promote environmental stewardship, protect health, and encourage safe work practices within the Iowa State University community. The cooperative efforts of the campus community will ensure that Iowa State University continues to be a great place to live, work, and learn.

Wendy Wintersteen
President

Directory of Service and Emergency Providers

Services

Environmental Health and Safety
2408 Wanda Daley Drive | (515) 294-5359

Iowa State University Occupational Medicine Department
G11 Technical and Administrative Services Facility (TASF), 2408 Pammel Drive | (515) 294-2056

McFarland Clinic PC, Occupational Medicine
1018 Duff Avenue | (515) 239-4496

Thielen Student Health Center
2647 Union Drive | (515) 294-5801

Emergency

Emergency - Ambulance, Fire, Police
911

Department of Public Safety/ Iowa State University Police
Armory, 2519 Osborn Drive | (515) 294-4428

Mary Greeley Medical Center
1111 Duff Avenue | (515) 239-2011

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A. Introduction

The Iowa State University Laser Safety Program is designed to ensure the safe use of lasers in research and entertainment, as well as the safety of all personnel and visitors to the university who may face potential exposure to lasers.

The laser safety policy requires that all Class 3B and 4 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 series, Standards for the Safe Use of Lasers and this *Laser Safety Manual*. Laser operators are required to follow the guidance of this manual.

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

To properly implement this program, laser operations at Iowa State University and Ames Laboratory are reviewed by Environmental Health and Safety (EH&S) or Environment, Safety, Health (ESH) at Ames Laboratory. Copies of the ANSI Z136.1 Standard for Safe Use of Lasers, ANSI Z136.5 Standards for the Safe Use of Lasers in Educational Institutions, ANSI Z136.6 Standard for Safe Use of Lasers Outdoors, and ANSI Z136.8 Safe Use of Lasers in Research, Development and Testing can be reviewed at these safety offices.

Setting Up a Laser Laboratory

This manual contains regulatory requirements, university policies, and prudent practices that apply to the use of lasers in laboratories and the use of lasers for entertainment purposes on the Iowa State University campus. Using the information contained in the *Laser Safety Manual*, laser users can be assured of establishing a safe and compliant laser system. Laser users must follow the authorization process for Class 3B and 4 lasers and the Laser Safety Officer (LSO)must subsequently evaluate and approve the application.

Laser Safety Overview

“Laser” is an acronym for Light Amplification by Stimulated Emission of Radiation. 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 ultraviolet (0.18 to 0.40 μm), visible (0.40 to 0.70μm) or infrared (0.70μm to 1mm)

regions of the electromagnetic spectrum.

The energy emitted by laser radiation can be transmitted, absorbed, or reflected, depending upon the characteristics of the material with which the laser light comes into contact. Materials that transmit laser beams are said to be transparent. Conversely, opaque materials either absorb or reflect the laser energy.

Transmission and Absorption

Laser transmission and absorption depend not only on the chemical and physical makeup of the target material, but also on the wavelength of the laser being used. 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 ultraviolet regions, radiation striking the eye is absorbed by the cornea and the lens rather than the retina. Although these structures are less easily damaged than the retina, excessive energy absorption can still cause cell damage and vision impairment.

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 multiple direction 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 increases the safety of the experiment.

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. The laser classification is most often supplied by the manufacturer. Custom-built and modified lasers shall be classified by the builder and verified by the LSO. The standards are enforced by the Occupational Safety and Health Administration (OSHA). The Laser Products Performance Standard is enforced by the Centers for Devices and Radiological Health, a division of the Food and Drug Administration.

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(s), but classification is more complex for these devices. The ANSI Z136.1 Standard is available by contacting either EH&S or ESH for details of both continuous-and pulsed laser classification.

Class 1 and 1M Lasers

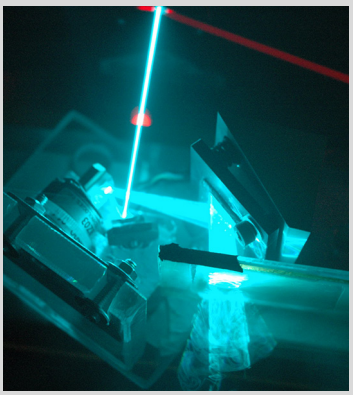
Class 1 lasers are considered to be incapable of producing damaging radiation levels during operation and are exempt from any control measures or other forms of surveillance. A completely enclosed laser that does not emit hazardous radiation under normal operating conditions would be considered a Class 1 laser. Equipment such as laser printers and laser disc players are examples of this class.

Class 2 and 2M Lasers

Class 2 lasers emit accessible, visible (0.4 to 0.7μm) laser light with power levels less than 1 milliwatt (mW) radiant power and are capable of causing eye damage through chronic exposure. The human eye blink reflex, which occurs within 0.25 s, provides adequate protection. It is possible to overcome the blink response and stare into the Class 2 laser long enough to damage the eye. Class 2 equipment housing lasers/laser systems shall bear a label warning against staring into the beam. Some visible continuous-wave Helium-Neon lasers and some laser pointers are examples of Class 2 lasers.

Class 2M lasers emit laser light in the visible portion of the spectrum and eye protection is normally afforded by the aversion response for unaided viewing. Class 2M is potentially hazardous if viewed with certain optical aids such as a microscope.

Class 3R Lasers

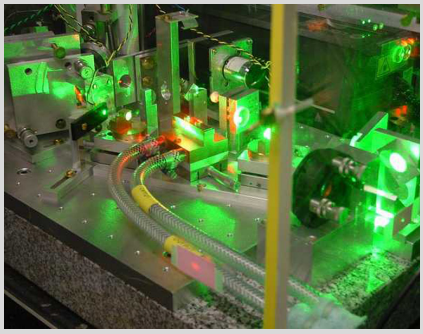


Class 3R laser systems are potentially hazardous under some direct and specular-reflection viewing conditions, if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffuse-reflection hazard. Some visible continuous-wave Helium-Neon lasers and some solid-state hand held lasers are examples of Class 3R laser systems. Class 3R lasers have power levels of 1 to 5 mW and normally do not produce a hazard if viewed only momentarily by the unprotected eye. However, they pose severe eye hazards when viewed through optical instruments (microscopes, binoculars, or other collecting optics). Therefore, Class 3R lasers shall bear a label warning against direct eye exposure or viewing directly with optical instruments.

Lasers used as pointers in classrooms and auditoriums at Iowa State University are restricted and must not be rated higher than Class 3R.

Class 3B Lasers

Class 3B laser systems may be hazardous under direct and specular reflection viewing conditions, but are normally not a diffuse reflection or fire hazard. Class 3B **continuous wave lasers** are ultraviolet, infrared, or visible laser systems with power levels of 5 mW to 500 mW but cannot emit an average radiant power greater than 500 mW for more than 0.25 s or cannot produce a radiant energy greater than 0.125 J (joules) for an exposure lasting less than 0.25 s.



Class 3B **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 longer than 0.25 s or cannot produce a radiant energy greater than 0.03 J per pulse. These lasers bear a sign warning against direct exposure to the beam.

Specific control measures covered in Class 3B 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 if accompanied by the laser operator, instructed in applicable safety requirements prior to entry, and provided with appropriate protective eye wear.

Class 4 Lasers

Class 4 lasers are systems with power levels greater than 500 mW. These laser systems are a hazard to the eye or skin from the direct beam and may pose a diffuse reflection or fire hazard. They may also produce laser-generated air contaminants (LGACs) and hazardous plasma radiation. These lasers/laser systems shall bear signs warning against eye and skin exposure from direct or scattered radiation.

Lasers Classified Under Previous Standards

There is no requirement to reassess lasers that were previously classified. Products that were previously in Class 1 remain in Class 1. Laser products previously classified as Class 3A are now Class 3R unless the emergent beam diameter exceeds 7 mm, in which case they could be Class 1M or 2M. The reclassification of a laser by the LSO may provide regulatory relief in labeling and signage.

Embedded Lasers

Embedded lasers are found in laser products with lower class ratings. However, 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 an embedded laser system is opened and the higher classified laser is accessible (for service or alignment), the requirements for the higher class laser shall be followed.

Administrative Responsibilities

Employees are expected to observe all applicable practices and procedures contained in the *Laser Safety Manual* and *Laboratory Safety Manual*, attend designated training sessions, and report hazardous or unsafe conditions to the laboratory supervisor, principal investigator, or their respective safety office.

Principal Investigators (PIs), laboratory supervisors, and instructors are responsible for ensuring that the policies and guidelines established in this manual are strictly followed by all employees, collaborating researchers, other visitors, and students under their jurisdiction.

Departments are responsible for adopting and implementing the guidelines within the *Laser Safety Manual* in laboratories under their administrative control.

EH&S develops programs for Iowa State University based on federal, state, and local rules and regulations. EH&S oversees the adoption and implementation of the *Laser Safety Manual* by individual departments and will designate an LSO to oversee the laser safety program. The LSO has the responsibility for the day-to-day administration and operation of the university's laser safety program. At Iowa State, health physicists and student technicians assist the LSO.

ESH develops programs for Ames Laboratory based on federal, state and local rules and regulations. ESH oversees the adoption and implementation of the *Laser Safety Manual* by individual departments and will designate an LSO to oversee the laser safety program in DOE-owned buildings or on DOE-funded projects. The LSO has the responsibility for the day-to-day administration and operation of the laser safety program.

Students are expected to observe all applicable safety practices and procedures contained in this *Laser Safety Manual* and the *Laboratory Safety Manual*, attend designated training sessions, and report any unsafe or hazardous conditions to the lab supervisor, PI, or EH&S.

Visitors are considered to be all persons entering a laboratory other than PIs, laboratory staff, enrolled students, and authorized university employees. Visitors to Iowa State University laboratories will be under the supervision of the host laboratory. The host is responsible for laboratory security during the visitation, visitor training and notification of potential hazards, and oversight of visitor compliance with applicable safety practices and procedures contained in the *Laser Safety Manual* and *Laboratory Safety Manual.*

Specific Administrative Responsibilities

Laser Operator

The laser operator is responsible for:

- meeting all applicable requirements including training, outlined in Section F, and medical surveillance, outlined in Section J, before operating lasers
- operating lasers safely and in a manner consistent with this manual, applicable standard operating Ppocedures (SOPs) and guidance from the LSO (EH&S (515) 294-5359 or ESH (515) 294-2153)
- meeting all safety requirements as outlined in the *Laboratory Safety Manual*

Principal Investigator

The PI or laser supervisor is responsible for:

- assuring a safety review or analysis is conducted by the LSO) prior to use or whenever there are changes in location or conditions (such as modifications) that may affect the safe use of lasers
- ensuring that each assigned laser is operated safely and in accordance with applicable requirements
- notifying his or her respective safety office of the intent to procure or build a laser and providing required information for authorization and hazard assessments
- ensuring that lasers are stored securely and safely when not in use so that they are not accessible by unauthorized personnel or used under unauthorized conditions
- permitting only authorized laser operators to use lasers
- providing the LSO written SOPs for approval and ensuring that lasers are used in accordance with the SOPs
- providing and documenting laser-specific training for operators,

in consultation with the respective safety office

- designating laser operators
- maintaining records of Class 3B and Class 4 laser training
- maintaining inspection records for each laser or laser system
- ensuring that all applicable requirements of the *Laboratory Safety Manual* are implemented for the laboratory
- ensuring medical surveillance, as outlined in Section J, is completed by all users prior to commencing work with lasers
- ensuring the LSO has been notified prior to disposal of a laser and/or laser system so that the final disposition of possible hazardous components contained within the laser and /or laser system can be properly disposed
- ensuring that unused or deactivated laser and/or laser systems are secured from unauthorized access

Departments

The department chair or director is responsible for:

- ensuring all employees follow the applicable requirements and safe practices of this laser safety program, including those specified in applicable SOPs
- ensuring the LSO has been notified prior to the acquisition or fabrication of a new laser so that a preliminary safety review can be completed
- ensuring the LSO has been 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 shall be responsible for the safe storage and use of each laser
- notifying the appropriate safety office in the event that a laser is reassigned to a new PI
- ensuring all laser operators complete applicable laser safety training and medical surveillance requirements before they are authorized to operate Class 3B or Class 4 lasers
- ensuring the LSO has been notified prior to disposal of a laser and/or laser system so that the final disposition of possible hazardous components contained within the laser and /or laser system can be properly disposed

- ensuring that unused or deactivated lasers and/or laser systems are secured from unauthorized access

EH&S and ESH

For laser use under their direction, each health and safety office is responsible for

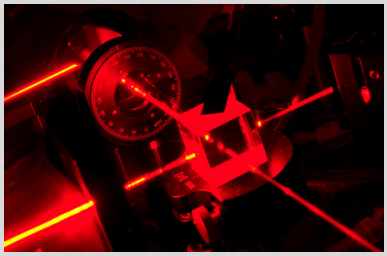
- maintaining inventories of all Class 3B and Class 4 lasers and verifying classification, if necessary
- approving SOPs, alignment procedures, and other control measures before initial use.
- ensuring that Class 3B and Class 4 lasers are inspected at least annually for compliance with safety requirements
- providing assistance in evaluating and controlling hazards
- maintaining records of Class 3B and Class 4 laser inspections
- participating in accident investigations involving lasers
- providing laser safety training
- designating an LSO for each safety office
- maintaining the Laser Safety Manual
- reviewing and authorizing the use of Class 3B and 4 lasers in research, artistic, demonstration, or entertainment applications
- notifying approved users of the necessity of a medical evaluation prior to laser use

B. Process Planning

Laser safety in the laboratory does not happen by accident. Properly planning laser processes will help you identify hazards, establish hazard control measures, and keep you and other laboratory personnel safe.

General Requirements for Laser Operations

The following safety measures are required prior to laser use. Additional requirements may apply to specific lasers at Iowa State University (ISU) or Ames Laboratory. Contact the Laser Safety Officer (LSO) for specific requirements.



- Class 2, Class 2M, Class 3R, Class 3B, and Class 4 lasers shall bear a warning label containing the laser classification, type, and other warnings.
- Class 3B and Class 4 lasers shall be registered with the LSO.
- Each laser and laser application shall meet the safety standards of ANSI Z136 series.
- The LSO may approve lasers or laser systems that meet standards equivalent to ANSI Z136 series.
- Each Class 3B and Class 4 laser shall be assigned to a principal investigator (PI) who is responsible for the safe use and storage of that laser. The LSO shall be notified whenever a laser is reassigned to a new PI or removed from service.
- Laser operators must complete all training and retraining requirements per Section F.
- Lasers shall be operated in accordance with applicable ANSI Z136.1 safety standards and in a manner consistent with safe laser practices. Written Standard Operating Procedures (SOPs) are required for all Class 3B and Class 4 laser systems.
- SOPs shall be specific to each laser or laser system. The SOPs shall include discussion of alignment procedures, interlock testing, and Personal Protective Equipment (PPE) requirements.
- Every Class 3B and Class 4 laser shall be used in a controlled area that restricts access to unauthorized personnel. These controlled laser areas shall be posted with appropriate warning signs.
- Each operator of a Class 3B or Class 4 laser must meet medical surveillance requirements as outlined in Section J.
- Class 3B and Class 4 lasers shall undergo a preliminary safety

review by the LSO prior to acquisition or fabrication. These lasers shall also receive a final safety review via completion of a Laser Hazard Assessment by the laser system supervisor and the LSO prior to initial use. The final review will cover user qualifications, safe operation practices, electrical safety, area controls, and written SOPs.

- Class 3B or Class 4 laser operators shall wear appropriately rated protective equipment (eyewear) as required.
- The LSO shall be notified when Class 3B and Class 4 lasers or laser systems are purchased or constructed.
- Class 3B and 4 lasers/laser systems require a Laser Use Authorization form. An authorization form will be generated upon the completion of a laser application, training, appropriate medical surveillance, and a Laser Hazard Assessment form.

Standard Operating Procedures (SOPs)

Process planning must begin with development of SOPs. This first step requires each investigator or laboratory work group to identify and evaluate all chemical, biological, radiological, and physical hazards associated with laser operations and describe safety precautions necessary to avoid employee exposures and injuries. **SOPs must be specific to each laboratory operation.**

SOPs must be reviewed and approved by the PI or the laboratory supervisor. After approval, SOPs are then incorporated into or attached to written materials and methods. Laboratory personnel must be trained on the elements of the SOP before performing an experiment or operation. See the Standard Operating Procedure template. At minimum, SOPs must include the following:

- **Health and safety information for materials used** – List and briefly describe the chemical, biological, radiological, and physical hazards associated with the operation of the laser or laser system. Identify available resources, such as safety data sheets (SDS) and operator's manuals, and specify where they can be accessed.
- **Hazard control measures** – Include containment devices, ventilation, specific personal protective equipment, and hygiene practices as recommended by the laser manufacturer or other authoritative guide.
- **Waste disposal practices** – Establish procedures for the safe and timely removal of laboratory waste. Refer to "Waste and Recycling" in the Laboratory Safety Manual, as appropriate or develop written procedures if necessary.

- **Spill/release containment and clean up procedures** – See "Emergency Planning" in Section C of the Laboratory Safety Manual.

SOPs must be readily available in the laboratory where the experiment or operation will be performed. SOPs should be reviewed and updated annually.

Class 3B lasers/laser systems require approved written procedures if the laser beam produced is a wavelength invisible to the eye or the laser produces a continues wave visible beam of more than 15mW.

All Class 4 lasers/laser systems require written SOPs for alignment, operating, maintenance, and service procedures, which have been approved by the LSO. These written SOPs shall be maintained with the laser equipment for reference by the operator and maintenance or service personnel.

Special Procedures

Special procedures must be developed for work involving materials or equipment that present a significant risk of exposure or damage to the human body. Examples include carcinogens, reproductive toxins, teratogens, highly toxic substances, explosives, controlled substances, select biological agents, radioactive materials, radiation producing devices, and lasers. The following special procedures must be developed and specified on the SOP.

- Identify authorized personnel who may work with these materials or equipment. Authorized persons must receive training on the unique hazards of these materials or equipment before use.
- Establish a designated use area (for example, a fume hood, glove box, lab bench, lasers) and identify the area with signs or postings. Restrict access to this area to authorized personnel. If an entire lab is designated, then access must be restricted to authorized personnel.
- Specify special safety precautions for experiments or laboratory operations where these materials of equipment are used. Be sure to identify specialized equipment, shielding, or security requirements to be used.

Laser Control Areas

Class 3B and Class 4 lasers shall 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 laser users. The control areas shall be equipped with the prescribed safety features. Operations must meet the following safe operating

standards

- The Class 3B laser control area must be posted with appropriate warning signs that indicate the nature of the hazard(s).
- Only authorized personnel listed on a laser use authorization or variance (required by the City of Ames and/or the Federal Aviation Administration (FAA) for outdoor laser displays) are allowed to operate Class 3B and Class 4 laser systems.
- Spectator access is controlled by the laser operator. Access should only be permitted to the area after appropriate instruction has been provided to the spectators by the laser operator and protective measures are taken. Written instructions and a list of spectators must be maintained by the laser operator.
- The laser beam must be terminated within the control area by appropriate beam stop devices.
- Light levels in excess of the maximum permissible exposure (MPE) limit must not pass the boundary of control areas.
- All openings through which laser light might escape control areas (entryways, 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 and wear appropriate eye protection within the controlled area.
- The use of lasers in outdoor areas or in areas that do not provide complete laser light containment must be specifically approved by the LSO.
- Class 3B IR and UV lasers require additional controls since beams are not readily detectable.
    - Highly absorbent, non-specular stops must terminate beams.
    - Signs and light should warn those in the area when lasers are being operated.
    - Special attention must be given to the production of ozone, skin sensitizing agents and other hazardous products when ultraviolet lasers are used.
- Class 4 lasers may 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 (lecture demonstrations, displays, etc.), temporary laser control areas can be

created. Contact the LSO for details.

Laser Usage for Display / Entertainment Purposes

The laser company must meet with a LSO prior to the show to discuss laser details, including compliance with the Laser Safety Manual.

A university staff member in charge of a laser light performance must:

- notify the LSO as soon as a laser company is scheduled to provide entertainment on university property
- notify the laser company of the university requirements for notification
- provide access to the laser light performance location to representatives of EH&S prior to and during laser performances

The laser operator must provide information to the LSO prior to the show regarding:

- operator training
- emission levels of beams
- type of communication between operator and surveillance personnel
- name of contact person between the laser company and performers
- emergency procedures
- safety procedures
- briefing of security personnel of hazards associated with lasers
- detailed description of each effect
- distance of separation of beams from audience
- time that the alignment procedure will be performed
- demonstration of the show to the LSO
- performance of alignment check between acts (when possible), if more than one act is performing
- termination of any effect that the LSO feels is unsafe

The LSO will:

- set up an interview with the operator to discuss show details
- observe alignment procedures and make recommendations
- notify the operator during the demonstration of any unsafe conditions and require the termination of all effects, if necessary

- after the demonstration, discuss with the operator any problems encountered

C. Authorization Process

Each new project involving the use of class 3B or 4 lasers must be specifically authorized by the Laser Safety Officer (LSO).

Application for Initial Use

The individual who is to be in charge of the project, referred to as the Principal Investigator (PI), begins the process by completing an Application for the Use of Class 3B or Class 4 Laser. The application must include detailed information in three general categories: information on users, project description, and facility description.

Information on User(s)

It is critical that those working with laser and laser systems have proper qualifications. This is determined by providing the following information:

- personnel – name, department, PI, major field, university address and phone number
- training – title and an indication of whether the Laser Safety Training provided by Iowa State University (ISU) or Ames Laboratory has been completed
- laboratory experience – duration of experience, specific experimental procedures employed, and procedures followed for laboratory safety and waste handling

Project Description

The project description consists of:

- scope of project – purpose and experimental procedures to be used
- radiation producing devices – energy being produced
- safety procedures – general, laboratory specific, and laser specific

Facility Description

A facility must meet certain requirements in order to be used for laser work. Determination of facility suitability includes:

- location of use – building, floor, room number, department
- room plan drawing
  - facility: locations of laser beam, windows, doors
  - construction materials: walls, bench tops

- ventilation
- occupancy of facility and adjacent area

Review and Approval of Application

The complete application must be submitted to the LSO, where it will receive an initial review. At this time the LSO may require additional information from the applicant. If the application appears to be adequate, the LSO or designee will meet the PI and perform a Laser Hazard Assessment. Once all issues have been addressed and the application has been approved, the LSO will sign the authorization form and forward it to the PI.

EH&S will also review procedures for additional hazards involving chemical and biological materials and physical hazards. Approval for procedures involving additional hazards may be delayed until safety and regulatory measures are addressed.

Application to Amend Use

Approval for any modification to an original authorization may be requested from EH&S, either in written or electronic form. Minor changes, such as additional personnel or changes in location, are reviewed and, if appropriate, approved by the LSO. More extensive changes will be subject to the same review and approval process as the original application.

Ordering Lasers and Laser Systems

The LSO should be contacted prior to ordering Class 3B and 4 laser or laser systems. Including the LSO as part of your ordering process will decrease procurement delays and reduce potential regulatory deficiencies. The LSO can recommend protective measures to consider for the specific system.

D. Emergency Planning

Planning for emergencies enables communication of hazards through signage and postings and allows laboratory personnel to develop and follow emergency action plans.

Postings and Signage

For information regarding general lab safety postings and signage and emergency action plans, refer to "Emergency Planning" in the *Laboratory Safety Manual*

The ANSI Z136 series requires that lasers and laser systems have appropriate warning labels and that the rooms in which they operate bear appropriate warning signs. Signs for laser laboratory doors are provided by the LSO; however, laboratory supervisors and laser users/operators must be familiar with the signage requirements.

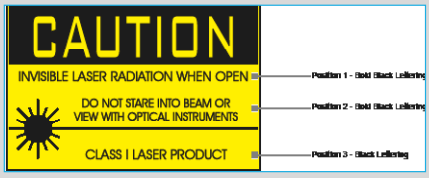
The signal word "Danger" indicates that death or serious injury will occur if necessary control measures are not implemented to mitigate the hazards within the laser controlled area. This signal work shall be restricted to those Class for lasers multi-kilowatt output power or pulse energies with exposed beams..

The signal word "Warning" shall be used on laser area warning signs associated with lasers and laser systems whose output exceeds the applicable MPE for irradiance, including all Class 3B and most Class 4 lasers and laser systems. The signal word "Caution" must be used with all sign and labels associated with all Class 2 and Class 2M lasers and laser systems that do not exceed the appropriate MPE for irradiance.

The signal word "Notice" must be used on signs posted outside temporary laser-controlled areas, such as during periods of service.

E. Equipment

Use of Engineering Controls



Engineering controls must be implemented where possible to reduce hazards associated with the use of lasers and laser systems. Engineering controls should be considered in the following order:

- substitution of less hazardous equipment or processes
- physical isolation of the operator or process
- local and general exhaust ventilation and/or filtration

Specific Engineering Controls

- All lasers require a protective housing.
- Beams must be enclosed as much as is operationally practical. Items to consider for enclosing the beam may include curtains, side shields, partitions, or entryway mazes.
- All Class 3B and Class 4 lasers must be equipped with protective housing interlock systems to prevent emission of laser radiation when the protective 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 laser systems must be equipped with filters, attenuators and interlocks to keep exposures below the MPE limit for all conditions of operation and maintenance.
- All Class 3B and Class 4 lasers must adhere to the following engineering controls guidelines:
  - Lasers must be equipped with removable master key switches and must not be operable when the keys are removed.
  - Lasers must be equipped with electrical connections allowing the lasers to be controlled by area interlock systems and remote shut-off devices.
  - When terminals are open-circuited, lasers must not emit any radiation in excess of the MPE.
  - Class 4 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 procedure).

- All listed engineering controls shall be designed and incorporated into locally built lasers and must function with the laser system.
- Exceptions shall be approved by the Laser Safety Officer (LSO).

Personal Protective Equipment

Despite the application of all practicable engineering and administrative controls, on occasion it is necessary to work near an open Class 3B or Class 4 laser beam. On these occasions, personal protective equipment (PPE) shall be used to protect the eyes and skin. For more information about general lab PPE, refer to the *Laboratory Safety Manual.*

Eye Protection

Eye protection suitable to the laser class must be provided and worn within the laser control area during operation and alignment 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, such as in low-light situations.

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 its designed wavelength, the optical density at that wavelength and the maximum power rating
- be inspected 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 laboratory must be equipped with eye protection that is suitable for the laser(s) in use.

Eyewear must meet the following minimum criteria:

- Eyewear must be labeled with the optical density (OD) and wavelengths for which the eyewear is designed. Labeling can be self-adhered and must be legible.
- The OD on eyewear must meet the levels required for the laser application.
- The protective eyewear must be appropriate for the wavelength(s) used in the laser application.
- The eyewear must be inspected for pitting, crazing, cracking, etc., of the filter material. The goggle frame must also be inspected for mechanical integrity and light leaks.
- The quantity of eyewear on hand must be sufficient for the expected number of daily users and visitors for each laser.
- Appropriate eyewear must be used for alignment procedures.
- Prescription eyewear is required to be up–to-date. A consultation with Occupational Medicine may be required to determine if a new set of eyewear is needed.
- Eyewear must be stored in the lab and in a manner that preserves its condition. Storage holders supplied by the eyewear vendor are recommended.

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 for lasers that are running in the ultraviolet region, because very large peak powers with pulsed ultraviolet lasers may be particularly dangerous. The LSO can assist in identifying protective equipment that is appropriate for the intended use. This equipment must be addressed in the written Standard Operation Procedure (SOP).

F. Training

Principal investigators and/or laboratory supervisors are responsible for ensuring that all personnel are properly trained before they begin work in a laboratory and that they receive additional training when new hazards or procedures are introduced. For details about what general lab trainings are required see the *Laboratory Safety Manual.*

Only qualified and authorized personnel are permitted to operate laser systems. Therefore, all Class 3B and Class 4 laser users are required to complete Laser Safety Training, participate in a medical surveillance program and complete all required departmental job activity training prior to performing this activity. Laser users must complete retraining every three years.

Laser Safety Training (Initial)

All Iowa State University and Ames Laboratory laser operators of Class 3B and 4 lasers and laser systems must complete laser safety training prior to performing laser work. This training can be accessed by logging onto the Learn@ISU website. The computer based training course includes a slide presentation and a final examination. Participants must achieve at least an 80% score on the examination. Ames Laboratory personnel must submit a certificate of completion to the Ames Lab Training Office in order to receive credit.

Retraining

Iowa State University and Ames Laboratory laser operators of Class 3B and 4 lasers and laser systems are required to complete retraining every three years by logging onto the Learn@ISU and completing the Laser Safety for the Operator online course The computer-based training course includes a slide presentation and a final examination.

Laser Safety Awareness Training

All Iowa State University and Ames Laboratory personnel working in a laboratory containing Class 3B or 4 laser systems but not operating these lasers must have Laser Safety Awareness training. This training can be accessed by logging onto the Learn@ISU. Participants must achieve at least an 80% score on the examination.

Laser Laboratory Specific Training

In addition to the lab-specific training mentioned in the *Laboratory Safety Manual,* each laser user must be trained on the operation of each laser or laser system by the laser supervisor (principal investigator). This

training must cover

- standard operating procedures (SOPs)
- alignment procedures
- secondary hazards
- protective equipment
- other pertinent safety information

Training records must also be maintained in the laboratory.

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 UV or infrared radiation. Contact the Laser Safety Officer (LSO) for specific requirements. For general lab safety practices, see the *Laboratory Safety Manual*.

Work Area Safety Practices

- The laser beam must be enclosed as much as practical.
- Laboratory must be closed and secured when unattended.
- Warning labels and signage must be posted.
- The room must be illuminated as brightly as possible.
- The laser must be set up so that the beam path is either above 6.5 ft or below 4.5 ft.
- To minimize reflections, shield or remove all unnecessary reflective surfaces.
- Windows to hallways or other outside areas must have adequate shades or covers.
- The main beams and reflected beams must be terminated or dumped.
- Electrical installation must meet electrical safety standards.
- Active laser must never be left unattended, unless it is a part of a controlled environment.

Laser Use Safety Practices

Use proper eye protection when working with Class 3B or Class 4 lasers. 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 to a certain type of laser and may not protect at different wavelengths or powers.

- Avoid looking into the primary beam at all times.
- Align the laser with the proper eye protection
- 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 wavelengths not visible to the human eye.
- Do not wear bright, reflective jewelry, or other reflective objects.

Outdoor Laser Use Safety Practices

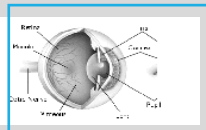
- Terminate the beam at the end of its useful path whenever possible.
- Locate the beam path at a point other than eye level.
- Prohibit beam propagation across pedestrian or vehicular thoroughfares.
- Select a height that avoids the eyes of area workers.
- Minimize specular reflections and use non-reflective tools.
- Enclose beams as much as possible.
- Locate lasers so that no beam hazard exists at locations where personnel are normally present.
- Post CAUTION signs in operational areas.
- Avoid direct beam viewing to align lasers.
- Design outdoor laser areas so that personnel can enter and leave the controlled area under emergency conditions.
- Design doors, gates, or other access control devices to laser areas so that they do not impede emergency egress.
- Post a laser classification label at each entrance to a controlled outdoor laser area.
- Install visual or audible beam-warnings for invisible lasers.
- Activate all warning devices whenever the beam is on.
- Check the requirements for flight zones contained in FAA Order 7400.2E, Procedures for handling Airspace Matters, reference ANSI Z136.6, Appendix A.

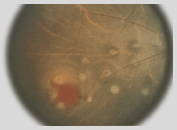
H. Safety Practices for Specific Hazards

The following are additional laser safety practices that apply to Iowa State Univeristy (ISU) laser laboratories. The *Laboratory Safety Manual* contains other safety practices that may apply to non-laser hazards associated with laser use.

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 watts (W), the beam can ignite flammable or combustible materials.





Thermal burn and photochemical damage to the retina may occur from laser light in the near ultraviolet (UV), visible and near infrared (IR) regions. 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 times. 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.

Non-Beam Hazards

Beam hazards of a laser are only one concern in using lasers. The other associated hazards described below must be understood to ensure the safe use of a laser or laser system. Contact the Laser Safety Officer (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. Electrical equipment in general presents three potential hazards – shock, resistive heating, and ignition of flammable materials. Several deaths have occurred when commonly accepted electrical safety practices were not followed by those working with high-voltage components of laser systems. The following is a list of recommended electrical safety practices:

- Prior to working on electrical equipment, de-energize the power source. Lock out and tag out the disconnect switch.

- 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.
- Check that each capacitor is discharged and grounded prior to working in the area.
- Use shock prevention shields, power-supply enclosures, and shielded leads in all experimental or temporary high-voltage circuits.

Biological Agents

Biological agents include Laser Generated Air Contaminates (LGAC) and infectious materials. LGAC may be generated when high power laser beams interact with tissue. Infectious materials, such as bacterial and bacterial organisms, may survive beam irradiation and become airborne. Contact the Biosafety Officer for a biological agent consultation if you have questions regarding your system.

Chemical Hazards

Many dyes used as lasing media are toxic, carcinogenic, corrosive, or pose a fire hazard. All chemicals used in the laser system must be accompanied by a safety data sheet (SDS). The SDS will supply appropriate information pertaining to toxicity, personal protective equipment (PPE), and storage of chemicals.

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

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 supply that requires more than 15 kilovolts (kV) may produce sufficient x-rays to cause a health hazard. Interaction

between x-rays and human tissue may cause cancer (such as leukemia) or permanent genetic effects. Contact the LSO for a collateral radiation consultation if you have questions regarding your system.

Compressed Gases

Compressed gases used in or with 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.

Cryogenic Liquids

Cryogenic liquids are used in the cooling systems of certain lasers. As these materials evaporate, they displace oxygen in the air; thus, adequate ventilation must be maintained where cryogenic liquids are used. Cryogenic liquids are potentially explosive due to expansion forces when ice collects in valves or connectors that are not specifically designed for use with cryogenic liquids. Although the quantities of liquid nitrogen used are small, protective clothing, eye protection, and face shields must be used to prevent freeze burns to the skin and eyes.

Electric, Magnetic and Electromagnetic Fields

Power supplies and other electrical equipment associated with some lasers are capable of generating intense power-frequency electric and magnetic fields that exceed published federal guidelines. Q-switches and plasma tubes are RF excited components. Unshielded components may generate RF fields that exceed federal guidelines. Appropriate warning signs and labels should be used.

Explosion Hazards

High-pressure arc lamps, filament lamps, and capacitors may explode violently if they fail during operation. These components shall be enclosed in a housing that is able to 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. Adequate mechanical shielding shall be used when exposing brittle materials to high intensity lasers.

Fire Hazards

Class 4 lasers represent potential fire hazards. 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. Under some situations where flammable compounds or substances exist, it is possible that fires can be initiated by Class 3 lasers.

Laser-Generated Air Contaminates (LGAC)

Air contaminates may be generated when certain Class 3B and Class 4 laser beams interact with matter. The quantity, composition, and chemical complexity of the LGAC depend greatly upon target material, cover gas, and the beam irradiance. Some compounds may be gaseous or particulate and can, under certain conditions, pose occupational concern. For further information, contact your safety office.

Plasma Emissions

Interactions between very high-power laser beams and target materials produce plasmas that may contain hazardous UV emissions. Plasma emissions created during laser-material interactions may contain sufficient UV and blue light (0.18 to 0.55 um) to raise concern about long-term ocular viewing without protection.

UV and Visible Radiation

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. Photosensitizing agents from industrial chemicals or medications can make an individual more susceptible to these effects.

I. Disposal and Transfer of Lasers

Laser laboratories need to ensure the proper disposal of contaminated laser-related material, such as flue and smoke filters, organic dyes, and solvent solutions.

Unwanted Lasers and Laser Systems

Generators of this unwanted material must manage them as outlined in the *Waste and Recycling Guidelines*, *Biosafety Manual*, *Radioactive Materials Manual*, and *Laser Safety Manual*.

The following minimum guidelines are required when dealing with unwanted lasers or laser systems.

- ensure all hazardous substances have been removed and the equipment decontaminated
- ensure a complete Laboratory Equipment Disposal Form has been forwarded to EH&S
- verify that Environmental Health and Safety (EH&S) has inspected/tested the equipment and authorized transfer and/or disposal through ISU Surplus
- for disposal of lasers within Ames Laboratory, contact Environment, Safety, Health (ESH) (515) 294-2153

On-Campus Transfer of Lasers and Laser Systems

Whenever lasers are transferred from one laboratory to another, the Laser Safety Officer (LSO) must be notified and provided with the following information:

- when the laser will be transferred
- the names of the person(s) transferring and receiving the laser
- the sending and receiving locations
- phone numbers of responsible person(s)

EH&S or ESH will update the laser inventory for both laboratories and perform a laser hazard assessment in the new location.

Off-Campus Transfer of Lasers and Laser Systems

When planning to transport or ship a laser or laser system off campus, EH&S or ESH must be informed in advance to determine correct shipping conditions. The laboratory is responsible for all costs associated with laser shipments. The LSO must be provided with the following information:

- when the laser will be transferred
- the names of the person(s) transferring and receiving the laser
- the sending and receiving locations
- phone numbers of responsible person(s)

Laser Laboratory Waste

Laboratories generate a wide variety of unwanted chemical, biological and/or radiological materials.

J. Medical Surveillance and Exposure Assessment

Medical Surveillance – Ames Laboratory Personnel

Medical surveillance is required for employees who are routinely engaged in work where they may be exposed to laser radiation from Class 3B and Class 4 lasers. Before laser operation, users must schedule an appointment for a baseline eye exam with Occupational Medicine, (515) 294-2056 located at G11 Technical and Administrative Services Facility (TASF), 2408 Pammel Drive

The medical exam will establish a baseline of ocular conditions before potential exposure to laser radiation. It will also detect and document, as early as possible, ocular damage in the event of a suspected exposure incident. The program serves both to assess the effectiveness of control measures and institute appropriate therapeutic measures. Laser users will be subject to the following baseline eye examinations:

- ocular medical history, including hyper-photosensitive 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 order additional examinations. Additional eye exams are required in the event of exposure or suspected exposure to laser radiation above the MPE. An eye exam is recommended upon termination of laser work or termination of employment.

Medical Surveillance – Iowa State University Personnel

Medical surveillance is required for laser workers who have worked with Class 3B and Class 4 lasers at another institution and have had or suspected a laser eye injury. Before laser operation, these users must omplete a baseline eye exam with Occupational Medicine.

Participation in the Occupational Medicine Program requires completion of a Hazard Inventory form. The online form must be completed by new employees who are exposed to hazards as part of their assigned job duties and/or current employees who have changes to their hazards or personnel information. EH&S will use this information to determine the need for enrollment in the ISU Occupational Medicine Program. Individuals and supervisors will receive an email after EH&S has completed the evaluation of the

hazards, and can login to see the results. If it is determined that the individual's workplace hazards require medical monitoring or training, the individual will receive a notice to contact Occupational Medicine, (515) 294-2056 located at G11 Technical and Administrative Services Facility (TASF), 2408 Pammel Drive.

This medical surveillance program will establish a baseline of ocular conditions before potential exposure to laser radiation. It will also detect and document, as early as possible, ocular damage in the event of a suspected exposure incident. The program serves both to assess the effectiveness of control measures and institute appropriate therapeutic measures. Laser users will be subject to the following baseline eye examinations:

- ocular medical history, including hyper-photosensitive 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 order additional examinations.

Additional eye exams are required in the event of exposure or suspected exposure to laser radiation above the MPE. An eye exam is recommended upon termination of laser work or termination of employment.

Work-related Injuries, Illnesses, and Exposures

Iowa State University employees exposed or injured while at work or in the course of employment must seek medical attention at the McFarland Clinic PC, Occupational Medicine Department, 1215 Duff Ave, Ames, IA; (515) 239-4496. Supervisors should call the McFarland Clinic Occupational Medicine Department during regular work hours to schedule an appointment for the employee. Any relevant safety information such as an SDS should accompany the employee to the appointment.

Reporting

All work related injuries, illnesses, or exposures must be reported to the employee's supervisor, even when medical attention is not required or is refused by the employee:

An Incident Report (IR) must be completed by the injured employee and/or the supervisor through the ISU Incident Portal within 24 hours of the incident. Upon submission of the report, the supervisor will

receive an email requesting information relating to the Accident Investigation as part of the incident reporting process. The supervisor is asked to reply directly to the email with answers to the questions asked within 24 hours of receiving the email. Questions regarding the form may be forwarded to University Human Resources at (515) 294-3753. Contact Environmental Health and Safety at (515) 294-5359 for guidance and assistance, especially when a serious injury or major loss occurs.

For additional information access EH&S accidents and injuries page.

Student Accidents and Injuries

Students not employed by Iowa State University who are exposed or injured in the classroom or laboratory should seek medical attention at the Thielen Student Health Center, 2647 Union Drive, (515) 294-5801. All accidents and injuries sustained by Iowa State University students while in academic classes or events sponsored by the university must be reported to Risk Management by the student and a university representative using the ISU Incident Portal.

Medical Emergencies

If injury, illness or exposure necessitates immediate treatment, transport the employee to the Emergency Room at Mary Greeley Medical Center, (515) 239-2155. If emergency transport is needed, dial 911. Be prepared to provide any relevant safety information, such as an SDS. When an employee requires emergency treatment, the incident must be reported to EH&S at (515) 294-5359 as soon as possible. Provide assistance to injured or exposed personnel by following the First Aid Procedures.

Glossary

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

Beam
A collection of light/photonic rays characterized by direction, diameter (or dimensions), and divergence (or convergence).

Blink Reflex or Aversion Response
The involuntary 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.

Coherent
A beam of light characterized by a fixed-phase relationship (spatial coherence) or single wavelength i.e., monochromatic (temporal coherence)

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 is regarded as a CW laser.

Controlled Area (laser)
An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser 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 (EH&S)
The department at Iowa State University that has the authority to evaluate, monitor and enforce the control of lasers and laser systems for all laser users.

Environment, Safety, Health and Assurance (ESH)
The department at Ames Laboratory that has the authority to monitor and enforce the control of lasers, laser systems and laser hazards for all laser users within Department of Education (DOE)-owned buildings or on DOE-funded projects.

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 protective enclosure that contains a laser. In the case of Class 3B and Class 4 lasers, this case

is required to be interlocked.

Infrared (IR) Radiation
Electromagnetic radiation with wavelengths that lie within a range of 0.7 µm 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 W/cm².

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

Laser Classification
An indication of the beam hazard level of a laser or laser system during normal operation or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4. In general, the potential beam hazard level increases in the same order.

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 (LSO)
The individual who has authority to monitor and enforce the safe use of lasers and laser systems.

Laser Supervisor
The responsible PI for a laser or laser system. See also *Principal Investigator*.

Maximum Permissible Exposure (MPE)
The level of laser radiation to which an unprotected 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:
$D_\lambda = -\log10\ \tau_\lambda$, where τ_λ is the transmittance at the wavelength of interest.

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 PI is appointed by the Department Chairperson. See also *Laser Supervisor*.

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-switch
A device for producing very short (~10-250 ns), intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium.

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

Radiant Exposure (H)
Surface density of the radiant energy received in units of J/cm².

Radiant Power (Φ)
Power emitted, transferred, or received in the form of radiation in units of watts (W). Synonym: radiant lux.

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

Shall
The word shall is to be understood as mandatory.

Should
The word should is to be understood as advisory.

Specular Reflection
A mirror-like reflection.

Standard Operating Procedure (SOP)
Formal written description of the safety and administrative procedures to be followed in performing a specific task. 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 (energy) to incident power (energy).

Ultraviolet (UV) Radiation (Light)
For the purpose of this laser safety manual, electromagnetic radiation with wavelengths between 0.18 and 0.40 µm.

Visible Radiation (Light)
Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths of 0.4 to 0.7 µm. Derivative standards may legitimately use 0.38 – 0.78 µm for the visible radiation range.

Wavelength
The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (e.g., the distance from one peak to the next).

Non-discrimination Statement

"Iowa State University does not discriminate on the basis of race, color, age, ethnicity, religion, national origin, pregnancy, sexual orientation, gender identity, genetic information, sex, marital status, disability, or status as a U.S. veteran. Inquiries regarding non-discrimination policies may be directed to Office of Equal Opportunity, 3350 Beardshear Hall, 515 Morrill Road, Ames, Iowa 50011, Tel. 515 294-7612, email eooffice@iastate.edu"