Laser Safety Manual

Laser Safety Committee
Office of Prospective Health
Radiation Safety Section

EAST CAROLINA UNIVERSITY
2020

LASER SAFETY MANUAL

FOREWORD

This manual is issued as a means of providing users of laser systems with information on the laser safety policies and procedures of East Carolina University. The responsibilities placed on the University make it imperative that all departments and their activities conform to the intent of this manual.

The Laser Safety Committee establishes University laser safety policies. This includes reviewing each proposal to use lasers or install and operate laser systems. Consultation and service necessary to insure proper laser protection and adherence to the ANSI standards is provided by the Office of Prospective Health-Radiation Safety Section.

All users of lasers and/or laser systems must be familiar with the requirements set forth in this manual and conduct their operation in accordance with them.

3/12/2020

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PURPOSE OF THIS MANUAL

With the increasing use of laser-based research and activities at East Carolina University, it has become necessary to provide a single document covering all laser safety procedures and regulations. The procedures outlined in this guide are intended to protect all individuals with a minimum of interference in activities. Regulations and recommendations stated within this document represent and reflect the most recent requirements of the University.

The major purposes of this manual are summarized below:

- Clearly outline the responsibilities of all parties involved in obtaining and using laser equipment at East Carolina University.

- Provide information on the proper disposal or transfer of laser equipment.

- State the laser control measures that are required for each hazard classification.

- Provide the laser operator with a reference so as to assist in the safe use of laser equipment.

- Clearly state the training required by all laser operators.

- Provide information for the protection against laser-related non-beam hazards.

- State the steps to be taken in case of any laser accident.

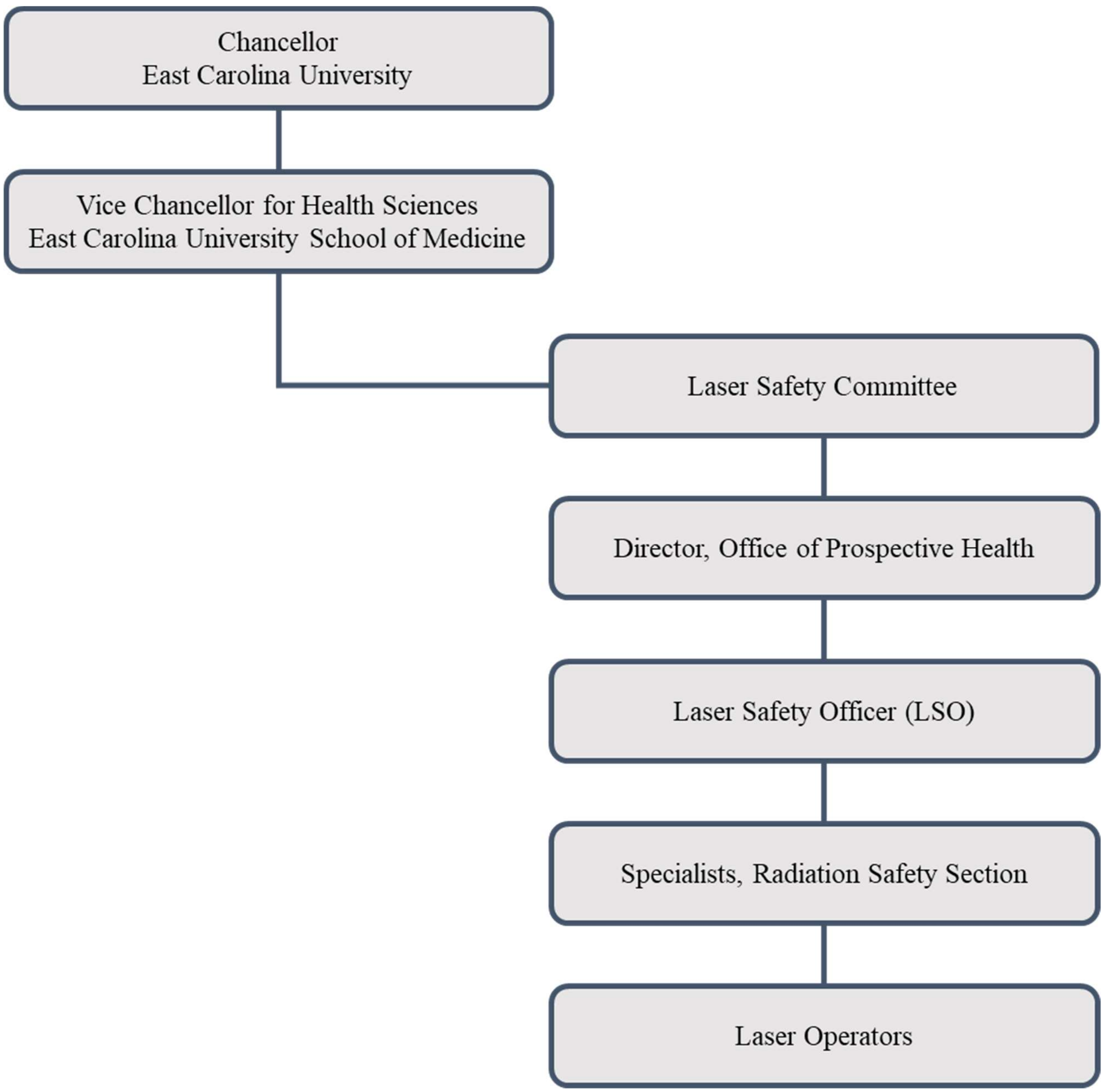
ORGANIZATION/POLICY

The Laser Safety Committee and the Office of Prospective Health-Radiation Safety Section have been commissioned to provide a quality laser safety program for East Carolina University. The committee has been authorized by the University Chancellor to review and approve proposals that utilize hazardous lasers. The Office of Prospective-Health Radiation Safety Section provides for the daily program operation.

The East Carolina University laser safety policy is based on the recommendations of ANSI (American National Standards Institute) Z136.1 and the applicable federal and state regulations. The laser safety program's primary objective is to ensure that no laser radiation in excess of the Maximum Permissible Exposure (MPE) reaches the human eye or skin. This program is also intended to ensure adequate protection against laser-related non-beam hazards.

Laser Safety Program Organization

The Laser Safety Committee will allow the responsible use of lasers providing the use is in agreement with the safety procedures set forth by the University, State and Federal requirements. Where unsafe practices involving the use of laser equipment or practices in violation of established regulation are observed, the Laser Safety Officer has the authority to require cessation of the use of lasers until thorough review can be made by the Laser Safety Committee. If the committee, at any time, is not satisfied with the adequacy of the laser safety practices employed in a procedure, they may require all use of lasers to be stopped until satisfactory procedures have been adopted.



ROLES AND RESPONSIBILITIES

Laser Safety Committee (LSC)

The Laser Safety Committee (LSC) directly oversees the laser safety program at ECU. The LSC consists of the Committee Chairman, the Laser Safety Officer (LSO), laser users, management representatives, persons knowledgeable in laser safety and/or laser technology, and others as needed. The LSCs' responsibilities include:

- Establish and maintain internal policies/procedures to ensure they comply with applicable regulations and standards.
- Resolve conflicts or issues identified by the LSO, laser users, or other parties.
- Maintain an awareness of all applicable new or revised laser safety standards.

Laser Safety Officer (LSO)

The Laser Safety Officer (LSO) has the responsibility to establish, monitor, and enforce control of laser hazards and is responsible to the LSC for the laser safety program's management and administration. The LSO's responsibilities include:

- Administer the day-to-day operation of the Laser Safety Program
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- Maintain a current inventory of Class 3b and 4 lasers.
- Function as liaison between Principal Laser Users (PLUs) and the LSC.
- Accompany outside inspectors/regulators on laser safety inspections.
- Perform laser hazard analyses and audits; ensure, by follow up and additional audits as necessary, that all laser safety deficiencies are addressed and resolved.
- Make recommendations to improve laser safety.
- Restrict or terminate use of lasers that present an imminent danger or excessive hazard.
- Ensure the availability of proper laser safety training.
- Make recommendations and provide consultation for selection of proper personnel protective equipment.
- Ensure/verify that outside personnel are qualified before servicing laser equipment.
- Investigate laser accidents and near misses.

- Update laser safety policy and procedures as needed.

- Review, approve, and maintain a copy on file of all laser SOPs (Standard Operating Procedures).

- Review, approve, and maintain a copy on file of all Laser Laboratory Pre-Operational Checklists; coordinate with the responsible PLU to ensure compliance prior to approval.

- Review, approve, and maintain a copy on file of all Laser Laboratory Authorizations; coordinate with the responsible PLU to ensure compliance prior to approval.

- Ensure maintenance of laser user's most recent laser safety training records until that user is no longer involved with laser use at ECU.

- Provide periodic reports on the status of laser safety to the LSC.

Department Chairs and Administrators

The Department Chairs and Administrators are in charge of all laser use in their department or area. The Chairs and Administrators are an integral part of the Application process that each Principal Laser User must follow in order to use lasers and each review process conducted prior to the use of laser systems. The Department Chairs and Administrators responsibilities include:

- Ensure that staff members who desire to use lasers contact the LSO and also secure a copy of this Laser Safety Manual on the Office of Prospective Health-Radiation Safety Section website (**https://www.ecu.edu/cs-dhs/prospectivehealth/radiation.cfm)**.

- Have permanent plans for all new buildings and modification of existing structures where lasers are to be used submitted for approval by the Laser Safety Committee through the Laser Safety Officer prior to construction or modification.

- Notify the Office of Prospective Health-Radiation Safety Section of any transfer of laser equipment to/or from East Carolina University.

- Inform the Office of Prospective Health-Radiation Safety Section of the final disposition of any lasers or laser systems in the possession of a terminated employee.

NOTE: The Laser Safety Officer will keep each Department Chair and all Administrators informed of the Principal Laser Users in the department who are conducting projects approved by the Laser Safety Committee.

Principal Laser User (PLU)

The Principal Laser User (PLU) is a physician or faculty member who has been approved by the Laser Safety Committee to use or supervise the use of lasers. The Principal Laser User is **fully responsible** for adherence to all requirements set forth in this manual and the safe use of lasers by themselves and those under their direction.

Every Class 3b or 4 (International Electrotechnical Commission, IEC Class 3B or 4) laser systems on site must be assigned to a PLU. If no PLU has been formally identified for a particular laser/laser system, the Departmental Chairman may designate a PLU, and inform the LSO of the designation. The PLU's responsibilities include:

- Planning and implementation of all safety measures required for safe laser operation for all lasers under their control, and prior to introducing additional laser equipment to their area.

- Complete a Laser Registration Form for each Class 3b or 4 (IEC Class 3B or 4) laser and send the form(s) to the LSO.

- Prior to use of a Class 3b or 4 (IEC Class 3B or 4) laser, complete and obtain the LSO's approval signature on a Laser Laboratory Pre-Operational Checklist.

- For every area using Class 3b and 4 (IEC Class 3B or 4) lasers under the PLU's control, complete and submit to the LSO a Laser Laboratory Authorization form. Coordinate with the LSO to obtain approval of the Laser Laboratory Authorization before operating a Class 3b or 4 (IEC Class 3B or 4) laser. Resubmit each Laser Laboratory Authorization to the LSO upon major changes (e.g. room relocation, different laser types, etc.) to the laser laboratory.

- Post a written SOP (as described later in this manual) in a location readily available to laser operators, for all unenclosed Class 3b and 4 (IEC Class 3B or 4) lasers; ensure compliance with the SOP. Provide a current copy of the SOP to the LSO and obtain LSO approval for the SOP before operation of the laser.

- Supervise the safe use of lasers in the laser environment.

- Ensure that all lasers under his/her control are properly classified and labeled.

- Train and supervise students, employees, and visitors in:
    - general procedures for laboratory personnel
    - operating procedures for laser systems
    - emergency procedures

- Establish and maintain a current list of those personnel approved to operate specific types of Class 3b or 4 lasers under their supervision and provide a copy of the list to the LSO.

- Complete the Laser Safety course at the interval specified in this Manual.

- Immediately notify the LSO in the event of a suspected overexposure to the output beam from a Class 3b or 4 (IEC Class 3B or 4) laser.

- Ensure that safety controls are not disabled, removed, or modified without written authorization from the PLU, and notify the LSO immediately of any changes in the status of safety controls.

- Notify the LSO of any OEM lasers (i.e. lasers that do not comply with all requirements of the Federal Laser Product Performance Standard, e.g., warning labels, interlock shutter, etc. because they are designed for incorporation into larger devices) that the PLU is using in an open beam configuration.

- Ensure the safe and responsible disposition of their unneeded, but potentially hazardous, Class 3b or 4 (IEC Class 3B or 4) lasers and laser components. See the *Laser Acquisition, Transfer, and Disposal* section of this manual for a list of appropriate disposal options.

Laser Operator (LO)

Only a PLU or a Laser Operator (LO) may operate a Class 3b or 4 (IEC Class 3B or 4) laser. Each LO must work under the supervision of a PLU. LO responsibilities include:

- Complete the ECU Laser Safety course before operating a Class 3b or 4 (IEC Class 3B or 4) laser and again at the interval specified in this manual.

- Use lasers safely.

- Comply with established policy, SOPs and other procedural requirements.

- Promptly report to the PLU any malfunctions, problems, accidents, or injuries, which may have an impact on safety.

- Do not disable, remove, or modify any safety control systems without prior written approval from the PLU.

ESCALATED ENFORCEMENT POLICY

Purpose

This section specifies the actions of the Laser Safety Officer (LSO) and the Laser Safety Committee to correct specific items of non-compliance, ensuring that laser users work with the LSO and the Committee to maintain safety and compliance. This enforcement policy does not apply to patient care areas. Instead, for these areas, the LSO will work with the Director or Departmental Chair to resolve any uncorrected compliance issues.

Enforcement Process

i. Radiation Safety staff will provide the PLU with written notification of any items of non-compliance discovered in that PLU's area of responsibility. If appropriate, Radiation Safety staff may request a written response from the PLU regarding corrective measures for any items of non-compliance discovered during routine laser laboratory audits. Any such written response shall be provided by the PLU to the auditor on or before the date specified in the written notification.

ii. Documented compliance issues should be resolved between the PLU and the LSO or his/her designee.

iii. If routine Radiation Safety staff surveys show a repeat violation (i.e. same item cited on last inspection) or other pattern of multiple violations, the PLU must, within one week of notification, send the Laser Safety Officer a brief written explanation of:
    - what caused the item(s) of non-compliance,
    - steps taken to date by the PLU to correct the item(s),
    - further steps to be taken by the PLU, and
    - measures the PLU took or will take to prevent recurrence.

iv. If the PLU has not achieved compliance to the Laser Safety Officer's satisfaction within one week of notification, the Laser Safety Officer and the PLU will discuss the matter with the PLU's Departmental Chair or Faculty Dean, or other representative of the Institutional Administration as appropriate.

v. If satisfactory resolution still cannot be obtained, the matter will be escalated to the Laser Safety Committee and, if necessary, senior Institutional Administration.

Enforcement Options

i. Laser Safety Intervention

The LSO is authorized to **immediately order the termination** or limitation of any procedure or other laboratory activity that in his/her professional opinion constitutes an immediate danger to life, health, property, or the environment.

The LSO is also authorized to order the termination or limitation of any procedure or laboratory activity of a PLU who willfully violates ECU Laser Safety Policy.

Such intervention may include, but is not necessarily limited to,
- the suspension of laser use,
- the withholding of pending deliveries of lasers and
- the disabling of lasers (e.g. by confiscation of the laser on/off switch key).

The LSO will notify the PLU, the chair of the Laser Safety Committee and appropriate senior management.

ii. Restriction and Revocation

The Chairman of the Laser Safety Committee may, upon the LSO's recommendation, restrict the authority of a PLU as a result of repeated or serious violations of East Carolina University policy.

Radiation Safety staff must immediately notify the PLU, the PLU's Departmental Chair or Faculty Dean, and the appropriate Institutional Administrators of any restriction and of the reason for that restriction.

Such restriction remains in effect until review by the Laser Safety Committee either reinstates, modifies, or revokes the restricted privileges by a majority vote.

LASER CLASSIFICATION

Laser Classification

All lasers and laser systems in the U.S. are categorized into one of several hazard classes. Corresponding labels affixed to the laser or laser system positively identify the class. These laser classifications are detailed in ANSI Z136.1, ANSI Z136.3; the Federal Laser Products Performance Standard (FLPPS), 21 CFR 1040.10 and 1040.11; and the International Electrotechnical Commission (IEC). See Appendix D for a summary of the classification schemes of these three organizations.

The manufacturer provides the classification for most lasers. For custom-built and modified lasers, the LSO can assist with classification.

CLASS 1 (IEC CLASS 1)

- Do not emit harmful levels of radiation during normal operation.
- Also includes higher class lasers completely enclosed and interlocked to prevent beam access, allowing a Class 1 laser system designation; any time the higher class laser is accessible (e.g. during alignment or servicing), the higher laser class controls must be observed.
- Can be used without restriction in the manner intended by the manufacturer and without special operator training or qualification.

CLASS 2 (IEC CLASS 2)

- Emit accessible laser light in the visible wavelength region.
- 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 blink reflex (aversion response) provides adequate protection.
- Can be used without restriction in the manner intended by the manufacturer and without special operator training or qualification.

CLASS 3A (IEC CLASS 1M, 2M, 3R)

- Normally not hazardous when viewed momentarily with the unaided eye, but may pose severe eye hazards when viewed through collecting optics (e.g., microscopes and binoculars).
- Power levels 1-5 milliwatt (mW).
- Same controls as Class 1 and Class 2 lasers for normal operations; if viewed through optical instruments (e.g., binoculars, telescopes, or microscopes), contact the LSO for a hazard review.

CLASS 3B (IEC CLASS 3B)

- Will cause injury upon direct viewing of the beam and specular reflections.
- Power output 5-500 mW for CW (continuous wave) or less than 0.03 joule (J) for a pulsed system (i.e. pulse width less than 0.25 second).
- Must implement specific control measures covered in this Manual.

CLASS 4 (IEC CLASS 4)

- Includes all laser systems with power levels greater than 500 mW CW or greater than 0.03 J for a pulsed system.
- Pose eye hazards, skin hazards, and fire hazards. Viewing the beam or specular reflections or exposure to diffuse reflections can cause eye and skin injuries.
- All control measures explained in this document must be implemented.

EMBEDDED LASERS

Lasers are often embedded in laser products or systems with a lower hazard class. When the laser system is used as intended, the controls for the system's class apply. When the system is opened (e.g. for service or alignment) and the embedded laser beam is accessible, a temporary control area must be established. The controls for the temporary control area must be based on the classification of the embedded laser (e.g. a Class 1 laser system/product might contain a Class 3b or 4 laser which will define the appropriate controls used for a temporary control area). The user and LSO must determine adequate controls. Confirmation of a system classification is the responsibility of the LSO, and therefore necessitates registering the system. An abbreviated SOP may be required, as in the case of such commercially available enclosed laser systems as a laser scanning confocal microscope.

IEC CLASSIFICATION SCHEME

The IEC (International Electrotechnical Commission) has established a hazard classification scheme similar to that described in this section, but with some minor differences. Laser products encountered at ECU may be labeled using this alternate system. Laser systems bearing the IEC 1M, 2M, or 3R classification require the same control measures as Class 3a lasers. See Appendix D [Summary of Laser Hazard Classification Schemes] for further information regarding these laser classification schemes

LASER ACQUISITION, TRANSFER, AND DISPOSAL

Laser Acquisition, Transfer, and Disposal

Notify the LSO of any decision to purchase, fabricate, or otherwise acquire a Class 3b (3B) or Class 4 laser. The LSO will review with the user the hazards of the proposed operation and make recommendations regarding the specific safety requirements that pertain to the proposed use, including requirements for SOPs, laser control areas, training, and personnel protective equipment.

Also notify the LSO before any Class 3b (3B) or 4 laser or laser system is relocated, transferred to another PLU or institution, or sent offsite as surplus equipment. Radiation safety staff will decommission the laser and verify that it is inoperable before it is sent off as surplus equipment.

Laser users have an obligation to ensure safe and responsible disposition of their unneeded, but potentially hazardous, Class 3b (3B) or 4 lasers and laser components. Appropriate means of laser disposal include:

- Donate the laser to an organization (e.g. school, industrial company, hospital) with a need for such a device. The donor should ensure that the donated laser system complies with all applicable product safety standards, such as the Federal Laser Product Performance Standard (FLPPS), and is provided with adequate safety instructions for operations and maintenance. The donor should also verify that the receiving organization has a viable laser safety program.

- Return the laser to the manufacturer, or to a vendor specializing in re-selling used laser equipment.

- Eliminate the possibility of activating the laser by removing all means by which it can be electrically activated. Once this has happened the laser could then be discarded (e.g. cut the cord before sending to surplus).

- Destroy the laser.

The last two methods also require proper disposal of any hazardous materials found inside the laser components, such as mercury switches, oils, dyes, etc. Users should contact the LSO if they need further information or assistance with proper disposal.

LASER HAZARD CONTROL MEASURES

Laser Hazard Control Measures

CONTROLS FOR CLASS 1, 2, AND 3A (IEC CLASS 1, 1M, 2, 2M AND 3R) LASERS

- Class 1, 2, and 3a (IEC 1, 1M, 2, 2M or 3R) laser beams may not be intentionally directed at a law enforcement officer or the head or face of another person, except for:
    - law enforcement purposes by police, or
    - medical use by authorized medical personnel.

- Class 3a (IEC 1M, 2M or 3R) laser beams must not be viewed with collecting optics (e.g. microscopes) unless the optical system is specifically designed and constructed to prevent eye exposure exceeding the applicable MPE (Maximum Permissible Exposure).

- Otherwise, no other specific laser safety requirements apply to Class 1, 2, and 3a (IEC 1, 1M, 2, 2M or 3R) lasers.

CONTROLS FOR CLASS 3B AND 4 (IEC CLASS 3B AND 4) LASERS

Class 3b (3B) and Class 4 lasers may be operated only in designated laser control areas, including operative suites, patient treatment rooms and patient examination rooms, or in other laser control areas approved by the Laser Safety Officer (LSO). The purpose of laser control areas is to confine laser hazards to well- defined spaces that are under the control of the laser user, thereby preventing injury to those visiting and working near the control area. All personnel authorized to enter a Class 3b (3B) or Class 4 laser controlled area shall be appropriately trained, and must follow all applicable administrative and operational controls.

Postings

The 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 LSO and conform to the ANSI Z136.1 guidelines. Such signs shall be posted at all entrances to the laser control area. In addition, an SOP approved by the LSO must be posted in a location readily available to laser operators.

Authorization

Only personnel who have been authorized by the Principal Laser User (PLU) may operate the laser. Personnel may be authorized upon completing the Laser Safety training. The PLU may stipulate additional authorization requirements. Class 3b (3B) and 4 lasers may only be operated upon the LSO's approval of the responsible PLU's Laser Laboratory Authorization.

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 (for Class 4 lasers) fire resistant.

Eye Protection

Laser protective eyewear of adequate optical density and threshold limit for the beams under manipulation must be provided and worn at any point where laser exposure could exceed the Maximum Permissible Exposure (MPE). This includes provision and use of M-rated eyewear in labs using unenclosed Class 3b (3B) or 4 laser systems capable of <1 ns pulses, and R-rated eyewear in labs using unenclosed Class 3b (3B) or 4 Q-switched laser systems (see Appendix F for further information). In addition:

- Procedures and practices must ensure that optical systems and power levels are not adjusted upstream during critical open beam operations, such as beam alignment.

- In clinical use, patients must also be provided with eye protection. If the patient is conscious or under conscious sedation, appropriate protective eyewear is to be used. If the patient is under general anesthesia, the eyes are to be protected with wet gauze pads or similar non-flammable material.

- The need for laser eye protection must be balanced by the need for adequate visible light transmission (VLT). It is the responsibility of the PLU to obtain appropriate laser protective eyewear. For assistance in selecting laser eye protection, contact the LSO. The LSO can assist the user in determining the proper parameters of such eyewear, and can provide contact information for vendors.

- Laser eye protection should be inspected before use and at regular intervals to ensure that it is in good condition.

- Damaged or faded eyewear must be removed from service immediately to prevent accidental overexposure.

Light Containment

Laser light levels in excess of the MPE 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. 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. Lasers should be mounted so that the beam path is not at eye level for standing or seated personnel. Special rules apply for outdoor use and laser control areas that do not provide complete containment. Contact the LSO for details.

ADDITIONAL CONTROLS FOR CLASS 4 LASERS

Only appropriately trained personnel may enter a Class 4 laser controlled area during the time a procedure utilizing the active beam is in progress. All personnel within the control area must be provided with appropriate protective equipment and are required to follow all applicable administrative controls. Class 4 laser control areas must meet all of the requirements that apply to Class 3b (3B) control areas and also the following requirements:

Rapid Egress and Emergency Access

There must be provisions for rapid egress from a laser control area under all normal and emergency conditions. Any control area interlock system must not interfere with emergency egress. In addition, access control measures must not interfere with the ability of emergency response personnel (fire, paramedical, police) to enter the laser control area in the event operating personnel become injured or incapacitated.

Laser Activation Warning Systems and Entry 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. These measures should include:

1. a visible sign or audible warning sign or signal must be at the entrance to the control area to indicate when the laser is energized and operating;

2. provision of personnel with proper training and laser protective eyewear;

3. doors or blocking curtains/barriers that attenuate the laser beam to below the MPE at the entranceway.

4. Entryway controls (e.g. interlocks, shutters, illuminated “Laser On” warning signs, barrier curtains) shall be checked periodically to verify proper operation

5. If entryway controls must be disabled for any reason, administrative and procedural controls providing the same level of protection must be instituted prior to the operation of the laser or laser system. Any such changes to entryway controls and alternate control measures must be pre-approved in writing by the PLU and communicated to all personnel working in the laser area. The PLU and all personnel in the laser area must also be notified upon restoration of the entryway controls.

The results of a formal hazard evaluation by the LSO may require more rigorous entryway controls to be put into place, depending upon the level of the hazard. These may include door interlocks or other entryway safety controls.

Locking entryway doors as a means of access control **is not acceptable**, because it is contrary to the principle of permitting rapid egress or emergency access.

Key Switches

For those laser systems equipped with a key switch to prevent unauthorized use, the key must **NOT** be left in the switch when the laser system is unattended.

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 SOP approval process. The LSO can be contacted for assistance in setting up a temporary laser control area.

SPECIAL REQUIREMENTS FOR INVISIBLE LASER BEAMS

Since IR (infrared light) and UV (ultraviolet light) 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 Lasers

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

Ultraviolet Lasers

UV radiation causes photochemical reaction in the eyes and the skin, as well as in materials that are found in laboratories. The latter may cause hazardous by-products such as ozone and skin-sensitizing agents. The direct beam and scattered radiation should be shielded to the practical maximum extent to avoid such problems. The use of long-sleeved coats, gloves, and face protectors is recommended. Some medications, including tetracycline, doxycycline, tricyclic antidepressants, and methotrexate, can increase a person's risk to UV radiation. Contact the LSO for more information about this subject.

SUBSTITUTION OF ALTERNATE CONTROL MEASURES

Upon documented review by the LSO, the engineering control measures recommended by ANSI Z136.1 for Class 3b (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 chapter.

LASER SAFETY TRAINING

Laser Safety Training

INITIAL TRAINING

All personnel who use Class 3b (3B) or Class 4 lasers **must** complete the ECU Laser Safety course. This includes faculty members, students, physicians, and those nursing and ancillary personnel working in operative or treatment areas during healthcare laser use. The Laser Safety course is available online and by classroom instruction through the Laser Safety Officer (LSO).

VISITORS

Guests of ECU requesting to use or observe Class 3b (3B) or Class 4 lasers must contact the LSO regarding the training requirement for non-ECU personnel. New employees and guests may use lasers under the direct supervision of a Principal Laser User (PLU) until completing the training requirement.

LASER-SPECIFIC TRAINING

Laser users are also responsible for knowing the safety requirements that apply to their specific laser or laser system and for knowing the contents of the applicable SOP. The PLU will administer laser-specific training to each Laser Operator (LO) and ensure that the LO reads and signs the SOP before starting work.

UPDATE TRAINING

All laser users must periodically retake Laser Safety training. This retraining can be satisfied through the Laser Safety Refresher Course offered online.

Research laser users: annual retraining interval
Healthcare laser users:

- Physicians with Laser Privileges: comply with applicable Credentialing training requirements
- All other ancillary personnel: annual retraining interval

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LASER RELATED NON-BEAM HAZARDS & CONTROL MEASURES

Laser Related Non-Beam Hazards & Control Measures

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 (LSO) and addressed by the Principal Laser User (PLU) in the Standard Operating Procedure (SOP) for the laser operation where applicable.

ELECTRICAL HAZARDS

Some lasers use high-voltage power supplies, large capacitors, or capacitor banks that present a lethal shock hazard. Additional hazards of electrical equipment include resistive heating and ignition source. Electrical safety controls include:

(a) Occupational Safety and Health Administration, OSHA [29 CFR 1910 S], requires additional controls and training for work on live circuits operating more than 50 volts; note also that capacitors maintain a lethal charge even in de-energized and unplugged equipment. Use extreme caution if servicing laser power supplies.

(b) Review and comply with ECU EH&S Electrical Safety Program. This includes lockout-tagout procedures required by OSHA [29 CFR 1910.147 J] and the EHS LOTO Program.

(c) Check the condition of electrical insulation and ensure that electrical terminals are covered; repair or replace damaged equipment.

(d) Ensure good equipment grounding (i.e. chassis/frame resistance to ground limited to a few ohms).

(e) Follow good wiring practices (e.g. use GFCI outlets, no wires on the floor, no overloaded circuits, etc.).

(f) Use equipment only for its intended/designed purpose.

(g) Keep equipment "power up" warning lights clearly visible.

LASER DYES

Dyes used as the optically active medium in some laser 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. For each dye used, the PLU must have the MSDS (Material Safety Data Sheet) available for staff review and in general ensure compliance with applicable ECU policies governing hazardous chemical use and disposal (see ECU EH&S Chemical Hygiene Plan).

COMPRESSED GASES AND CRYOGENICS

Hazardous gases may be used in laser applications; i.e. excimer lasers (fluorine, hydrogen chloride). Cryogenic fluids are used in cooling systems of some lasers. The SOP should contain references for the safe handling of compressed gases. See ECU EH&S Compressed Gas Safety for further guidance.

LASER GENERATED AIR CONTAMINANTS

Laser Generated Air Contaminants (LGAC) may be generated when Class 3b (3B) and Class 4 laser beams interact with matter. When target irradiance reaches a threshold of about 10^7 W/cm^2, target materials including plastics, composites, metals, and tissues may liberate toxic and noxious airborne contaminants. Generally, the PLU must ensure that any laser operation that creates visible smoke or plume has adequate local exhaust ventilation in place and included in the SOP; **respiratory protection is not an acceptable alternative to local exhaust ventilation**. If, in addition to local exhaust ventilation, respiratory protection is required or worn voluntarily, consult the ECU EH&S Respiratory Protection Program.

PLASMA RADIATION

Interactions between very high power (~10^{12} W/cm^2) laser beams and target materials may produce a *plasma*, which in turn generates "blue light" and UV emissions that pose an eye and skin hazard. Similarly, targets heated to very high temperatures (e.g. in laser welding and cutting) emit an intense light. The PLU must ensure adequate control measures are in place and addressed in the SOP for such operations.

UV AND VISIBLE RADIATION

Laser discharge tubes and pump lamps may generate sufficient UV and visible radiation to pose an eye and skin hazard. To address this issue, maintain the integrity of the laser housing and avoid operating any laser with the housing removed.

EXPLOSION HAZARDS

High-pressure arc lamps, filament lamps, and capacitors may explode if they fail during operation. Keep these components enclosed in the laser 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. Ensure adequate mechanical shielding when exposing brittle materials to high intensity lasers.

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 thyratrons and electric discharge lasers. Any power supplies that require more than 15 kilovolts may produce enough x-rays to be a health concern. Consult Radiation Safety for review and control of such hazards.

MEDICAL SURVEILLANCE

MEDICAL SURVEILLANCE

Personnel working with Class 3b (3B) and/or Class 4 lasers or laser systems are not required to obtain either a pre- or post-employment medical examination specific to laser use. Following any suspected laser injury, employees must report to a supervisor and the Office of Environmental Health and Safety (328-6166) if they believe that they have been injured. They will provide guidance with the Workers' Compensation Program and coordinate with the Office of Prospective Health in scheduling medical appointments.

LASER ACCIDENTS

Laser Accidents

IMMEDIATE RESPONSE AND GENERAL PROCEDURES

General Laser Accident Reporting

Laser users must report all laser accidents on site, no matter how minimal, to the Principal Laser User (PLU) responsible for the laser system involved. The PLU must report any accidents causing injury or property damage to the Laser Safety Officer (LSO). If immediate assistance is required, dial 911 (on East Campus) or 744-2246 (on Health Sciences Campus), indicate to the ECU Police that a laser accident has occurred, and direct them to notify Radiation Safety, who will contact the LSO to respond to the situation.

Known or Suspected Laser Overexposure

If a known or suspected overexposure to laser radiation occurs at ECU:

(a) Notify the supervisor of the injured individual(s) to ensure action is taken to prevent any further injury to other personnel.

(b) Take all seriously injured persons directly to the Emergency Department at Vidant Medical Center.

(c) The supervisor and/or injured individual must immediately report the incident to the ECU Environmental Health and Safety (328-6166).

(d) The supervisor shall notify the LSO within 24 hours after the initial reporting of the incident.

(e) The LSO will inform relevant personnel of actions being taken or required as part of the investigation.

Follow-up Procedures by the Laser Safety Officer

The following guidelines describe the initial procedure to be followed by the LSO in the event of a laser accident or incident:

If indicated, the LSO will respond on-site to the department reporting the incident.
The LSO will document the following information for future review:

- Date and time of call.
- Name and department of caller.
- Name of reporting person's immediate supervisor
- Model, serial number, ECU property number, manufacturer, and nomenclature of device.

The LSO will contact the caller's supervisor to ensure that he/she is informed, and to remind him/her to report incidents to the ECU Office of Environmental Health and Safety (OEHS). The LSO will notify the OEHS and provide them with complete documentation (if indicated). The OEHS will provide further guidance to the LSO if any is necessary.

After the LSO has verified that the exposed individual(s) have received the appropriate medical care, and that the appropriate administrative personnel have been notified of the incident, the LSO will continue to investigate the circumstances of the accident by obtaining the following information:

(a) Name(s) of individual(s) alleged or suspected to have been overexposed.

(b) Laser nomenclature, characteristics and operating parameters at the time of the incident (wavelength, peak and average power, pulse width and frequency, beam diameter and divergence, etc.).

(c) Date, location, and time of the incident, as well as the duration of the exposure and the individual's position relative to the laser.

(d) Description of what happened. If possible, obtain a signed brief description from all individuals who have first-hand knowledge of the incident.

(e) Protective equipment / clothing in use at the time of the accident, and eyewear transmission characteristics at the wavelength of the laser.

(f) Facility configuration at the time of the event.

(g) The name and telephone number of the attending physician.

Following the initial reporting of the alleged or suspected overexposure, the LSO will coordinate with appropriate organizations to prepare a detailed report of the incident. This report shall consist of a summary of the estimated exposure, timetable of medical evaluations, recommendations to prevent recurrence of the incident, and discussion of further medical follow-up recommendations. When requested by the appropriate organizations, the LSO shall provide consulting services on laser incident investigations.

STANDARD OPERATING PROCEDURE (SOP)

Standard Operating Procedure (SOP)

The Principal Laser User (PLU) must provide a written SOP, approved by the Laser Safety Officer (LSO) prior to laser use, for all Class 3b (3B) and Class 4 laser systems. This SOP must be posted near the laser(s) and include:

- hazard identification and mitigation;
- manufacturer's start up and shut down procedures;
- safe alignment procedures;
- safety procedures;
- protective equipment; and
- emergency procedures.

A general laser SOP template is available via the Office of Prospective Health-Radiation Safety Section web site (**https://www.ecu.edu/cs-dhs/prospectivehealth/radiation.cfm).** The use of the template is highly recommended. The template provides a guide for the laser user in identifying the characteristics of the laser operation and collateral hazards, and in formulating set-up and alignment procedures. Contact the LSO for assistance in developing control measures and completing the SOP.

In the case of enclosed systems (e.g. laser scanning confocal microscopy) the requirement for an SOP may be reduced or waived entirely after a review by the LSO, who will then determine which if any SOP sections are required.

All SOPs should be reviewed annually by personnel working with lasers to ensure the accuracy of the procedure(s). If no new hazards have been added to the system, the users can perform the review without notifying the LSO. If new hazards (use of a sub-nanosecond laser system, for example) have been added to the experiment, a review by the LSO is necessary to assure all applicable safeguards have been implemented.

REFERENCES & ACKNOWLEDGEMENTS

References

(1) American National Standards Institute (ANSI) Z136.1-2014, American National Standard for the Safe Use of Lasers (or later revision)

(2) American National Standards Institute (ANSI) Z136.3-2011, American National Standard for the Safe Use of Lasers in Health Care Facilities (or later revision)

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

Acknowledgements

The Office of Prospective Health-Radiation Safety Section wishes to thank Duke University and their Laser Safety Officer for allowing East Carolina University to use the Duke Laser Safety Policy (*Revision 2017*) as a guide in the preparation of this manual.

APPENDICES

APPENDIX A

APPENDIX A

LIST OF ABBREVIATIONS

ANSI Z136.1 – American National Standards Institute Z136.1-2014 (or latest version thereof) *Standard for the Safe Use of Lasers*

ANSI Z136.3 – American National Standards Institute Z136.3-2011 (or latest version thereof) *Safe Use of Lasers in Health Care Facilities*

CFR – Code of Federal Regulations

CW – Continuous wave laser (laser operating with continuous output for more than 0.25 seconds)

ECU – East Carolina University

FAA – Federal Aviation Administration

FLPPS – Federal Laser Product Performance Standard

GFCI – Ground Fault Circuit Interrupter

IEC – International Electrotechnical Commission. This group establishes standards for the safe use of lasers that are similar to the ANSI Z136 series of standards and which, like the ANSI standards, are recognized by the various U.S. government agencies regulating laser use in this country

IR – Infrared light (700 nm – 1000 μm wavelength). *[Visible radiation (light) is characterized as having a wavelength in the range of 400 nm – 700 nm according to the ANSI standards.]*

LGAC – Laser Generated Air Contaminants

LO – Laser Operator

LSC – Laser Safety Committee.

LSO – Laser Safety Officer

MPE – Maximum Permissible Exposure, i.e. the laser radiation level to which a person can be exposed without hazardous effect or adverse biological changes in the eye or skin.

MSDS – Material Safety Data Sheet / or SDS – Safety Data Sheet

NHZ – Nominal Hazard Zone

OD – Optical Density

OEHS – ECU Office of Environmental Health and Safety

OSHA – Occupational Safety and Health Administration

PLU – Principal Laser User

PPE – Personal Protective Equipment

SOP – Standard Operating Procedure

UV – Ultraviolet light (100 – 400 nm wavelength)

VLT – Visible Light Transmission

APPENDIX B

APPENDIX B

GLOSSARY OF LASER TERMS

Absorb To transform radiant energy into a different form, with a resultant rise in temperature.

Absorption Transformation of radiant energy to a different form of energy by the interaction with matter, depending on temperature and wavelength.

Accessible Emission Level The magnitude of accessible laser (or collateral) radiation of a specific wavelength or emission duration at a particular point as measured by appropriate methods and devices. Also means radiation to which human access is possible in accordance with the definitions of the laser's hazard classification.

Accessible Emission Limit (AEL) The maximum accessible emission level permitted within a particular class. In ANSI Z 136.1, AEL is determined as the product of accessible emission Maximum Permissible Exposure limit (MPE) and the area of the limiting aperture (7 mm for visible and near-infrared lasers).

Aperture An opening through which radiation can pass.

Argon A gas used as a laser medium. It emits blue-green light primarily at 448 and 515 nm.

Attenuation The decrease in energy (or power) as a beam passes through an absorbing or scattering medium.

Aversion Response Movement of the eyelid or the head to avoid an exposure to a noxious stimulant, bright light. It can occur within 0.25 seconds, and it includes the blink reflex time.

Beam A collection of rays that may be parallel, convergent, or divergent.

Beam Diameter The distance between diametrically opposed points in the cross section of a circular beam where the intensity is reduced by a factor of e^{-1} (0.368) of the peak level (for safety standards). The value is normally chosen at e^{-2} (0.135) of the peak level for manufacturing specifications.

Beam Divergence Angle of beam spread measured in radians or milliradians (1 milliradian = 3.4 minutes of arc). For small angles where the cord is approximately equal to the arc, the beam divergence can be closely approximated by the ratio of the cord length (beam diameter) divided by the distance (range) from the laser aperture.

Blink Reflex See aversion response

Brightness The visual sensation of the luminous intensity of a light source. The brightness of a laser beam is most closely associated with the radio-metric concept of radiance.

Carcinogen An agent potentially capable of causing cancer.

Carbon Dioxide Molecule used as a laser medium. Emits far infared energy at 10,600 nm (10.6 µm).

Closed Installation Any location where lasers are used which will be closed to unprotected personnel during laser operation.

CO_2 Laser A widely used laser in which the primary lasing medium is carbon dioxide gas. The output wavelength is 10.6 µm (10600 nm) in the far infrared spectrum. It can be operated in either CW or pulsed.

Cornea The transparent outer coat of the human eye, covering the iris and the crystalline lens. The cornea is the main refracting element of the eye.

Coherence A term describing light as waves which are in phase in both time and space. Monochromaticity and low divergence are two properties of coherent light.

Collimated Light Light rays that are parallel. Collimated light is emitted by many lasers. Diverging light may be collimated by a lens or other device.

Collimation Ability of the laser beam to not spread significantly (low divergence) with distance.

Continuous Mode The duration of laser exposure is controlled by the user (by foot or hand switch).

Continuous Wave (CW) Constant, steady-state delivery of laser power.

Controlled Area Any locale where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

Diffuse Reflection Takes place when different parts of a beam incident on a surface are reflected over a wide range of angles in accordance with Lambert's Law. The intensity will fall off as the inverse of the square of the distance away from the surface and also obey a Cosine Law of reflection.

Divergence The increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser radiant exposure or irradiance is e^{-1} or e^{-2} of the maximum value, depending upon which criteria is used

Embedded Laser A laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate to the engineering features limiting accessible emission.

Emission Act of giving off radiant energy by an atom or molecule.

Enclosed Laser Device Any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure. The laser inside is termed an "embedded laser."

Energy (Q) The capacity for doing work. Energy is commonly used to express the output from pulsed lasers and it is generally measured in Joules (J). The product of power (watts) and duration (seconds). One watt second = one Joule.

Erythema The medical term for redness of the skin due to congestion of the capillaries.

Excimer An abbreviation for *excited dimer*. A gas mixture used as the active medium in a family of lasers emitting ultraviolet light.

Exposure Duration The total amount of time the ocular structures or skin are exposed to the laser beam.

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

Gas Discharge Laser A laser containing a gaseous lasing medium in a glass tube in which a constant flow of gas replenishes the molecules depleted by the electricity or chemicals used for excitation.

Gas Laser A type of laser in which the laser action takes place in a gas medium.

Helium-Neon (HeNe) Laser A laser in which the active medium is a mixture of helium and neon. Its wavelength is usually in the visible range. Used widely for alignment, recording, printing, and measuring.

Infrared Radiation (IR) Invisible electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 μm. These wavelengths are often broken up into regions: IR-A (0.7-1.4 μm), IR-B (1.4-3.0 μm) and IR-C (3.0-1000 μm).

Iris The annular pigmented structure that lies behind the cornea of the human eye. The iris forms the pupil.

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

Irradiance (E) Radiant flux (radiant power) per unit area incident upon a given surface. Units: Watts per square centimeter. (Sometimes referred to as power density, although not exactly correct).

Joule (J) is a unit of energy (1 joule = 1 Watt-second).

Laser An acronym for light amplification by stimulated emission of radiation. A laser is a cavity with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. It produces an intense beam of light with the unique properties of coherency, collimation, and monochromaticity.

Laser Accessories The hardware and options available for lasers, such as secondary gases, Brewster windows, Q-switches and electronic shutters.

Laser Controlled Area See Controlled Area.

Laser Device Either a laser or a laser system.

Laser Medium (Active Medium) Material used to emit the laser light and for which the laser is named.

Laser Rod A solid-state, rod-shaped lasing medium in which ion excitation is caused by a source of intense light, such as a flash lamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal.

Laser Safety Officer (LSO) One who has authority to monitor and enforce measures to control laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser System An assembly of electrical, mechanical and optical components which includes a laser. Under the Federal Standard, a laser in combination with its power supply (energy source).

Lens A curved piece of optically transparent material which, depending on its shape, is used to either converge or diverge light.

Light (see Visible Radiation)

Limiting Aperture The maximum circular area over which radiance and radiant exposure can be averaged when determining safety hazards.

Macula The small, uniquely pigmented and specialized area of the retina.

Maintenance Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this glossary.

Maximum Permissible Exposure (MPE) The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

Nd:Glass Laser A solid-state laser of neodymium:glass offering high power in short pulses. A Nd-doped glass rod used as a laser medium to produce 1064 nm light.

Nd:YAG Laser Neodymium:Yttrium Aluminum Garnet. A synthetic crystal used as a laser medium to produce 1064 nm light.

Neodymium (Nd) The rare earth element that is the active element in Nd:YAG lasers and Nd:Glass lasers.

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

Ocular Fundus The back of the eye. The ocular fundus may be seen through the pupil by use of an ophthalmoscope.

Optical Cavity (Resonator) Space between the laser mirrors where lasing action occurs.

Optical Density A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter.

Optical Fiber A filament of quartz or other optical material capable of transmitting light along its length by multiple internal reflection and emitting it at the end.

Optical Pumping The excitation of the lasing medium by the application of light rather than electrical discharge.

Optical Radiation Ultraviolet, visible, and infrared radiation (0.35-1.4 μm) that falls in the region of transmittance of the human eye.

Output Power The energy per second measured in watts emitted from the laser in the form of coherent light.

Plasma Radiation Black-body radiation generated by luminescence of matter in a laser-generated plume

Power The rate of energy delivery expressed in watts (Joules per second). Thus: 1 Watt = 1 Joule / 1 Sec.

Protective Housing A device designed to prevent access to radiant power or energy.

Pulse A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output.

Pulse Duration The "on" time of a pulsed laser, it may be measured in terms of milliseconds, microseconds, nanoseconds, picoseconds, and femtoseconds as defined by half-peak-power points on the leading and trailing edges of the pulse.

Pulse Repetition Frequency (PRF) The number of pulses occurring per second, expressed in hertz.

Pulsed Laser Laser which delivers energy in the form of a single or train of pulses.

Pump To excite the lasing medium. See Optical Pumping or Pumping.

Pumped Medium Energized laser medium.

Pumping Addition of energy (thermal, electrical, or optical) into the atomic population of the laser medium, necessary to produce a state of population inversion.

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

Radiant Energy (Q) Energy in the form of electromagnetic waves usually expressed in units of Joules (watt-seconds).

Radiant Exposure (H) The total energy per unit area incident upon a given surface. It is used to express exposure to pulsed laser radiation in units of J/cm^2.

Reflection The return of radiant energy (incident light) by a surface, with no change in wavelength.

Refraction The change of direction of propagation of any wave, such as an electromagnetic wave, when it passes from one medium to another in which the wave velocity is different. The bending of incident rays as they pass from one medium to another (e.g., air to glass).

Resonator The mirrors (or reflectors) making up the laser cavity including the laser rod or tube. The mirrors reflect light back and forth to build up amplification.

Retina The sensory tissue that receives the incident image formed by the cornea and lens of the human eye. The retina lines the posterior eye

Ruby The first laser type; a crystal of sapphire (aluminum oxide) containing trace amounts of chromium oxide.

Scanning Laser A laser having a time-varying direction, origin, or pattern of propagation with respect to a stationary frame of reference.

Secured Enclosure An enclosure to which casual access is impeded by an appropriate means (e.g. door secured by lock, magnetically or electrically operated latch, or by screws).

Semiconductor Laser A type of laser which produces its output from semiconductor materials such as gallium arsenide (GaAs).

Service Performance of adjustments, repair or procedures on a non-routine basis, required to return the equipment to its intended state.

Solid Angle The ratio of the area on the surface of a sphere to the square of the radius of that sphere. It is expressed in steradians (sr).

Source The term source means either laser or laser-illuminated reflecting surface, i.e., source of light.

Spectator An individual who wishes to observe or watch a laser or laser system in operation and who may lack the appropriate laser safety training.

Specular Reflection A mirror-like reflection.

Tunable Laser A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.

Tunable Dye Laser A laser whose active medium is a liquid dye pumped by another laser or flash lamps to produce various colors of light. The color of light may be tuned by adjusting optical tuning elements and/or changing the dye used.

Ultraviolet (UV) Radiation Electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).

Viewing Portal is an opening in an experimental system, allowing the user to observe the experimental chamber. All viewing portals and display screens included as an integral part of a laser system must incorporate a suitable means to maintain the laser radiation at the viewing position at or below the applicable MPE (eye safe) for all conditions of operation and maintenance. It is essential that the material used for viewing portals and display screens not support combustion or release toxic vapors following exposure to laser radiation

Visible Radiation (light) Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths in the range between 400 nm and 700-780 nm.

Watt (W) The unit of power or radiant flux (1 watt = 1 joule per second).

Wavelength The distance between concentric oscillations of the light wave, usually measured from crest to crest, which determines its color. Common units of measurement are the micrometer (micron), the nanometer, and (earlier) the Angstrom unit.

YAG Yttrium Aluminum Garnet, a widely used solid-state crystal composed of yttrium and aluminum oxides and a small amount of the rare earth neodymium.

APPENDIX C

APPENDIX C

USE OF LASERS OUTSIDE OF THE CLINICAL OR LABORATORY SETTING

Introduction

The use of a laser outside of a controlled area can present special hazards. This appendix addresses the control of any Class 3a, 3b, or 4 (IEC Class 3R, 3B, or 4) laser used outside the normal research laboratory or clinical environment. These applications may include; lasers used for the purpose of telecommunication, laser research being performed outdoors, and lasers used for entertainment or public viewing.

General Requirements

Any Class 3b, or 4 laser used for entertainment, displays, demonstrations, or any related use intended for public viewing (indoors or outdoors) shall be operated in accordance with federal, state, local, and campus regulations and requirements.*

Any Class 3b (3B), or 4 laser used outdoors for telecommunication applications or for research projects shall be registered with the Laser Safety Officer per the requirements of the ECU Laser Safety Policy.*

The operators of laser systems used for entertainment are required by law to file a "Report on Laser Light Show Display" (or a variance document), with the Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH). No laser light show, display, or device may vary from compliance with 21CFR1040.11(c) in design or use unless an approved Application for a Variance from 21CFR1040.11(c) for a Laser Light Show, Display, or Device has been issued by the FDA per 21CFR1010.4. If the venue is outdoors and the beam(s) may terminate in navigable airspace, then the operators are also required to file a report with the Regional Federal Aviation Administration (FAA) office.

All Class 3a (3R), 3b (3B), or 4 laser systems being used on East Carolina University property must be used in accordance with the ECU Laser Safety Policy. The Laser Safety Committee must approve any variation from the Laser Safety Policy.

Procedures

Laser Light Shows (Indoor or Outdoor)

ECU organizations, departments, or campus affiliated groups (student or otherwise) shall inform the LSO on the contracting of outside companies to conduct any laser light show (indoor or outdoor) to be performed on ECU property.

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*The FAA specifies several levels of irradiance; it is not necessary to injure a pilot to disrupt a flight. See App. C for further discussion of outdoor laser use.

For any light show (indoor or outdoor) conducted by an ECU affiliated entity, that entity must coordinate with the Laser Safety Officer (LSO). Due to the nature of the close proximity to the Pitt-Greenville Airport *PGV*, special considerations need to be discussed with the LSO prior to approval. The LSO will request from the light show operators a copy of the required “Report on Laser Light Show Display” (or variance document) prior to the show. Upon receipt, the LSO shall review the description of the show and the operator’s safety procedures. The LSO may require additional safety measures to assure the safety of the operators, performers, or audience. Specific requirements for laser light shows include:

1. The CDRH and ANSI requirements specified by the LSO must be met.

2. Any audience exposure to laser radiation must not exceed the ANSI Class 1 limit.

3. Operators, performers, and employees must be able to perform their duties without having to directly view laser radiation exceeding the ANSI Class 1 limit, and without being exposed to laser radiation exceeding the ANSI Class 2 limit.

4. All laser scanners (including mirror balls) must incorporate proper scanning safeguards.

5. If the laser is not under continuous operator control, any Class 3b, or 4 level of laser radiation cannot be closer than 6 m vertically or 2.5 m horizontally from any standing surface or standing position where the audience may be located.

6. If the laser is under continuous operator control, any Class 3a, 3b, or 4 level of laser radiation cannot be closer than 3 m vertically or 2.5 m horizontally from any standing surface or standing position where the audience may be located.

7. An operator with an accessible control to terminate the beam must be available if conditions become unsafe.

8. FAA notification is required (for Class 3a/3R, 3b/3B, and 4 lasers) if the display is being used in navigable airspace.

9. Additional safety requirements may be needed as specified by the LSO.

10. The CDRH “Report on Laser Light Show Display” forms are available from the LSO.

NOTE: An SOP is not normally required for laser light shows.

Research Projects Involving Outdoor Laser Use

The Principal Laser User (PLU) shall inform the LSO of any lasers used outdoors for research projects. Such laser uses will need to be covered under a Standard Operating Procedure (SOP) approved by the LSO as specified in the ECU Laser Safety Policy. The department will be responsible for informing the LSO of any indoor or outdoor telecommunication applications being pursued by that department. In both cases, the application and operation of the laser system(s) shall be evaluated by the LSO to ensure that appropriate safety measures are in place prior to operation. Specific laser safety requirements for (non-light show) uses of lasers include:

1. The PLU must create a written SOP and meet the specified SOP safety requirements.

2. The LSO will establish a Nominal Hazard Zone (any area where the maximum permissible exposure (MPE) is exceeded).

3. The NHZ (Nominal Hazard Zone) must be posted and/or restricted as directed by the LSO.

4. The PLU must ensure that only trained personnel enter the NHZ, and that appropriate PPE (personal protective equipment) is issued and used.

5. The PLU must ensure users are properly trained and meet the campus laser safety training requirements.

6. The PLU must ensure only authorized personnel are allowed to operate the laser.

7. The PLU must ensure the use of any required administrative/engineering controls.

8. Laser beams shall not be directed toward structures, automobiles, aircraft, or other vehicles within the NHZ unless adequate training and protective equipment is provided and used by all personnel within these structures/vehicles.

9. The laser beam path shall **not** be maintained at eye level without LSO approval.

10. FAA notification is required (for Class 3a/3R, 3b/3B, or 4 lasers) if the laser is being used in navigable airspace.

11. Additional safety requirements may be needed as specified by the LSO.

Emergencies

The potential for injuries from a laser light show/display is minimal if the operators observe the CDRH requirements. In the event that an individual suspects an eye injury, the operators of the laser system shall be notified immediately so that the laser beam(s) can be terminated. The event staff shall also be notified and medical attention shall be provided to the injured individual if needed. The LSO shall be informed as soon as possible should any laser injury be suspected. The LSO or his alternate can be contacted at any time by calling 911 and asking for the ECU Radiation Safety Office.

APPENDIX D

APPENDIX D

SUMMARY OF LASER HAZARD CLASSIFICATION SCHEMES

FDA/CDRH (21CFR1040.10)	ANSI Z136	IEC/EN 80625
Class I - levels of laser radiation are not considered hazardous	Class 1 – no hazard; exempt from all control measures	Class 1 – no risk, even with viewing instruments Class 1M[a] – no risk except perhaps to eye when viewed through viewing instruments (eye loupes or binoculars)
Class IIa – levels of laser (applies to visible only) radiation are not considered hazardous if viewed ≤ 1,000 seconds but are considered a chronic viewing hazard for any period of time >1,000 seconds Class II – levels of (visible only) laser radiation considered a chronic viewing hazard	Class 2 – visible (0.4 – 0.7 µm) lasers not considered hazardous for momentary viewing (<0.25 seconds), but for which the Class 1 accessible emission limit may be exceeded for longer exposure durations; avoid prolonged staring	Class 2 – no eye risk for short term exposures, even with viewing instruments; no risk to skin (applies to visible lasers only) Class 2M[a] – no eye risk for short term exposures, except perhaps with viewing instruments; no risk to skin (visible only
Class IIIa – levels of laser radiation are considered, depending upon the irradiance, either an acute intrabeam viewing hazard or chronic viewing hazard, and an acute viewing hazard if viewed directly with optical instruments	Class 3a – with "Caution" label: does not exceed the appropriate irradiance MPE, except perhaps when viewed through collecting optics (e.g. microscopes, telescopes) – with "Danger" label: may exceed the appropriate irradiance MPE	Class 3R[b] – low risk to eyes, no risk to skin
Class IIIb – levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct radiation	Class 3b – emit greater than Class 3a limits and pose an acute eye hazard; more rigorous controls are required to prevent exposure of the unprotected eye	Class 3B – medium to high risk to eyes, low risk to skin
Class 4 – levels of laser radiation are considered an acute hazard to the skin and eyes from direct and scattered radiation	Class 4 – acute eye and skin hazard, plus ignition source (fire) and laser-generated airborne contaminants hazards; strict control measures required	Class 4 – high risk to eyes and skin

a. The "M" designation in the IEC classification scheme is derived from "magnifying" optical viewing instruments.
b. The "R" designation in the IEC classification scheme is derived from reduced or relaxed requirements for manufacturers (no key switch or interlock connector required) and users (usually no eye protection required).

The ANSI Z136.1 Standard is currently under revision and is proposing the adoption of the IEC Standard's Classification Scheme described above.

APPENDIX E

APPENDIX E

ADDITIONAL CONSIDERATIONS FOR OUTDOOR LASER USE

A laser need not cause a pilot eye injury to disrupt the normal operation of an aircraft. The FAA identifies three (non-injury) categories of air crew visual impairment:

- Glare: dazzling sensation induced by relatively bright light, producing unpleasantness, discomfort, or interference with optimal vision; generally ceases once stimulus removed, but residual effects (spatial disorientation, loss of situational awareness) can persist;
- Flash blindness: visual loss during & following exposure to high intensity light flash; may last a few seconds to several minutes; and
- Afterimage: persisting sensation or image after stimulus removed.

An FAA study of flight crews in simulators exposed to various levels of laser radiation found that exposure to ≥0.5 µW/cm² causes visual impairment (FAA, 2004). Landing approach is the most critical time, and in fact distractions during this crucial period are limited by law (49CFR121.542, 125.311 &135.100). To prevent distractions associated with pilot laser exposure, the FAA's Order 7400.2 (Part 6 Chapter 29 "Outdoor Laser Operations") long ago established maximum allowable irradiance levels (flight safe exposure limits) in the area around airports, as follows:

- Laser Free Zone – 2 nautical miles (3.7 km) from runway centerline in all directions, plus additional 3 NM along flight path, to 2,000 ft; 50 nW/cm² (distraction)
- Critical Flight Zone – 10 NM (18.5 km) from airport center point; 5 µW/cm² (glare)
- Sensitive Flight Zone – (distance established on case by case basis) 100 µW/cm² (level for significant flash blindness & afterimage)
- Normal Flight Zone – 2.5 mW/cm² (exposure <MPE)

The table below indicates the approximate range within which a typical 5 mW red (~680 nm) diode laser pointer (~1 mrad divergence) will exceed the specified FAA exposure limits [based on ANSI Z136.1-2014 NOHD Eq B.51].

Approximate Laser Pointer Hazard Distance *D* (neglecting atmospheric attenuation)

Exposure Limit	*D* (m)
MPE (2.5 mW/cm²)	~16
SFZ (100 µW/cm²)	~80
CFZ (5 µW/cm²)	~356
LFZ (50 nW/cm²)	~3560

Operators of any laser must ensure that the beam is not directed into navigable airspace.

APPENDIX F

APPENDIX F

PROTECTIVE EYEWEAR FOR ULTRASHORT PULSED LASERS

Executive Summary

Researchers (e.g. Koschinski et al, 1998) some years ago observed induced transmittance in protective filter materials upon exposure to very high irradiances from ns, ps and fs pulsed lasers. This temporary loss of filter material attenuation can negate the protective capability of eyewear and thereby place laser users at risk of injury due to excessive laser radiation exposure. In response, the European Laser Protective Eyewear Standard EN207 has established additional eyewear testing and marking protocols to address this potential hazard. This Standard adds a pulse duration rating to the previously-established "L" attenuation number (which corresponds to the OD of the eyewear) and wavelength, as follows:

- D: rated for continuous wave lasers
- I: rated for "long pulse" lasers (>100 ns)
- R: rated for Q-switched lasers (1 ns to 100 ns)
- M: rated for ps and fs lasers (< 1 ns)

M-rated eyewear recently became commercially available. In addition to meeting the wavelength and OD ("L number") requirements specified by ECU Laser Safety, provision and use of "M-rated" eyewear should be mandated for all laboratories using unenclosed class 3b or 4 ps and fs pulsed laser systems.

Technical Basis

Koschinski et al (1998) reported dramatic decreases in the attenuation provided by some glass and polycarbonate laser protective eyewear filter materials exposed to very high irradiances, although the filter material appeared physically undamaged. Increased transmittance was observed for polycarbonate material exposed to irradiances in excess of $4x10^9$ W/cm² from a 1064 nm Q-switched (~15 ns pulse duration) Nd:YAG laser. The filter material's OD dropped by over six orders of magnitude as the irradiance was increased from $4x10^9$ W/cm² to $4x10^{11}$ W/cm², with ablation of filter material beginning around 10^{12} W/cm². Similarly the transmittance of semi- conductor doped glass filter material increased upon exposures to 800 nm 250 fs pulse Ti:Sapphire irradiances in excess of 10^{11} W/cm². The OD dropped by five orders of magnitude as the irradiance increased to 10^{12} W/cm². The authors propose an "absorption center" model that accurately predicts this increased transmittance as a function of irradiance for the materials tested.

Several other researchers have confirmed and extended these findings to other wavelengths and filter materials. For example, Schirmacher et al (2005) compared induced transmittance in 11 types of polycarbonate filter materials and three types of glass filters exposed to 50 ns and 200 fs pulses in the 70-800 nm range, finding temporary induced transmittance at irradiances below those that caused any visible damage to the eyewear. These effects are real and have serious implications for users of ultra short pulsed laser systems.

Although US laser safety standards have been slow to react, the European laser safety community has responded to this issue by specifying improved testing and marking requirements for laser protective eyewear. The European Laser Protective Eyewear Standard EN207 adds a "D", "I", "R" or "M" pulse duration rating to the previously-established "L" attenuation number (which corresponds to the OD of the eyewear) and wavelength, as noted in the section above.

References

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