

**ILLINOIS INSTITUTE OF TECHNOLOGY
SAFETY POLICY COMMITTEE**

Laser Safety Program

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1) **PURPOSE/SCOPE**

The primary objective of the IIT Laser Safety Program is to ensure that no laser radiation in excess of the Maximum Permissible Exposure Limit reaches the human eye or skin. Additionally, the program is designed to ensure adequate protection against non-beam hazards related to laser use. Non-beam hazards include the risk of electrical shock, fire hazard from a beam, chemical exposures from the use of toxic gases, dyes, solvents, and vaporization of targets.

The policies and procedures contained in this manual apply to all departments, laboratories, and persons using and possessing Class 3B and Class 4 lasers at IIT.

The IIT Laser Safety Program is based on the American National Standards Institute (ANSI) Z136.1-2014, *Safe Use of Lasers*, and any other pertinent standards, as well as other applicable federal and state regulations.

This Laser Safety Manual is intended to be a guide to the implementation of the IIT Laser Safety Program, the ANSI Z136.1 2014, *Safe Use of Lasers*. Recommendations of ANSI Z136.1 not specifically referenced in this manual are to be considered in effect unless specified otherwise by this Laser Safety Manual. Additional laser safety policies and procedures as set forth by the University are incorporated into this manual.

2) **DEFINITIONS**

Any capitalized term not defined herein shall have that meaning as set forth in ANSI Z136.1-2014.

3) **OVERSIGHT**

This Laser Safety Program will be overseen by the Director of Environmental Health and Safety and implemented and enforced by the Laser Safety Officer and the Laser Safety Committee. Class 3B and Class 4 lasers which are not in use or do not have approved Standard Operating Procedures, proper safety controls, or appropriate protective eyewear will be locked out and tagged out by the Laser Safety Officer until they are in place and verified. Violations of this program may result in appropriate disciplinary measures in accordance with applicable University disciplinary policies and procedures.

a) **Laser Safety Organization and Responsibilities**

- i. **Laser Safety Committee**: The Laser Safety Committee will consist of members with expertise in laser technology or in the assessment of laser hazards representing departments possessing any Class 3 or Class 4 lasers. The committee chair and department representatives are appointed or removed by, and the committee is directly responsible to the Director of Environmental Health and Safety. The Faculty Laboratory Safety Coordinator and the Director of Environmental Health and Safety shall be *ex officio* members. The Laser Safety Officer shall be a voting member of the committee. Members are appointed for a three-year term and may be reappointed.

Duties and responsibilities of the Laser Safety Committee include, but are not limited to:

1. Establish and maintain policies and practices for the evaluation and control of laser hazards within the university.
 2. Make recommendations for appropriate laser safety training programs and materials and Standard Operating Procedures.
 3. Maintain an awareness of all applicable new or revised laser safety standards.
 4. Facilitate compliance within their respective departments with laser safety standards, including federal and state regulations, and non-regulatory standards as outlined in the American National Standards Institute Z136 series of laser safety standards.
 5. Review reports from the Laser Safety Officer or other individuals with delegated responsibilities for health and safety practices of the university involving laser radiation sources, including personnel training records, laser hazard control measures, laser safety inspections, and other matters concerning use and operational hazards of lasers.
 6. Assist in investigating alleged infractions of safety rules or improper use of laser equipment brought to its attention by the Laser Safety Officer or other responsible personnel, and recommend remedial action to correct such infractions.
- ii. Laser Safety Officer: Laser Safety Officer is the operational arm of the Laser Safety Program at the University. ANSI Z136.1-2014 defines the Laser Safety Officer as one who has the authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation of those hazards. This position is responsible for:
1. Implementing this program.
 2. Ensuring the University's compliance with laser safety regulations promulgated by federal and state agencies, and relevant ANSI standards.
 3. Providing consulting services to laser users on laser hazard evaluation, controls, and personnel training programs.
 4. Conducting periodic safety audits/inspections of all Class 3 and Class 4 laser equipment, associated personnel, and facilities (at least once a year).
 5. Ensuring that adequate safety education and training are provided to all personnel who may be exposed to laser energy levels above the Maximum Permissible Exposure limits.
 6. Ensuring that the prescribed control measures are in effect, recommending or approving substitute or alternate control measures when primary ones are not feasible or practical. This shall include, but not be limited to, such actions as establishing a Nominal Hazard Zone, approving Standard Operating Procedures,

avoiding unnecessary or duplicate controls, selecting alternate controls, conducting periodic facility and equipment audits, and training.

7. Classifying, or verifying classification of lasers and laser systems used at IIT.
8. Approving establishment of Nominal Hazard Zones in laser work areas.
9. Approving laser systems operations to include Standard Operating Procedures, alignment procedures, maintenance, and servicing.
10. Recommending protective equipment that may be required to assure personnel safety.
11. Approving wording on area signs and equipment labels.
12. Effect medical examinations when necessary.
13. Maintaining an inventory of all Class 3B and Class 4 lasers at IIT.
14. Recommending corrective actions if a violation persists.
15. Ensuring necessary records required by applicable government regulations are maintained.
16. Investigating, and submitting written reports on, known or suspected accidents involving laser equipment.
17. The Laser Safety Officer shall have final authority in determining laser control measures and may approve alternate controls when these are appropriate based on the judgment of the Laser Safety Officer. Class 3B and class 4 lasers shall be operated only with the written approval of the Laser Safety Officer, who shall have the authority to terminate laser operations at any time.
18. Approve acquisition of all laser purchases.
19. Inspect and have final authority of all end-user performed modifications to laser systems prior to use, such as modifying a Class 3B laser to a lower classification.

iii. Principal Investigators Principal Investigators are faculty/staff members with appropriate training and experience relative to the use of lasers in their respective research activities. Principal Investigators are responsible for all aspects of their laboratory's laser safety compliance program including, but not limited to:

1. Supervising the safe use of lasers and ancillary equipment.

2. Registering all Class 3 and 4 lasers with the Director of Environmental Health and Safety. Lasers are registered by notifying the Laser Safety Officer. The Laser Safety Officer will then arrange to meet with the Principal Investigator to complete the registration process. Lasers should be purchased and registered in accordance with this manual.
 3. Notifying the Director of Environmental Health and Safety of the intent to acquire or fabricate Class 3 or Class 4 lasers.
 4. Creating and implementing laser systems operations to include Standard Operating Procedures, alignment procedures, maintenance and servicing operations.
 5. Ensuring that lab associated laser users and laser non-users have satisfactorily completed laser safety training (both general and laser/lab specific) prior to work in a laser work area Nominal Hazard Zone.
 6. Meeting University requirements for posting, access control, personal protective equipment, and medical surveillance.
 7. Reporting to the Laser Safety Officer known or suspected accidents involving laser equipment.
 8. Completing and submitting the IIT Laser Procurement Form, prior to moving, purchasing, modifying, or acquiring a laser. This form is also necessary when any significant change is made in the Standard Operating Procedure or in the use of the laser. The Laser Safety Officer should be notified in advance to assess the intended space in advance to ensure minimum requirements for a Class 3 or Class 4 laser laboratory are met.
- iv. Individual Users and Operators: faculty, research personnel, technical personnel, students, and other workers engaged in laboratory research and research support, which involves working in the laser laboratory when the lasers may be operating or involves the use and operation of either Class 3 or Class 4 lasers. These personnel are responsible for the following:
1. Wearing appropriate personal protective equipment.
 2. Completing required training.
 3. Following approved Standard Operating Procedures.
 4. Conducting laser activities in a safe manner.

Individual laser “non-users” and incidental personnel whose work makes it possible but unlikely that they may be exposed to laser energy sufficient to damage their skin or eyes must satisfactorily complete appropriate laser safety training.

- b) **Acquisition, Registration and Tracking**: The Laser Procurement Form (attached to as Exhibit C) must be completed by the Principal Investigator prior to any purchase/procurement of a new laser system, significant new use of the system, modification of the system (such as

permanent modification of a Class 3B laser to 3M laser), development of a new procedure, movement to a new location or disposal. The Laser Safety Officer is responsible for completing any state-required forms and maintaining a list of lasers at the University. Department chairs are responsible for providing laser use information to the Laser Safety Officer for their departments.

- c) **Training:** Prior to the initial use of Class 3 or Class 4 lasers all laser users, including the Principal Investigator, must complete an appropriate laser safety training program. The training consists of two parts.
- I. The first requires successful completion of an on-line (via Blackboard) laser safety training program administered by the Director of Environmental Health and Safety. Alternatively, users may complete a basic laser safety course from Argonne National Laboratory or other approved facility. If taken at a facility outside IIT, documentation of training is required to be provided by the Principal Investigator prior to use.
 - ii. **The second part entails a Principal Investigator-provided laboratory-based training program specific to use of lasers under their responsibility.** The Principal Investigator must also conduct laboratory-based training for their non-laser using research, clerical, and maintenance personnel who, despite controls to prevent otherwise, may be exposed above the Maximum Permissible Exposure.
 - iii. All required training shall be documented such as in a laboratory notebook and a copy of the training will be sent to the Director of Environmental Health and Safety upon request.
 - iv. Guests/visitors using either Class 3 or Class 4 lasers must contact the Laser Safety Officer regarding the training requirements. New employees and guests, such as visiting researchers, must satisfactorily complete the training requirements prior to using Class 3 or Class 4 lasers under the direct supervision of a Principal Investigator. The Laser Safety Officer must be notified of these new employee or guest laser users. e.g. University facilities/maintenance and housekeeping, will be conducted annually by the Laser Safety Officer.
 - v. **Laser safety training for incidental personnel not directly associated with a laser lab, Laser users, including the Principal Investigator, must participate in periodic retraining based upon the specific needs of the Principal Investigator and their designated laser users. The retraining interval will not exceed three years. The minimum retraining requirement may be met by successfully repeating on-line laser safety training program or participating in documented in-lab training conducted by the Principal Investigator and approved by the Laser Safety Officer.**

d) Medical Examinations

- I. Baseline ophthalmologic examinations shall be provided to all Class 3 and Class 4 laser users at their request. The examination shall, at a minimum include the protocol similar to ANSI Z136.1-2014, Appendix F.
- II. Medical examinations shall be performed as soon as practical (usually within 48 hours) when a suspected injury or adverse effect from a laser exposure occurs. In addition to the acute symptoms, consideration shall be given to the exposure wavelength, emission characteristics and exposure situation to ensure appropriate medical referral. Appendix F in ANSI Z136.1-2014 contains recommended examination protocol commensurate with the observed symptoms and laser system.
- III. All examinations shall be performed by an ophthalmologist.

4) STANDARD OPERATING PROCEDURES

- a. Prior to their use, the Principal Investigator is responsible for developing a written Standard Operating Procedure for all Class 3 and Class 4 laser systems under his/her control. The Standard Operating Procedure must cover laser operations (i.e. description of activities, hazard identification and mitigation, routine alignment procedures, schematics of laser set-up) and other relevant hazards in the laser environment. General laser Standard Operating Procedure templates are available from the Laser Safety Officer on the Environmental Health and Safety web site. The templates provide a guide for the Principal Investigator in identifying the characteristics of the laser operation and collateral hazards, and in formulating set-up and alignment procedures. For assistance in developing appropriate control measures and completing the Standard Operating Procedure, users may contact the Laser Safety Officer. Appendix A includes acceptable laser alignment guidelines which should be utilized in the development of the laser Standard Operating Procedure.
- b. In the case of enclosed systems (e.g. laser scanning confocal microscopy) an abbreviated Standard Operating Procedure can be applied if determined necessary by the Laser Safety Officer. This abbreviated Standard Operating Procedure will follow the Standard Operating Procedure approval process. This approach can only be used after an experimental review by the Laser Safety Officer, who will then determine the required sections of the abbreviated Standard Operating Procedure.
- c. All Standard Operating Procedures should be reviewed at least annually by the Laser Safety Officer as part of a routine laser audit/inspection. However, regular review by personnel working with lasers to ensure the accuracy of the procedure(s) is highly recommended. If no new hazards have been added to the system, the users can perform the review without notifying the Laser Safety Officer. If new hazards (use of a sub-nanosecond pulsed laser system, for example) have been added to the experiment, a review by the Laser Safety Officer is necessary prior to implementing the change to assure all applicable safeguards have been satisfied.

- d. In the event a Standard Operating Procedure has not yet been approved, at the discretion of the Laser Safety Officer a specified time period, agreed upon by both the Principal Investigator and the Laser Safety Officer, may be established between the setting up of the laser equipment and the approval of the Standard Operating Procedure. With the assistance of the Principal Investigator, the Laser Safety Officer will develop a set of documented conditions for the laser user to operate the laser during the interim. These documented conditions will be made readily available to laser users by the Principal Investigator.

5) **CONTROL**

AREAS: Key

Switches

For laser systems equipped with a key switch to prevent unauthorized use, the key shall not be left in the switch when the laser is unattended.

Outdoor Use of Lasers and Demonstrations

The use of Class 3 or Class 4 lasers outdoors shall be conducted in compliance with ANSI Z136.6 (current edition), *Standard for the Safe Use of Lasers Outdoors*. Contact the Laser Safety Officer for more information.

Special control measures shall be employed for those situations where lasers or laser systems are used for educational demonstrations, artistic display, entertainment or other related uses where the intended viewing group is the general public. Contact the Laser Safety Officer for additional information.

Spectators

Spectators are not permitted within a laser control area during periods of active laser operation unless:

1. Appropriate approval from the Principal Investigator has been obtained, and;
2. The hazards of the area (and how to avoid those hazards) has been explained, and;
3. Appropriate protective measures have been implemented.

Laser Pointers

The power limit for any laser pointer at IIT shall not exceed 5 mW. Laser pointers modified must be properly labeled with the Class and “NOT A LASER POINTER” and not used as a laser pointer. Laser pointers must be Class 2, Class 2M or Class 3R only.

Never look directly into the beam or point the laser at anyone. Never point a laser at a mirror or similarly reflective surface.

6) **Class 3 and Class 4**

Class 3 and Class 4 lasers must be operated in designated laser control areas approved by the Laser Safety Officer. The purpose of laser control areas is to confine laser hazards to well-defined spaces under the direct control of the user. This is an attempt to prevent injury to those visiting or working in the area near the control area. All personnel who require entry into a Class 3 or Class 4 control area during laser operations, maintenance or servicing (where the laser is activated) shall be appropriately trained.

a. Class 3 Control Areas

- I. Nominal Hazard Zone:** In situations requiring open laser beams it is necessary to define an area, within the Control Area, of potentially hazardous laser radiation. This area is referred to as the Nominal Hazard Zone, which is defined as a space within which the level of direct, scattered, or reflected laser radiation exceeds the Maximum Permissible Exposure. The purpose of a Nominal Hazard Zone is to define the area in which control measures (e.g. laser eyewear) are required. The Laser Safety Officer and Principal Investigator will determine the Nominal Hazard Zone. The Nominal Hazard Zone may in some situations comprise the entire Control Area.
- II. Posting:** The Control Area must be posted with appropriate warning signs that indicate the nature of the hazard. The wording on the signs will be specified by the Laser Safety Officer and conform to the ANSI Z136.1 guidelines. Such signs shall be posted at all entrances to the laser control area.
- III. Authorization:** Only personnel who have been authorized may operate the laser. Personnel may be authorized upon completion of their training requirements. At a minimum, authorized personnel have met all training requirements stipulated for the Class laser they wish to operate. The Principal Investigator may stipulate additional authorization requirements.
- IV. Terminal Beam Stop:** All laser beams, other than those applied to tissue for surgical or therapeutic purposes must be terminated at the end of their useful paths by a material that is non-reflective and fire resistant.
- V. Eye Protection:** Lasers should be mounted so that the beam path is not at eye level for standing or seated personnel (i.e. above 6.5 feet or below 3 feet). Laser protective eyewear of adequate optical density and threshold limit for the beam(s) under manipulation must be provided to all present individuals and worn at any point where the laser exposure could theoretically exceed the Maximum Permissible Exposure. Procedures and practices must ensure that optical systems and power levels are not adjusted upstream during critical open beam operations, such as beam alignment. The need for laser eye protection must be balanced by the need for adequate visible light

Transmission. It is the responsibility of the Principal Investigator to obtain appropriate laser protective eyewear. For assistance in selecting laser eye protection, contact the Laser Safety Officer. The Laser Safety Officer can assist the user in determining the proper parameters of such eyewear, and can provide contact numbers for vendors. Laser eye protection should be inspected periodically to ensure that it is in good condition.

VI. Light Containment: Laser light levels in excess of the Maximum Permissible Exposure must not pass the boundaries of the control area. All windows, doorways, open portals, and other openings through which light might escape from a laser control area must be covered or shielded in such a manner as to preclude the transmission of laser light. Special rules apply for outdoor use and laser control areas that do not provide complete containment. Contact the Laser Safety Officer for details.

b. **Class 4 Control Areas:** Only appropriately trained personnel may enter a Class 4 laser control area during active laser operations. All personnel within the control area must wear the appropriate personal protective equipment and follow all applicable administrative controls and standard operating procedures. Class 4 laser control areas must meet all of the Class 3B control area requirements listed above *and* the following additional requirements:

I. Emergency Stop: A clearly marked “Panic Button” will be available for deactivating the laser (or reduce the output to at or below the MPE.).

II. Entryway Controls: Procedural area or entryway controls must be in place to prevent inadvertent entry into a laser control area, or inadvertent exposure to the active laser beam. The Class 4 laser Control Area shall incorporate at least one of the following controls:

1. **Non-defeatable (no override) area or entryway controls:** Non-defeatable safety latches or area interlocks (e.g. electrical switches, infrared or sonic motion detectors, pressure-sensitive floor mats shall be used to deactivate or reduce output power to at or below the applicable MPE in the event of an unexpected entry into the Control Area.
2. **Defeatable area or entryway controls:** Defeatable safety latches, entryway or area interlocks shall be used if non-defeatable safety controls limit the intended use of the laser or are otherwise unfeasible.
3. **Procedural area or entryway controls:** Where safety latches or interlocks are not feasible, the following shall apply:

- a. All authorized personnel shall be adequately trained and adequate and appropriate personal protective equipment shall be provided prior to entry.
 - b. A door, blocking barrier, screen, curtain, etc. shall be used to block, screen or attenuate the laser radiation at the entryway to below MPE levels.
 - c. At the entryway there shall be a **visible, lighted laser warning sign or audible signal indicating** that the laser is energized and operating.
 - d. Locking or blocking entryway doors with chains, hasps or other mechanisms which prevents **emergency egress from the area** is unacceptable.
- c. **Temporary Laser Control Areas:** Temporary laser control areas can be created for the servicing and alignment of embedded lasers, enclosed lasers, and in special cases where permanent laser control areas cannot be provided. They are subject to the normal Standard Operating Procedure approval process.
- d. **Substitution of Alternate Control Measures:** Upon documented review by the Laser Safety Officer, the engineering control measures recommended by ANSI Z136.1 for Class 3B and Class 4 lasers or laser systems may be replaced by administrative or other alternate engineering controls that provide equivalent protection. Approvals of these controls are subject to the same review procedure as described in this manual.
- e. **Eyewear:** Laser safety eyewear is *required* for the operation of all Class 3B and Class 4 lasers with exposed beams. The Laser Safety Officer may require eyewear or approve laser operation without eyewear on an individual basis based on a hazard evaluation performed by the Laser Safety Officer.

7) **BEAM AND NON-BEAM HAZARDS**

a. **Beam Hazards**

The most prominent safety concern with lasers is the possibility of eye damage from exposure to the laser beam, as outlined below. The nature of the damage and the threshold level at which each type of injury can occur depends on the beam parameters. These include wavelength, output power, beam divergence, beam diameter, and exposure duration. For pulsed lasers, the parameters include pulse energy, pulse duration, pulse repetition frequency, and pulse train characteristics.

Where feasible, the laser user is required to keep all laser beams within the operating field, on the optical table or within the experimental envelope at all times. To maintain this control

it is essential to be aware of all beams, including stray beams and/or reflections, and to terminate them with beam stops at the end of their useful paths. When a beam traverses to other tables or across aisles, the beam must be enclosed or the access to the aisle must be blocked to prevent personnel from exposure to the beam.

Since IR and UV laser beams are not within the boundaries of normal human vision, they possess a higher hazard potential than visible light lasers. Because of the invisible nature of the optical radiation, the use of laser eyewear that will protect against worst-case exposures is required at all times.

Infrared laser beams (> 700 nm) must be terminated by a highly absorbent, non-specular reflective backstop. Note that many surfaces that appear dull are excellent IR reflectors and would not be suitable for this purpose. Beam terminators for Class 4 IR laser beams must be made of a fire-retardant material, or of a material that has been treated to be fire-retardant.

Retina: Laser light in the visible (400 nm - 700 nm) or near infrared (700 nm - 1400 nm) regions that enters the eye is focused on the retina. This can result in either thermal burns or acoustic damage.

Thermal Burn to the retina: Normal focusing by the eye results in an irradiance amplification of approximately 10,000; therefore, a 1-mW/cm^2 beam entering the eye will result in a 100 W/cm^2 exposure at the retina. The most likely effect of intercepting a laser beam of sufficient irradiance with the eye is a thermal burn that destroys the retinal tissue. The ANSI Maximum Permissible Exposure values are set well below the threshold level for thermal burns.

Acoustic damage to the retina: Laser pulses of duration less than 10 microseconds (μs) induce a shock wave in the retinal tissue that causes a rupture of the tissue. This damage is permanent, as with a retinal burn. Acoustic damage is potentially more destructive than a thermal burn. Acoustic damage usually affects a greater area of the retina, and the threshold energy for this effect is substantially lower. The ANSI MPE values are reduced for short laser pulses to protect against this effect.

Photochemical damage: Laser light having wavelengths below 400 nm is absorbed by the lens and cornea and does not reach the retina. Depending on the level of exposure, this may cause immediate thermal burns or the development of cataracts over a period of years.

The light can be laser output, ultraviolet (UV) from the pump light, or blue light from a target interaction. The effect is cumulative over a period of days. The ANSI standard is designed to account only for exposure to the laser light. If UV light from a pump light or blue light from a target interaction is emitted, additional precautions must be taken.

Other skin and eye damage: The cornea and the conjunctiva tissue surrounding the eye can also be damaged by exposure to laser light. Damage to the cornea and conjunctiva tissue usually occurs at greater power levels than damage to the retina; therefore, these issues only

become a concern for those wavelengths that do not penetrate to the retina (i.e., UV and FIR radiation).

Since the skin is the largest organ of the body, it has the greatest risk of coming into contact with a laser beam. When discussing the skin we will almost always speak in terms of arms, hands, or head. These three body parts are most likely to accidentally move into the beam during alignment or other operations requiring close proximity to the beam.

If the beam is of sufficient energy the skin can experience thermal burns, acoustic lesions, and photochemical changes from laser exposure. These effects are almost entirely independent of the coherent nature of the laser light but are aggravated by the high power density of lasers. Also, the wavelength of the beam determines the layer of the skin that will be affected.

When dealing with lasers that have the potential to cause burning of the skin, personnel should observe common-sense safety practices such as wearing long-sleeved shirts and gloves of fire-resistant or fire-proof material and using low powered lasers for alignment purposes. ***Somemedications, including tetracycline, doxycycline, tricyclic antidepressants, and methotrexate, can increase a person's risk to UV radiation.***

Following is a summary table of some of the biological effects of laser radiation:

Wavelength	Eye Effects	Skin Effects
180-280 nm (UV-C)	Photokeratitis	Erythema ("sunburn"), skin cancer
280-315 nm (UV-B)	Photokeratitis	Accelerated skin aging, increased skin pigment darkening
318-400 (UV-A)	Photochemical-induced cataracts	Pigment darkening
400-700 nm (Visible)	Photochemical and thermal retinal injury	Photosensitive reactions
700-1400 nm (IR-A)	Cataract, retinal burns	Skin burn
1400-3000 nm (IR-B)	Corneal	burn,
3000-10000 nm (IR-C)	Corneal burns	Skin burn

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 reviewed by the Laser Safety Officer or the Director of Environmental Health and Safety representative and addressed in the Standard Operating Procedure for the laser operation or as a separate procedure where applicable. Contact the Laser Safety Officer or the Director of Environmental Health and Safety regarding non-beam hazards related to chemicals, biological agents, fiber optic fragments, respiratory or hearing protection, and electrical or other physical workplace hazards (such as ergonomics or limited work spaces) to ensure proper procedures and training are followed.

- i. Electrical Hazards:** Lasers may contain high-voltage power supplies and large capacitors or capacitor banks that store lethal amounts of electricity. In general, systems that permit access to components at such lethal levels must be interlocked; however, during maintenance and alignment procedures such components often become exposed or accessible. This has caused numerous serious and some fatal shocks. Electrical hazards may include electric shock, resistive heating, electric spark ignition of flammable materials, and arc flash. Where these hazards may exist, an EHS electrical safety technical expert shall be consulted by the Principal Investigator to ensure proper training and required controls measures are in place.
- ii. Laser Dyes:** In some laser systems, liquid dye solutions are used as the optically active medium. Laser dyes are often toxic and/or carcinogenic chemicals dissolved in flammable solvents. This creates the potential for personnel exposures above permissible limits, fires, and chemical spills. Frequently, the most hazardous aspect of a laser operation is the mixing of chemicals that make up the laser dye. In addition, hazardous waste disposal concerns need to be addressed. Consult the applicable laser dye Safety Data Sheet for handling and disposal information. Refer to the Chemical Hygiene Policy for Lab Safety Standards or contact the Director of Environmental Health and Safety regarding proper labeling and disposal of laser dyes.
- iii. Compressed and Compressed Toxic Gases:** Hazardous gases may be used in laser applications; i.e. with excimer lasers (fluorine, hydrogen chloride). As required by the standard, the Standard Operating Procedure shall contain a procedure for, or reference to, the safe handling of compressed gases such as cylinder restraints, use of gas cabinets, regulators rated for the type of gas to be used, relief valve settings, proper tubing and fittings, etc. All compressed gases having a hazardous material information system (HMIS) health, flammability, or reactivity rating of 3 or 4 shall be contained in an approved and appropriately exhausted gas cabinet that is alarmed with sensors to indicate potential leakage conditions. Sensors may also be installed in other locations as appropriate, including exhaust ventilation ducts. Exhaust ductwork should be of rigid construction, especially for hazardous gases. Contact the Laser Safety Officer to arrange for a review of the hazardous gas installation and procedure.

- iv. Cryogenic Fluids: Cryogenic fluids are used in cooling systems of certain lasers, and can create hazardous situations. As these materials evaporate they can replace the oxygen in the air, thereby creating oxygen deficient atmospheres and an asphyxiation hazard. Adequate ventilation must be provided. Cryogenic fluids are potentially explosive when ice collects in valves or connectors that are not specifically designed for use with cryogenic fluids. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the liquid oxygen comes in contact with any organic material. While the quantities of liquid nitrogen employed are usually small, protective clothing and face shields must be used to prevent freeze burns to the skin and eyes.
- v. Laser Generated Air Contaminants (LGAC): Air contaminants may be generated when certain Class 3B and Class 4 laser beams interact with matter₂. When the target irradiance reaches a given threshold of approximately 10 W/cm₂, target materials including plastics, composites, metals, and tissues may liberate toxic and noxious airborne contaminants. In other words, when laser beams are sufficiently energized to heat up a target, the target may vaporize, creating hazardous fumes or vapors that may need to be captured or exhausted. The Director of Environmental Health and Safety must pre-approve the method of ventilation utilized to capture or exhaust the LGACs.
- vi. Plasma Emissions: Interactions between very high power laser beams and target materials may in some cases produce plasma. The plasma generated may contain hazardous “blue light” and UV emissions, which can be an eye and skin hazard. When targets are heated to very high temperatures, as in laser welding and cutting, an intense light is emitted. This light often contains large amounts of short wavelength or blue light, which may cause conjunctivitis, photochemical damage to the retina, and/or erythema (sunburn-like reactions) in the skin.
- vii. UV and Visible Radiation: Laser discharge tubes and pump lamps may generate UV and visible radiation at levels that could present eye and skin hazards.
- viii. Explosion Hazards: High-pressure arc lamps, filament lamps, and capacitors may explode if they fail during operation. These components are to be enclosed in housing, which will withstand the maximum explosive forces 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.
- ix. Ionizing Radiation (X-rays): X-rays could be produced from two main sources: high voltage vacuum tubes of laser power supplies such as rectifiers and thyatrons and electric discharge lasers. Any power supplies that require more than 15 kilovolts may produce enough x-rays to be a health concern. Contact Environmental Health and Safety (EHS) Radiation Safety for additional guidance.

- x. Nanoparticles: The use of nanoparticles can pose a hazard to lungs, tissues and organs. Processes that produce laser-generated nanoparticles shall be engineered so as to avoid the entry of the particles into the body via inhalation, ingestion, or absorption processes.
- xi. Biological Agents: Infectious materials may survive laser radiation and become airborne. Contact the Director of Environmental Health and Safety and the Laser Safety Officer for additional guidance.

8) **RESPONSE TO LASER INCIDENTS**

Follow the IIT Emergency Response and Evacuation Plan for response to laser incidents.

The major causes of overexposure to laser radiation in the laboratory are:

- Eye exposure during alignment (#1)
- Misaligned optics/upwardly directed beams (#2)
- Lack of standard operating procedures/failure to follow Standard Operating Procedures
- Improper handling of high voltage circuits
- Lack of training/unfamiliarity with instrument
- Improper/lack of maintenance and lack of proper restoration after maintenance
- Improper use (fires, laser generated airborne contaminants, etc.)
- Equipment malfunction

Contributing factors to injury include but are not limited to:

- Lack of eye protection (not used, not available, improper for wavelength, etc.)
- Unintentional skin exposure

Ensuring all beam and non-beam hazards are addressed appropriately prior to working with Class 3 or 4 lasers is critical to the prevention of accidents. Appropriate engineering controls, Standard Operating Procedures, training, Personal Protective Equipment and other safety measures, as required by this manual, must be in place to safeguard workers. Should an accident occur with the laser beam or a non-beam hazard, the following outlines the proper procedures.

9) **IMMEDIATE ACTIONS FOR BEAM AND NON-BEAM INCIDENTS:**

In the event of an overexposure or suspected overexposure:

1. Immediately secure the equipment (close the shutter or shut off the power).
2. In event of a fire: evacuate the building and pull the fire alarm on exit. Follow up with a call to 911.
3. In the event of a personnel injury, seek immediate medical attention.

4. Notify the Principal Investigator. The Principal Investigator shall ensure the equipment is secured.
5. Principal Investigator will then notify the Laser Safety Officer or Director of Environmental Health and Safety. Do not resume laser operations without Laser Safety Officer approval.

For suspected eye injuries, an ophthalmologist must evaluate the eye injury within 48 hours of the suspected injury.

10) APPROVAL

The IIT Safety Policy Committee has reviewed and recommended the adoption of this Program on April 24, 2017, and this Laser Safety Program is approved and effective this 26th day of April 2017. The Safety Policy Committee will review the contents, implementation and effectiveness of this Program no less than annually (but as often as necessary) to ensure that it meets all required legal and regulatory requirements and is adequately providing a safe and healthful environment for IIT faculty, employees and students. Any modification to this Policy have been reviewed and approved, and effective as of the date noted on the cover page.

By: /s/ Frances Bronet
Provost

By: /s/ Bruce Watts
Vice President for Administration, Facilities and Public Safety

APPENDIX A

LASER ALIGNMENT GUIDELINES

Laser alignment for experimentation is always a challenge and rarely will it follow any standardized operating procedure. However the alignment operation carries the highest risk associated with all laser operations. The following good practices are recommended:

- Follow all laser-specific operating requirements stipulated in the designated Standard Operating Procedure.
- No unauthorized personnel will be in the room or designated laser control area during the alignment procedure.
- Only appropriately trained personnel shall perform, or be physically present during laser alignment operations.
- If applicable, laser safety curtains/partitions shall be put in place.
- Remove all wristwatches, jewelry, I.D. badges, etc. that may cause unintended stray reflections.
- Clear the laser optic table of any unnecessary equipment and or materials. Ensure beam blocks and stray beam shields are in place and securely mounted.
- Designated protective eyewear shall be worn. For visible-wavelength-lasers, this may involve designated “laser alignment” eyewear intended to allow the researcher to view the beam while providing a reduced level of eye protection.
- Use the lowest practical power during the alignment process. If possible use an alignment laser (e.g. HeNe).
- Utilize appropriate alignment tools (e.g. fluorescence cards, alignment scopes, etc.).
- Avoid having beams cross aisle ways – if this is unavoidable ensure the accessible aisle way is appropriately marked and barricaded during laser operations.
- Avoid beam alignment out of the horizontal plane.
- Establish beam path(s) at safe height(s), below eye level when standing or sitting.
- Whoever moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component.

APPENDIX B

IIT Standard Operating Procedure For Class 3 and 4 Lasers

LASER EMERGENCY DIAL 911

I. User information

Principal Investigator: _____

Department: _____

Laser(s) location: _____

Principal Investigator Campus Phone: _____

Principal Investigator Alternate Phone: _____

II. Laser system data:

Laser #1:

Type: _____ Wavelength: _____ Class: _____

Manufacturer: _____ Model/SN: _____

Beam Diameter and Divergence: _____

Pulsed

Q-Switched Max Energy/pulse: _____

Pulse duration: _____ Repetition rate: _____

Continuous wave Max Power: _____

Laser #2:

Type: _____ Wavelength: _____ Class: _____

Manufacturer: _____ Model/SN: _____

Beam Diameter and Divergence: _____

Pulsed

Q-Switched Max Energy/pulse: _____

Pulse duration: _____ Repetition rate: _____

Continuous wave Max Power: _____

III. Laser Safety Program:

Refer to the IIT Laser Safety Program for the following:

- Responsibilities of the Laser Safety Committee, Laser Safety Officer, Principal Investigator and Users
- Training Requirements
- Laser acquisition, registration, transfer and disposal requirements
- Pre-use medical screening
- General Personal Protective Equipment requirements
- Signage and labeling
- Non radiation hazards

IV: Laser Application Summary. (Briefly describe the intended use).

V: Hazard Identification and Risk Mitigation

Check the applicable hazards below and describe steps that have been taken to reduce the likelihood of exposure. If additional space is required, address it in an attached document at the end.

YES NO Open/assessable beam

YES NO Laser operations at “eye level” (3 feet < Beam Path < 6.5 feet)

YES NO UV or IR Operation

YES NO Non-beam reflective surfaces

YES NO Stray/uncontrolled beam(s)

YES NO Exposed high voltage power supplies or capacitors

YES NO Collecting optics

YES NO Unvented fumes/vapors

YES NO Plasma radiation

YES NO Compressed gases

YES NO Hazardous chemicals

YES NO Hazardous wastes

YES NO Flammable or combustible material

YES NO Poor housekeeping

YES NO Other identified hazards

VI: Controls. Check the controls present. If No or NA is selected for a particular control, provide additional information in the space provided. If additional space is required, attach additional pages at the end.

YES NO N/A Entryway controls (Engineered or Administrative)

YES NO N/A Designated Control Area and posting

YES NO N/A Nominal Hazard Zone (NHZ) established

YES NO N/A Laser master switch/key removed when not in use

YES NO N/A Beam enclosure used

YES NO N/A Laser beam enclosure interlocks operational

YES NO N/A Laser system cover interlocks operational

YES NO N/A Appropriate beam attenuators utilized

- YES NO N/A Laser secured to base

- YES NO N/A Associated equipment secured to base

- YES NO N/A Protective barriers used (e.g. curtains/partitions)

- YES NO N/A IIT Laser Safety Policy available

- YES NO N/A Alignment procedure established

- YES NO N/A Researcher-conducted maintenance program

- YES NO N/A Emergency stop/off (“panic switch”) identified/operational

- YES NO N/A Rapid egress and emergency access satisfactory

- YES NO N/A Appropriate PPE available and in use

- YES NO N/A Non-beam hazard satisfactorily addressed

- YES NO N/A Training requirements for all personnel completed

VII: Eyewear

YES NO Eyewear specific to laser wavelength

YES NO Optical density appropriate for all ranges of energy/power operations

YES NO Proper fit

YES NO Sufficient pairs available

YES NO Free of damage or excessive wear

Complete the following table

Laser Eyewear Use Chart

FOR THIS LASER			USE THIS EYEWEAR			
Type of Laser	Wavelength (nm)	Notes	Designation or Mfg	Attenuated Wavelengths (nm)	Optical Density (OD)	Notes

VIII: Operating Procedures

If space below is insufficient, attached *single document* for complete procedure.

Initial preparation of laboratory environment for normal operation. (Include key positions, interlock activation, outside warning signals, personnel identification, operational logs, etc.)

Alignment Procedure:

Target area preparation:

Normal operational procedure (include power settings, Q-switched mode, pulse rate, etc.):

Normal shutdown procedure:

Special procedures (servicing/maintenance, safety tests, interlock bypass operations, etc):

Emergency shutdown procedure:

Hazardous waste management if different from IIT standard procedure:

IX: Additional documentation as necessary

X: Laboratory Personnel Listing and Training

(INSERT IIT TRAINING RECORD and INSTRUCTIONAL SAFETY VERIFICATION forms here)

APPENDIX C

IIT Laser Procurement, Use/Procedure, Relocation, Disposal

Select as applicable:

Procurement New Use, Modification or Procedure New Location Disposal

Laser Information:

Type: _____ Wavelength: _____ Classification: _____

Manufacturer: _____ Model: _____ Serial (if known): _____

Beam diameter: _____ Beam Divergence: _____

Prospective Location: _____

Pulsed

Q-Switched : _____ Max energy/pulse: _____

Pulse Duration: _____ Repetition rate: _____

Continuous Wave Max Power: _____

Laser Application Summary/Use or Procedure Change

Principal Investigator: _____ Date: _____

Follow-up review needed: YES NO

Reviewed, Laser Safety Officer or EHS: _____ Date: _____