Laser Safety Manual
Southern Illinois University
Carbondale Illinois

Prepared by:

The Radiological Safety Committee

Southern Illinois University

Carbondale, Illinois

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FOREWARD

The Laser Safety Program was prepared by the Southern Illinois University Carbondale (SIUC) Radiation Control Committee (RCC). The following procedures and/or regulations are promulgated to assure the safe utilization of laser systems on all properties under the control of SIUC.

The SIUC Laser Safety Program contains the rules, regulations, and procedures necessary to ensure compliance with the State of Illinois Division of Nuclear Safety. It also includes the rules and procedures which the RCC has deemed necessary in order to safeguard personnel, property and the community-at-large from possible exposure to hazardous levels of laser radiation.

The purpose of this program is to supplement state regulations for the control of laser radiation, but in no case is intended to replace these regulations. In the event that future state regulations are found to differ from the requirements herein, SIUC laser users shall comply with the rules and regulations that are most stringent.

The RCC shall review this Laser Safety Program annually and update it as needed. Changes may be made to this manual to facilitate administration of the Laser Safety Program. If these changes affect the safe operation of lasers or laser systems, a memo will be sent out instructing laboratory personnel to review the changes immediately and to take proper precautions.

A. INTRODUCTION

Southern Illinois University Carbondale (SIUC) has established a Laser Safety Program to ensure the safe use of Class 3b and Class 4 lasers or laser systems for conducting research. This manual was written to provide policies and procedures to faculty, staff, and students on maintaining and documenting the Laser Safety Program. This manual is also designed to ensure the safety of all personnel who may face potential exposure to lasers along with serving as a reference source for laser users.

SAFETY IS EVERYONE'S CONCERN!!!

Faculty conducting or supervising research, which involves lasers, are responsible for **all** personnel within the laser environment. The skills and safety awareness of the laser operator are the most important aspects when it comes to laser safety. For those individuals who are assisting the laser operator, knowledge and the consistent application of laser safety practices will ensure a safe working environment with lasers.

The safety standards contained within in the manual are based primarily on the Illinois Division of Nuclear Safety (IDNS) regulations Part 315, "Standards for Protection Against Laser Radiation." Pursuant to provisions of the Laser Safety Act of 1997, these requirements address issues or laser safety for the use of Class 3b and Class 4 lasers and incorporate references from Title 21 of the Code of Federal Regulations, the American National Standard for the Safe Use of Lasers (ANSI Z136.1-2000) and the American National Standard for the Safe Use of Lasers in Health Care Facilities (ANSI Z136.3-1996).

All Class 3b and Class 4 lasers used at SIUC are administered by the policies and procedures approved by the Radiation Control Committee (RCC). The Laser Safety Officer (LSO) is responsible for implementing the policies and procedures approved by the RSC. The Principle Investigator is responsible for using lasers according to the policies and procedures approved by the RCC.

B. RESPONSIBILITIES

The effectiveness of the SIUC Laser Safety Program depends on the complete cooperation and commitment of all parties involved. Each party must assume individual responsibility for conducting procedures in the proper manner and according to established protocols.

a. Radiation Control Committee (RCC)

The Radiation Control Committee (RCC) has been granted authority by the Dean and Provost of SIUC to administer the Laser Safety Program. The RCC is responsible for laser protection oversight at SIUC. The RCC has the authority to authorize, suspend, and specify conditions for use of all lasers at facilities and areas of administration by SIUC. The RCC is responsible for the following:

1. Reviewing internal policies/procedures to ensure they comply with applicable regulations and standards.
2. Approving all standard operations procedures (SOPs) for laser usage.
3. Establishing enforcement action for deficiencies in practices of the principal investigator and other authorized laser users.
4. Performing annual program reviews.

b. Laser Safety Officer

The Laser Safety Officer (LSO) is responsible for the Laser Safety Program development, program implementation, and program compliance. The LSO shall be provided with administrative support and adequate resources as are required to carry out the provision of this program. The LSO shall report to the RCC on a regular basis with material information about the operation of the program as required by the RCC. Duties of the LSO include, but are not limited to the following:

1. Administering the overall Laser Safety Program.
2. Maintaining a current inventory of Class 3b and Class 4 lasers.
3. Functioning as a liaison between the principal investigator, laser users and the RCC.
4. Making recommendations to improve laser safety.
5. Reporting problems of non-compliance with laser safety to the RCC.
6. Suspending, restricting or terminating the use of lasers that present an imminent danger or excessive hazard.
7. Reviewing/inspecting protective equipment (i.e. eyewear, clothing, etc.) at intervals at least every six (6) months.
8. Ensuring that adequate safety education and training is available for laser users.
9. Investigating any real or suspected accidents involving lasers, and initiating appropriate corrective actions if necessary.
10. Maintain records as required by the IDNS and SIUC.

c. Department Chairperson

Department chairpersons are responsible for assuring their Principal Investigators, who use lasers, operate those lasers safely and implement the Laser Safety Program.

d. Principal Investigator

Principle Investigators (PIs) are directly responsible for implementing the SIUC Laser Safety Program to the operation of lasers and laser systems within their laboratory/under their supervision. The PI must be a permanent faculty or staff

member (i.e. not a postdoctoral or graduate student) and are responsible for the following:

1. Ensuring they have the appropriate credentials for approved research use of lasers at SIUC.
2. Registering all lasers with the LSO by completing a Laser Registration Form (See Appendix E) for each laser within their laboratory areas.
3. Providing, implementing, and enforcing the Laser Safety Program specific to their laboratory laser.
4. Ensuring that SOPs (which shall be approved by the RCC) are written for all Class 3b and Class 4 laser activities and available to laser operators under their supervision.
5. Ensuring that laser operators, prior to operating or working in proximity to Class 3b and Class 4 lasers, undergo SIUC Laser Safety training and complete and submit the Laser User Statement of Training and Experience Form (See Appendix VI).
6. Supervising the safe use of lasers in the laser environment.
7. Ensuring the availability of the correct personal protective equipment (PPE) for the particular laser (See Appendix G section 7).
8. Notifying the LSO immediately if an exposure or suspected accident Occurs.
9. Notifying the LSO promptly when acquiring a new laser by purchase or transfer, or when the location of a laser has changed by relocation or transfer.
10. Assist the LSO in the scheduled inspection of lasers and protection equipment under their control.

e. Laser Operator

Laser Operators are responsible for their own safety during laser operations. **All laser operators must meet the laser safety training requirement prior to the use of Class 3b or Class 4 lasers.** All laser operators are responsible for the following established safety procedures of the Laser Safety Program and will promptly report known or suspected accidents to the PI and the LSO. Laser operators are responsible for the following:

1. Completing SIUC Laser Safety Training.
2. Following SOPs while operating lasers.
3. Using the required PPE when using a laser.
4. Ensuring familiarity with the specific safety hazards of the lasers they are operating or working in proximity to.
5. Operating a Class 3b or Class 4 laser only if authorized by the PI and/or the LSO and only after completing and submitting the Laser User Statement of Training and Experience Form (See Appendix F).

6. Reporting known or suspected accidents to the PI and the LSO.
7. Ensuring that spectators or visitors are properly informed of and protected from potential laser hazards.

f. Purchasing

Purchasing will notify the LSO of all laser purchase requests, excluding laser printers, bar code readers, and laser pointers.

C. LASER CLASSIFICATION

The hazard class of a laser is extremely important in determining the appropriate hazard controls to make the laser system safe. 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. All lasers are divided into classes and corresponding labels are affixed to the lasers or laser systems to positively identify the class and alert the user to follow the necessary safety precautions. Understanding the laser classification is a fundamental prerequisite for any discussion of laser safety.

All commercially manufactured lasers come marked with a hazard class as required under the Federal Drug Administration (FDA) Center for Devices and Radiological Health (CDRH) regulations. Lasers made or modified as SIUC will need to be evaluated by the LSO and appropriately classed. It is the responsibility of the PI to assist the LSO by supplying the appropriate radiometric parameters of the laser system in the Laser Use Registration Form (See Appendix E).

a. Class 1 (Eye Safe Lasers)

Class 1 lasers do not emit harmful levels of radiation during normal operation and are therefore, exempt from control measures. However, for good practice, unnecessary exposure to Class 1 laser light should be avoided. Very few lasers are designated as Class 1, yet many laser systems can be made into Class 1 systems by totally enclosing the laser beam and interlocking the enclosure. When using a Class 1 laser, the PI is not required to fill out Laser Use Registration Form.

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b. Class 2 (Safe Through the Aversion Response)

Class 2 lasers emit accessible laser light in the visible region and are capable of creating eye damage through chronic exposure. In general, the human eye will blink within 0.25 seconds when exposed to Class 2 laser light. This natural blink reflex provides adequate protection. However, it is possible to overcome the blink reflex and to stare into a Class 2 laser long enough to cause damage to the eye. Class 2 lasers have a power level less than 1.0 milliwatt (mW), and are commonly found in alignment applications.

c. Class 3a Lasers

Class 3a lasers and laser systems are normally not hazardous when viewed only momentarily with the unaided eye, but can cause severe eye hazards when viewed through optical instruments, such as telescopes, microscopes and binoculars. Class 3a lasers have power levels from 1.0 - 5.0 mW.

d. Class 3b Lasers (Intrabeam/Specular Reflection Hazard)

Class 3b laser light will cause injury upon direct viewing of the beam and specular reflections. The power output of **Class 3b *continuous wave lasers*** are ultraviolet, infrared, or visible laser systems with power levels ranging from 5.0 – 500 mW. These systems cannot emit an average radiant power greater than 500 mW for more than 0.25 seconds or cannot produce a radiant energy greater than 0.125 Joules (J) for an exposure lasting less than 0.25 seconds.

Class 3b *pulsed lasers* are visible or near infrared systems with power levels of 5.0 – 500mW. These systems cannot emit an average radiant power greater than 500 mW for longer than 0.25 seconds 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. **Thus, all of the control measures covered in the SIUC Laser Safety Program must be implemented**. All Class 3b lasers require a Laser Use Registration Form (See Appendix E).

e. Class 4 Lasers (Diffuse Reflection and Fire Hazard)

Class 4 lasers include all lasers with power levels greater than 500 mW. These lasers are considered eye, skin, fire, and diffuse reflection hazards. These lasers operate at power levels greater than 500 mW (continuous) or greater than 0.03 J (pulsed). **All of the control measures covered in the SIUC Laser Safety Program must be implemented**. All Class 4 lasers require a Laser Use Registration Form (See Appendix E).

D. MAXIMUM PERMISSIBLE EXPOSURE

The Maximum Permissible Exposure (MPE) levels have been established by ANSI Z136.1 for various laser wavelengths and exposure durations. The MPE is the level of laser radiation to which a person may be exposed to without hazardous effects or adverse biological changes in the eye or skin. Since the determination of the MPE for various wavelengths and exposure situations can be quite complicated, **it is deemed by the LSO**

that all open beam Class 3b and Class 4 lasers are assumed to be exceeding the MPE level and appropriate precautions must be taken.

E. NOMINAL HAZARD ZONE

The Nominal Hazard Zone (NHZ) is a term used in ANSI Z136.1 to describe the space within which the level of direct, scattered or reflected laser light emitted during laser operation exceeds the MPE. Outside of the NHZ, the level of radiation is less than the applicable MPE. Thus, the NHZ for Class 3b and Class 4 lasers will comprise the enclosure (room or area the beam is restricted to by virtue of walls, curtains, or other barriers) in which the laser(s) is operating. For specific conditions, the PI must for determine the NHZ by using information supplied by the laser manufacturer, by measurement, or by using the appropriate laser range equation or other equivalent assessment. The PI shall not allow persons to be exposed to levels of laser radiation exceeding the MPE.

F. LASER HAZARD CONTROL MEASURES

Control measures for Class 3b and Class 4 lasers are designed to reduce the possibility of eye and skin exposure to hazardous levels of radiation and to other hazards associated with laser systems.

a. Training

All PI's, students, technicians, and other personnel associated with research laser procedures shall have the appropriate training **BEFORE** beginning work. It is the PI's responsibility to ensure that all personnel are properly trained before they begin work in the laboratory. Records of this training shall be maintained for the duration of employment and will be reviewed during the annual safety assessment of the laser area.

1. Initial Training

Each person who operates or assist with the operation of Class 3b or Class 4 lasers must read both the SIUC Laser Safety Manual and the SIUC Laser Safety Training Module. The training module will include the following:

i. Understanding laser warning signs.
ii. Identification of the hazards associated with laser use.
iii. Identification of basic methods to reduce the risks related to laser use.
iv. Following standard operating procedures (SOPs)
v. Use of personal protective equipment.
vi. Electrical Safety.
vii. Concerns related to the use of hazardous materials such as dyes and solvents.
viii. Accidents and emergency procedures.

Additionally, the PI must provide supplemental training specific to their laser system for those under their supervision who operate Class 3b and Class 4 lasers. The following topics should be included in the supplemental training:

i. SOP for the laser in the laboratory
ii. Alignment procedures
iii. Emergency procedures and telephone numbers of people to contact in the event of an emergency.

To verify that SIUC Laser Safety Manual and Training Module have been reviewed and understood, the laser operator is required to complete a short quiz, sign a training certificate, and submit both the quiz and certificate to the LSO for review and filing. The quiz and training certification document can be found in the Laser Safety Training Module.

The LSO is responsible for maintaining a file for the quizzes and training certificates. **No person is allowed work in the NHZ prior to completing laser safety training**

2. Refresher Training

An annual refresher training is required for all personnel who operate or assist with the operation of Class 3b or Class 4 lasers. It is the PI's responsibility to ensure that all personnel have undergone annual refresher training. The training should include everything listed in the initial training plus any supplemental training topics specific to the laser system present in the laboratory.

It is the responsibility of the PI to document refresher training for all personnel. Documentation must include the date, the name of training (i.e. PI's name(s)), topics covered, and names of trainees.

b. Standard Operating Procedures

Each Class 3b and Class 4 laser under the control of the PI shall have specific written standard operating procedures (SOP) for its operation. An SOP specifies the safe use and operating procedures for the laser system. **The SOP must be present at the operating console or control panel of the laser.** Laboratory personnel must be trained on the elements of the SOP before performing an experiment or operation. At a minimum SOP's must include the following:

1. Operating instructions

List specific steps for properly operating the laser or laser systems in the laboratory.

2. Health and safety information for materials

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 specific where they can be accessed.

3. Hazard control measures

Include containment devices, ventilation, specific personal protective equipment, hygiene practices, and warning signs as recommended by the laser manufacturer or other authoritative guides.

4. Waste disposal practices

Establish procedures for the safe and timely removal of laboratory waste. Refer to the Chemical Hygiene Plan in the Chemical and Biological Safety Manual or contact the Center for Environmental Health and Safety (CEHS) at 453-7180 for questions.

5. Spill/Release containment and clean up procedures

Refer to SIUC Chemical Hygiene Plan or contact CEHS for questions.

The SOP shall be available for inspection by the LSO at any time. See Appendix G for a template for Laser Safety Standard Operating Procedures.

c. Safety Interlocks

The protective housing for each Class 3b and Class 4 lasers shall be interlocked such that removal of the protective housing will prevent exposure to laser radiation greater the MPE levels. Interlocks shall not be defeated or overridden during normal operation of the laser. Pulse laser interlocks shall be designed to prevent unintentional firing of the laser. An example of this would be by dumping the stored energy into a dummy load. Continuous wave lasers interlocks shall disrupt (turn off) the power supply or interrupt the beam (for example, by means of shutters).

Service access panels that allow access to the beam during normal operation shall either be interlocked or require a special tool for removal and have an appropriate warning label. All commercially manufactured lasers come equipped with suck interlocks and labels. Adjustment during operation, service, testing, or maintenance of a laser containing interlocks shall not cause the interlocks to become inoperative except where a laser controlled area is specified as in 32 Ill. Adm. Code 315.100 (a)(5) of the referenced regulation.

a. Safety Interlocks-Alternatives

The regulations recognize that in situations where an engineering control might be inappropriate, the LSO shall specify alternate controls to obtain equivalent laser safety protection. Alternate controls must be submitted in writing to the RSC and, if accepted, will be documented in the SOP.

Where safety latches or interlocks are not feasible or are inappropriate, the following shall apply:

i. All authorized personnel shall be trained in laser safety and appropriate PPE shall be provided upon entry.
ii. A door, blocking barrier, screen, or curtains shall be used to block, screen, or attenuate the laser radiation at the entryway.
iii. The level at the exterior of these devices shall not exceed the applicable MPE, nor shall personnel experience any exposure above the MPE immediately upon entry.
iv. At the entryway there shall be a visible or audible signal indicating that the laser is energized and operating at Class 3b or Class 4 levels.
v. A lighted laser warning sign, flashing light and other appropriate signage are acceptable methods to accomplish this requirement. As an alternative, an entryway warning light assembly may be interfaced to the laser in the following manner: one light will indicate when the laser is not operational (high voltage off) and by an additional light when the laser is powered up (high voltage applied, but no laser emission) and by an additional (flashing optional) light that activates when the laser is operating.

d. Personal Protective Equipment

Each PI shall provide personal protective equipment (PPE) that shall be used to protect the eyes and skin.

1. 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, 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.

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 chose 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 required 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 requirements:

i. Provide a comfortable and appropriate fit all around the area of the eye.
ii. Be in proper condition to ensure the optical filter(s) and holder provide the optical density or greater at the specific wavelength to reduce the incident energy to less than the MPE of the laser, and retain all protective properties during its use.
iii. Have the optical density or densities and associated wavelengths permanently and prominently labeled on the filters or eyewear.
iv. Be examined at intervals not exceeding six (6) months, to ensure the reliability of the protective filters and integrity of the holders. Unreliable eyewear shall be discarded and replaced.
v. Eye protection is required when there is a potential for eye injury due to projectiles or chemicals. Safety goggles shall be worn while performing any work that generates debris or chemical hazards to the eye. This includes the use of power tool, any construction, soldering, and the use of chemicals.

The LSO can assist in identifying protection equipment that is appropriate for the intended use. The equipment must be addressed in the written SOP

2. Skin Protection

Skin protection may be required if one is likely to be chronically exposed to scattered ultraviolet light, such as acutely exposing oneself to levels greater than the MPE for the skin. Even at levels less than the MPE for the skin, skin covers are highly recommended. One should always strive, if the laser application permits, to enclose as much as the beam as possible, or to use protective barriers.

Leather gloves, leather aprons and jackets are generally considered the most desirable in protection against ultraviolent (UV) exposure. Woven fabrics vary greatly in their attenuation properties. Loosely woven fabrics, through which can readily see light when held up to a light source, have a UV-B diffuse transmission ranging from 5 – 30%. Rayon and rayon blends transmit somewhat less (10 – 15%), and heavy wool and flannel materials may transmit 1% or less. Poplin is reported to have very low transmittance. Nylon is very ineffective with a transmission of 20 – 40%. This is important to note since many lab coats are nylon based.

Attenuation of laser light can also be greatly enhance by the use of layered clothing.

For Class 4 lasers, consideration must be given to the use of skin-protective material which is fire resistant. The LSO can assist in identifying protection equipment that is appropriate for the intended use. The equipment must be addressed in the written SOP.

e. Equipment Labels

All lasers, except Class 1, are required to contain warning labels in accordance with the Federal Laser Production Performance Standard. Labels shall contain the laser sunburst logo and the appropriate cautionary statement. Manufacturers place these labels on laser equipment and there are not to be removed.

f. Warning Systems

Each Class 3b or Class 4 laser shall provide visual or audible indication during the emission of accessible laser radiation. The indication **s**hall occur prior to emission of radiation with sufficient time to allow appropriate action to avoid exposure. Any visual indication shall be visible through protective eyewear for the wavelength of the laser.

g. Magnification of laser beam

If at any time a laser beam is optically magnified or concentrated, special precautions shall be taken by the PI to prevent specular or diffuse reflection or other exposure greater than the MPE for the laser. The special precautions shall be documented in the SOP for the laser.

h. Viewing Optics and Windows

Using optical systems such as cameras, microscopes, etc., to view laser beams may increase the eye hazard. All collecting optics must incorporate suitable means (such as interlocks, filters, or attenuators) to prevent eye exposures above the MPE. When optical systems such as lenses, and microscopes are used, that were not supplied as part of a certified laser product, the LSO shall determine the potential hazard and specify procedures and controls.

i. Infrared Lasers

An infrared laser beam shall be terminated in a fire-resistant material so that the laser beam is no inappropriately reflected.

j. Fiber Optic Transmission

Optical cables used for transmission of laser radiation shall be considered part of the laser protective housing. Disconnection of fiber optic connector, which results in access to radiation in excess of the MPE, shall take place in a controlled area. All connectors shall bear appropriate labels. Optical cables shall be encased in an opaque sleeve to prevent leakage of laser radiation in case of breakage.

Note: If the fiber is designed to emit light through the walls of the fiber, the PI shall notify the LSO and include justification for lack of opaque cover in the SOP.

k. Eye Examinations

Personnel working with Class 3b or Class 4 lasers are not required to obtain either a pre- or post- employment medical examination specific to laser use. Following any suspected laser injury, employees shall report to the PI and the LSO if they believe an injury has occurred.

G. CONTROLLED AREAS

Each Class 3b or Class 4 laser shall only be operated in a controlled area. Control areas confine laser hazards to well-defined spaces that are entirely under the control of laser users. The PI is responsible for establishing a controlled area to limit access of personnel to laser radiation. Access to the controlled area shall be controlled by a door, blocking barrier, screen, or curtain, which attenuates the laser radiation to below the MPE, and individuals who enter the controlled area shall not experience radiation above the MPE immediately upon entry.

Personnel must be provided with and wear appropriate eye protection or other PPE that is required when in the controlled area. Visitors are not permitted into the laser controlled area unless they have approval from the PI and protective measures have been taken. Visitors must be informed by laboratory personnel of laser safety precautions and required control measures (required PPE) before entry into laser controlled areas. As a necessary precaution, it is highly recommend that any person entering a controlled area wear appropriate skin protection (clothing, gloves, and/or shields) to prevent exposure of the skin to levels exceeding the skin MPE.

a. Warning Signs and Labels

Each controlled area utilizing Class 3b or Class 4 lasers shall post signs that are conspicuously displayed in locations which serve to warn/alert personnel and visitors to laser hazards. Normally, warning signs are posted on doors, or at entryways into laser controlled areas. For labels, laser hazard signs, or advice on their use, please contact the LSO.

1. For Class 3b lasers and laser systems, each entrance shall have a posted sign that reads "DANGER" and the laser sunburst. Above the tail of the sunburst, it shall read "LASER RADIATION – AVOID DIRECT EXPOSURE TO THE BEAM." Below the tail of the sunburst the Class of the laser shall be listed (See Appendix D).

2. For Class 4 lasers and laser systems, each entrance shall have a posted sign that reads "DANGER" and the laser sunburst. Above the tail of the sunburst, it shall read "LASER RADIATION – AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION." Beneath the tail of the sunburst the Class of the laser shall be listed (See Appendix D)

H. SAFETY PRACTICES AND SPECIFIC HAZARDS

a. Beam Hazards

The most prominent safety concern with laser beams is the possibility of eye damage. The nature of the damage and the threshold level at which each type of injury can occur depends on the beam parameters (wavelength, output power, beam divergence, beam diameter, and exposure duration). For pulsed lasers, additional parameters include pulse duration and pulse repetition frequency. 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.

Damage to the retina 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.

Acoustic damage and photochemical damage can also occur. Acoustic damage is when laser pulses of a duration of less than 10 microseconds induces a shock wave in the retinal tissue that can cause the rupture of tissue. This damage is permanent and is potentially more destructive than a thermal burn. MPE values are reduced for short laser pulses to protect against this effect. Photochemical damage occurs when laser light with wavelengths less than 400nm do not focus on the retina. The effect is cumulative over a period of days.

b. Non-Beam Hazards

While beam hazards are the most prominent laser hazards, other hazards pose equal or possibly greater risk of injury or death. These hazards must be addressed in the SOP where applicable.

1. Electrical Hazards

The most lethal hazards associated with lasers are the high-voltage electrical systems required to power lasers. Systems that permit access to components at lethal levels must be interlocked. Even through a system may be interlocked, electrical components often become exposed or accessible during maintenance and alignment procedures. The following basic safety precautions are highly recommended to be applied laser or laser system laboratories:

i. No one should work on lasers or power supplies unless qualified and approved to perform the specific tasks.
ii. Do not wear rings, watches or other metallic apparel when working with electrical equipment.
iii. Do not handle electrical equipment when hands or feet are wet or when standing on a wet surface.
iv. When working with high voltages, regard all floors as conductive and grounded.
v. Be familiar with electrocution rescue procedures and emergency first aid.
vi. If lockout tagout is need for electrical equipment, contact the LSO.
vii. When possible, use shock preventing shields, power supply enclosures and shielded leads in all experimental or temporary high voltage circuits.
viii. All modifications to power lines or power supplies shall be performed with circuit breakers off.

2. Chemical Hazards

Many dyes used in 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, 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 or questions on handling and disposal, refer to the SIUC Chemical Hygiene Plan in the Chemical and Biological Safety Manual and/or contact the Center for Environmental Health and Safety (CEHS) at 453-7180.

3. Ionizing Radiation

X-rays may be produced form two main sources: high voltage vacuum

tubes of laser power supplies, such as rectifiers and thyratrons, and electric discharge lasers. Any power supply that requires more than 15 kilovolts may produce enough x-rays to be a health concern.

4. 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.

5. Cryogenic Liquids

Cryogenic liquids are used in the cooling systems of certain lasers and can create hazardous situations. As these materials evaporate, they displace oxygen in the air, thus adequate ventilation must be maintained when cryogenic liquids are used. Cryogenic liquids are potentially explosive 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.

6. Laser Generated Air Contaminants (LGAC)

Air contaminants may be generated when certain Class 3b and Class 4 laser beams interact with matter. When the target irradiance reaches a given threshold, target materials (including plastics, composites, metals, and tissues) may liberate toxic and noxious airborne contaminants. Hazardous fumes or vapors need to be exhausted.

7. Fire hazards

Class 4 lasers represent potential fire hazards. Depending on the construction materials, beam enclosures, barriers, stops, and wiring are potentially flammable if exposed to high beam irradiance for more than a few seconds.

8. 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 can 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.

9. Ultraviolet (UV) and Visible Radiation

Laser discharge tubes and pump lamps may generate UV or visible radiation. The levels produced may exceed safe limits thus causing skin and eye damage.

10. Plasma Emissions

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

I. LASER REGISTRATION

The PI must receive permission from the RCC prior to the purchase of all laser systems that include a laser categorized as Class 3b and Class 4. The PI is required to submit a completed Laser Registration Form (See Appendix E) to the LSO prior to the laser operation. **Note: Purchasing has been instructed to notify the LSO whenever a Class 3b or Class 4 laser system purchase request is received.**

a. Acquisitions, Modification, Sale or Transfer of Lasers

The campus LSO shall be informed of the acquisition, modification, sale, or transfer of any Class 3b or Class 4 lasers. Whenever any Class 3b or Class 4 laser system is to be brought into SIUC, for any temporary use, the LSO shall be notified and the equipment registered within 30 days prior to use. It is the responsibility of the PI to inform the LSO whenever acquisition, modification, sale, or transfer of a laser or laser system occurs.

J. LASER SAFETY INSPECTIONS

Every six (6) months the LSO shall inspect all laboratory facilities containing the Class 3b and Class 4 laser for which each PI is responsible, to assure that lasers are being operated in a safe manner. The PI is responsible to correct unsafe conditions or protection equipment in a timely manner. The LSO will inform the RCC of any uncorrected unsafe conditions. If the PI is unable to correct unsafe conditions in a timely manner, he/she may be asked to attend a RCC meeting to brief the RCC on the situation.

K. INCIDENT REPORTING

Each PI shall immediately seek appropriate medical attention for injured individuals and notify the LSO within 24 hours of any exposure injury involving a laser possessed by

SIUC. Emergency procedures and emergency contacts can be found in Appendix C. A written summary of an injury or non-injury must be forwarded to the LSO no later than 24 hours following the incident. The LSO is responsible for investigating laser incidents, providing a report to the PI and RCC, and maintaining records of incidents.

L. REFERENCES

a. Illinois Division of Nuclear Safety, 32 Ill. Adm. Code: Chapter II, Part 315, "Standards for Protection Against Laser Radiation – 2001.

b. American National Standard for the Safe Use of Lasers, ANSI Z136.1–2000.

c. American National Standard for the Safe Use of Lasers in Health Care Facilities, ANSI Z136.3–1996.

d. U.S. Department of Labor, Occupational Safety and Health Administration Instruction Publication 8-1.7, "Guidelines for Laser Safety and Hazard Assessment"

*Parts of this program have been adapted from the following:

- University of Florida Laser Safety Manual
- University of California: Santa Barbara Laser Safety Manual
- Iowa State University Laser Safety Manual

APPENDIX A

Beam Control Precautions

1. Do not look directly into the beam or at a specular reflection, regardless of its power.

2. Terminate the beam at the end of its useful path.

3. Locate the beam path at a point other than eye level when standing or sitting at a desk at all times.

4. Orient the laser so that the beam is not directed toward entry points to the controlled area or toward aisles or hallways.

5. Minimize specular reflections.

6. Securely mount the laser on the stable platform, if applicable.

7. Limit beam traverse during adjustments.

8. Clearly identify beam paths. Ensure the path does not cross to populated areas, study areas, desk areas, or traffic paths.

9. A beam path that exist from a controlled area must be enclosed wherever the beam irradiance exceeds the MPE.

10. Minimize unnecessary reflective objects in the laboratory area.

11. Monitor for condensation on cooled systems. Condensate can provide a specular reflective surface.

12. Utilize appropriate eye protection at all times when the laser is in operation, including during beam alignment.

APPENDIX B

Safety Considerations Regarding Laser Usage

The following are general safety laser operation considerations, but apply specifically to Class 3b and Class 4 lasers:

1. Only individuals with proper qualification and training shall operate lasers and associated equipment.

2. Follow approved SOPs (required for Class 3b and Class 4).

3. Utilize all required safety features/interlocks.

4. Areas where lasers are used shall be posted with standard laser warning signs, as required.

5. The laser beam shall not be directed at a person.

6. Do not allow chairs or stools in the laser area that place the eye at laser height.

7. Beam shutters or caps shall be utilized, or laser turned off, when laser transmission is not actually required.

8. Lasers shall be turned off when unattended for a substantial period of time.

9. When feasible, only remote or electronic means shall be used to guide the laser beam during alignment.

10. Stray beams shall not be allowed to pass outside the controlled area through doors/openings. The relevant doors/openings must be closed whenever lasers or laser systems are activated.

11. When possible, the optical setup must be designed so beams are either parallel to or perpendicular to the optical table. Tilted beams may reach eye height at other locations in the area.

12. When possible, beams should be contained in beam tubes or enclosures.

13. All non-essential reflective material (e.g. jewelry, watches, belt buckles) must be eliminated from the beam area.

14. Beams used in research areas will be terminated with beam blocks that are constructed of material that will minimize reflection and that is appropriate for the beam being terminated.

15. Beam stops will be secured with strong mechanical mounts to avoid the possibility of beam blocks dropping and exposing individuals to high intensity beams.

16. Unless personnel are out of range, lasers should not be used in areas where there is significant dust and/or mists.

17. A safety review should be conducted by the LSO when a Class 3b or Class 4 laser is significantly modified or moved to a new location that may require different control methods.

APPENDIX C

Emergency Procedures for Laser Accidents

In the event of a laser accident, immediately do the following:

1. Shut down the laser system.
2. Provide for the safety of personnel (first aid, evacuation, etc.) as needed.

   NOTE: If a laser eye injury is suspected, have the injured person keep their head upright and still to restrict any bleeding in the eyes. A physician should evaluate laser eye injuries as soon as possible.

3. Obtain medical assistance for anyone who may be injured.

   AMBULANCE /URGENT MEDICAL CARE = 9-1-1

4. If there is a fire, leave the area, pull the fire alarm, call 9-1-1 and stay outside until help arrives. Do not fight the fire unless it is very small and you have been trained in fire safety and fire extinguisher training.
5. Inform the LSO as soon as possible at 536-2015.

   Emergency Number for the LSO = 618-201-7927

   After normal working hours (8am-4:30pm) contact SIUC Department of Public Safety at 453-3771.

6. Inform the PI as soon as possible. If there is an injury, the PI must submit a report of injury to the LSO.
7. After an accident, do not resume use of the laser system until the RCC has reviewed the incident.

APPENDIX D

Laser Warning Sign

APPENDIX E

Laser Registration Information

All Class 3b and 4 lasers used at SIUC are required to be registered with the LSO. Safe laser use and procedural compliance is the responsibility of the faculty who are assigned as the PI. To register your laser, please provide the following information on each laser and send it to:

SIUC LSO, Office of Radiological Control, Mail Code 6898

Fill in the spaces below.

1. **Applicant(s):**

   For joint registration, underline the name of the person who will be the principal "Laser User" for communications, inspections, etc.

   Title: **Department:**

   Address: **Mailcode:**

   E-mail: **Office Phone/Ext:**

2. **Location Information:**

   Building: **Room Number(s)**

   Laser Manufacturer

   Model Number: **Serial Number:**

3. **Description of Laser**

   Laser Classification Marked on Laser (mark one): ☐ 3b ☐ 4

   Laser Type (Nd:YAG, HeNe, etc.):

   Laser Use (describe briefly):

4. Optical Characteristics: Mark one of the below

	Continuous Wave (CW)	**Pulsed**
Wavelength (nm)		
Maximum Power (W)		
Maximum Power (J)		
Pulse Duration (sec)		
Average Power (W)		

5. Individuals Participating in Operation of Laser:
All participants (PI, Faculty, student, etc.) must have documented training. Attach additional names as necessary.

Name	**Title**

Note: Operators of laser equipment must complete Appendix F: Laser User Statement of Training and Experience

6. Designated Controlled Area:

Attach a picture/diagram of laboratory room(s) where laser is used and/or stored. Indicate on diagram adjacent rooms and hallways.

7. Certification

I certify I have read and understand the Laser Safety Program requirements as stated in the Laser Safety Program Section B part d, I agree to meet the responsibilities and execute my authority as PI. I agree that all uses of lasers will be in accordance with the requirements set forth therein and in this application, and that the LSO will be notified before any changes are made in the use of the laser as herein described.

Signature:

PI: _____ Date: _____

Department Chairman: _____Date: _____

APPENDIX F

LASER USER STATEMENT OF TRAINING AND EXPERIENCE

(*To be completed by ALL SIUC personnel who operate lasers*)

Name:

Classification (PI, Faculty, student, etc.)

Department: **Supervisor:**

Department Phone:

Types of Laser(s) Used

Laser Location: Building: **Room:**

LASER SAFETY TRAINING

Training Location:

Date of Training: **Time:**

Name of Trainer:

Trainer Employer:

Subject/Topics:

*****_Training topics should at least cover Laser Operations, Laser Classifications, Control Measures, Bio-effects of Laser Radiation Exposure, Non-Radiation Hazards associated with lasers, Investigator and User Responsibilities._

If additional space is needed, use the back of this sheet. Keep a copy and return original to:

Office of Radiological Control – Mail Code 6898

LASER USE EXPERIENCE

Laser Type: ND: YAG, HeNe, etc.	Laser Class	Max Output Power	Dates of Experience	Duration of Experience	Location of Experience

Note: In addition to the information request above, please submit to the LSO any training documentation, including certification, specific to the safe operation and/or application of lasers in medical procedures.

Print: _____

Signature: _____ **Date:** _____

APPENDIX G

Laser Safety Standard Operating Procedure (SOP)

All Class 3b and Class 4 lasers used SIUC are required to have written safety operating procedures available at the instrument for review by the laser operator(s). Complete this form for each laser system. Safe laser use and procedural compliance is the responsibility of the faculty who is assigned as the P

I.

- **This procedure must be read and signed by all persons who use lasers listed in this SOP.**
- **This procedure must be reviewed <u>every two years</u> by the PI to ensure it reflects the most current conditions.**

1. Location Information:

Department:

Date: Department Phone:

Building: Room Number(s):

2. Laser Safety Contacts:

Name of PI: Department:

PI email address: Department Phone:

Lab Supervisor Name:

Lab Supervisor email

Laser Safety Officer (LSO): Matt Barnstable LSO Office Phone: 536-2015

SIUC Police Phone: 453-3771

Medical Emergency:

1. **Call 9-1-1**
2. **Notify PI and LSO of all laser-related injuries ASAP**

3. Laser Information:

Manufacturer:

Model Number: Serial Number:

Laser Classification: ☐ 3b ☐ 4

Laser Type (nd: Yag, NeNE, etc.):

Mode of Operation: ☐ Continuous ☐ Pulsed

Wavelength (nm):

4. General Operating Procedures:

Procedure Overview (brief description of the project)

Health and safety information for materials used (briefly describe the hazards associated with the materials and/or equipment OR document your hazard assessment in Section….)

Enter your operating procedures for this laser system in A – D below. Be brief and concise. If a category is NOT APPLICABLE to your operation, denote that with N/A.

A. Initial preparation of laboratory environment for normal operation (key position, warning light on, interlock activation, warning signs posted, personnel protective equipment available, other):

B. Special Procedures (alignment, safety tests, maintenance tests, etc.)

C. Operation procedures are as follows:

i.

ii.

iii.

iv.

v.

vi.

vii.

viii.

ix.

x.

D. Shutdown procedures for this laser are as follows:

i.

ii.

iii.

iv.

**Attach and additional sheet of paper if more space is needed.*

5. General Laser System Control Measures:

Provide some information regarding the general laser safety control mechanisms in place for this laser system in the text boxes below. If a particular control measure is not in place, or it is NOT APPLICABLE to your system, denote that by N/A.

X or N/A	Control	Comments
	Entryway (door) interlocks or controls	
	Laser Enclosure Interlocks	
	Laser Housing Interlocks	
	Emergency Stop Panic Button	
	Beam Stop/Attenuator	Infrared laser must terminate in fire resistant material and the absorber must be inspected periodically.
	Maser Switch (operated by key or computer code)	
	Laser Secured To Base	
	Protective Barriers	
	Warning Signs	

	References to Equipment Manual	
	Maser Switch (operated by key or computer code)	

6. Specific Laser and Collateral Hazards and Control Measures

Provide some information regarding the specific laser and collateral hazards, and the control mechanisms in place, in the text boxes below. If a particular hazard is not present, or is NOT APPLICABLE to your system, denote that by N/A.

X or n/a	Hazard	Control(s)
	Unenclosed Beam (Access to Direct or Scattered Radiation)	
	Laser at eye levels of person sitting or standing	
	Ultraviolet Radiation	
	Reflective Material in Beam Path	
	Hazardous Materials (dyes, solvents, etc.)	
	Fumes/Vapors	
	Laser at eye levels of person sitting or standing	

	Ultraviolet Radiation	
	Reflective Material in Beam Path	
	Hazardous Materials (dyes, solvents, etc.)	
	Fumes/Vapors	
	Electrical	
	Capacitors	
	Compressed Gases	
	Fire (access to alarms, extinguishers, etc.)	
	Trip/Fall Hazard (cables on floor, etc.)	

**Controls may also be written on a separate sheet of paper. Please make sure to attach the separate sheet to this page.*

7. Personal Protective Equipment

Please list the type of lab coat, eye protection, and hand protection that will be used for laser operation.

Name of PI who provided above information:

Date:

Training Record

Use the following table to record the training associated with this SOP.

Print Name	Signature	Trained by	Date