Northwestern University

Office for Research Safety

Laser Safety Handbook

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Contents

1.0 Introduction

Lasers are an integral part of the research environment at Northwestern University. Lasers are tremendous tools that allow scientists, engineers and medical practitioners to perform unique experiments and to explore unique applications. If improperly used or controlled, however, laser radiation can cause significant injury to the eye and skin.

To help control the potential for overexposure, Northwestern University has adopted laser safety policies and procedures that follow the requirements of Illinois Administrative Code Title 32 Part 315 Standards for Protection against Laser Radiation as well as programmatic recommendation in American National Standard for Safe Use of Lasers, ANSI Z136.1 (latest edition). A copy of the standard is available for review at the Office for Research Safety (ORS) on the Chicago and Evanston campuses.

Each Principal Investigator who uses a class 3B or 4 laser system is encouraged to obtain a copy of the ANSI standard to keep in the laboratory. One source for the standard is Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826.

2.0 Program Organization and Responsibilities

The University has established a Laser Safety Committee responsible for formulating policy related to the safe use of lasers. The Committee is also charged with monitoring the University's compliance with regard to federal and state regulations for the safe use of laser radiation. The Laser Safety Officer (LSO) is responsible for ensuring that the policies and guidelines established by the Committee are implemented. The LSO is also responsible for informing the Committee of any compliance issues at the University.

As the overall manager of the laser safety program, the LSO is responsible for monitoring laser safety practices and informing responsible persons of situations where recommended safety practices are not being followed. Monitoring is through the laser safety audit program in which the LSO performs periodic audits in all laser laboratories. The LSO is authorized to terminate any activity or process that presents an immediate danger to life or health.

The LSO provides basic laser safety awareness training and maintains training resources and some supplies (signs, labels, etc.) to assist laser owners and operators. The LSO also maintains copies of current Standards and regulations, which may be reviewed by any interested individual.

It is the policy of Northwestern University that the Principal Investigator (PI), or faculty member in charge of a laboratory, is responsible for safety associated with laser use in his or her area.

For class 3B and 4 lasers and laser systems, this responsibility includes, but is not limited to:

- developing written operating, safety and emergency procedures (see Appendix A),
- performing a hazard evaluation in each laboratory,
- training operators in operating, safety and emergency procedures (see Section 5.0),
- procuring laser eye protection appropriate for the wavelength of the laser radiation and requiring its use (see Section 6.0),
- ensuring that shared laser eye protection is properly maintained and stored,
- proper posting of signs and warnings,
- registering each new laser system with ORS, and
- notifying ORS when a laser system is permanently taken out of service.

Each laser operator shall follow the standard operating procedure for that specific laser. Also, he or she must inform the PI of any departure from the established procedure including any exposure incident involving an injury from direct or reflected laser radiation. The operator and PI share responsibility for ensuring that required training is performed annually.

3.0 Laser Certification and Classification

Lasers must be certified to the Federal Laser Product Performance Standard (FLPPS; 21 CFR 1040.10 and 1040.11), which is administered by the Center for Devices and Radiological Health (CDRH), a bureau within the U.S. Food and Drug Administration. . The FLPPS requires that laser product manufacturers and modifiers of laser products must certify that their product conforms to the requirements of the FLPPS. The first step in this process is classification of the lasers, because the certification requirements are, to a large extent, class dependent. There are four fundamental laser classes which are explained in Appendix B. Certified laser products are easily identified by the certification label that must be affixed to the product. PIs and other individuals who purchase lasers and laser systems must ensure that the devices are certified per the requirements of the FLPPS.

It is possible that some home-made lasers or lasers systems may also have to comply with the requirements of the FLPPS. This can occur if the home-made laser system is transferred and is no longer used by the individual(s) who designed and constructed the laser or laser system.

Home-made lasers and laser systems that are used by the individual(s) who designed and constructed the device are not subject to the requirements of the FLPPS, but must be classified per the requirements of the ANSI Z136.1 standard so that appropriate control measures can be implemented.

4.0 Laser Registration

All class 3B and class 4 lasers and laser systems must be registered with ORS through NSIS, the Northwestern Safety Information System accessible on-line and managed by ORS. This includes laser systems operated by contractors at University locations, whether indoors or outdoors.

An investigator is only required to register Class 3B and 4 lasers with ORS. Laser systems containing embedded Class 3B or 4 lasers are exempt when the systems' lower classification is

established by the manufacturer according to CDRH requirements. If not otherwise specified by the manufacturer, the embedded system must be registered in NSIS.

Lasers are to be registered before being placed in service so the LSO can verify that the system is operating within University and State requirements for safe use. On behalf of the University, ORS must register each system with the Illinois Emergency Management Agency (IEMA). Therefore, when new lasers are acquired and when old lasers are taken out of service or relocated, ORS must be notified promptly. Even when lasers are on loan and/or borrowed, ORS must be notified promptly.

5.0 Operator Training and Registration

Before operating a Class 3B or 4 laser or laser system, a laser operator must meet the registration and training requirements outlined below and operational qualifications established by the PI.

The operator candidate must complete the Laser Operator Registration in NSIS and complete the Basic Laser Safety training in Learn@Northwestern with a score of 80% or better.

Before starting to operate any laser sources, the candidate must wait for the electronic authorization sent by NSIS. The authorization is sent following the PI's electronic signature on the Laser Operator Registration request and the LSO approval.

By signing the form, the PI is certifying that the individual has completed the ORS training and will be trained on all Lab-specific operating and emergency procedures before being allowed to operate class 3B and 4 lasers and laser systems. Remember that only **trained** and **registered** laboratory workers are allowed to operate class 3B and class 4 lasers and laser systems.

Each laser operator is allowed to use laser sources in multiple facilities within Northwestern University (for example, in Core and Shared Facilities). After the successful completion of the Basic Laser Safety training, the candidate may submit multiple Laser Operator Registration requests in NSIS, one per facility. An electronic authorization shall be needed for each facility selected.

The basic safety training for new operators is only one part of the training requirement. In addition, operators must be provided with site-specific safety training regarding the procedures and equipment used in the laser laboratory. The site-specific training is part of the standard operating procedure for a particular lab. The PI is responsible for ensuring that all who work in areas where Class 3B or 4 lasers or laser systems are used are sufficiently trained to allow understanding of the risks from laser radiation.

Workers who operate lasers must also receive written safety instructions (standard operating procedures, see Appendix A), so that they can properly utilize equipment and follow all safety procedures. The PI or laboratory supervisor must retain records of lab- or equipment-specific operator training for review by the LSO during laser safety audits and by the IEMA inspectors during periodic inspections.

Refresher safety training must be provided annually. The individual providing the lab-specific training must be designated by the PI and have knowledge adequate and appropriate to the subject matter being presented. This would include, but not be limited to: knowledge of lasers, laser safety concepts, laser safety standards and each laser system used in the lab.

On-the-job training for Class 3B and Class 4 laser operators must include a thorough review of hazards associated with each laser that a person may operate. The training must also include the protective methods employed by the laboratory. At a minimum, the training must include basic instruction on the laser characteristics, laser hazards, control measures for the beam and non-beam hazards, use of laser eye protection, and emergency response procedures.

During the laser safety audits, the LSO will assess the effectiveness of training provided by the PI. Each operator must demonstrate competence with operating, safety and emergency procedures.

6.0 Control Measures

Laser Eye Protection (LEP) - Each PI must ensure that appropriate eye protection is provided to individuals working with Class 3B and 4 lasers and laser systems, and must ensure that protection is worn. LEP is specific to the types of laser radiation in the lab and must be worn whenever working with Class 3B or 4 lasers with open beams or when reflections can occur.

In general, LEP may be selected on the basis of protection against reflections, and may fail if struck by the direct beam. Failure may occur due to thermal effects (plastics melt and glasses fracture) or due to saturable absorption of absorbers exposed to short pulses (absorption decreases with increasing intensity of exposure) where there is no observable damage. Failure of plastic lenses may occur in a few seconds of direct exposure to tens of watts of radiant power, or may occur with glass lenses while cooling subsequent to being heated by the beam. LEP should be viewed as providing minimal protection for the direct laser beam and maximal protection for the scattered laser beam.

Factors important in the selection of LEP include, but are not limited to, wavelength compatibility, attenuation at that wavelength or wavelengths (optical density), visible light transmission, damage threshold and fit. Special care and attention must be paid to LEP used with lasers and laser systems that are capable of emitting multiple wavelengths to ensure that the LEP has the necessary optical density at all wavelengths. Additionally, it must be verified prior to use of LEP for short and ultra-short pulsed lasers that the LEP has been tested by the manufacturer to ensure adequate performance.

LEP that has been damaged or that has a significantly scratched lens must not be used and should be discarded. LEP should be cleaned routinely using manufacturer's recommendations or using a mild soap and warm water. Glass cleaners such as Windex should not be used to clean LEP.

Special attention must be paid to LEP that is shared between labs. This includes storage, ease in locating, cleanliness and routine inspection.

Entryway controls – Suitable entryway controls are required for all Class 4 and recommended for all Class 3B laser laboratories. The principal method in use at Northwestern University is called procedural entryway controls. This includes an ANSI-type warning sign and a visual warning device (e.g., a single red light bulb, a lighted warning sign, etc.) located outside of and adjacent to the entryway. Within the entrance, there must be a light-blocking barrier that will not ignite or be otherwise immediately damaged when struck by the direct beam. The barrier must be positioned such that it blocks the direct beam, reflections and other stray beams, providing protection to individuals entering the lab and individuals outside of the lab. LEP should be stored, donned and removed in this safe entryway zone.

7.0 Operational Requirements

The PI must provide written operating and safety procedures to personnel who operate lasers. These procedures must include all restrictions required for the safe operation of each laser. They may incorporate sections of the manufacturer's technical manuals if those documents are available to the operator. For Class 4 laser systems, written alignment procedures must be available and used by anyone who aligns the optics (see Appendix C for safe alignment guidelines). Personnel shall be instructed in and be able to demonstrate competence with the PI's operating and safety procedures before operating lasers

In each laser use location, a hazard evaluation must be performed when a new system is commissioned to determine where users may exceed the maximum permissible exposure (MPE). The numerical hazard evaluation will be performed by the LSO and must be used to demarcate the laser controlled area. The hazard evaluation, along with the guidance in ANSI Z136.1, will determine where and what warning signs are to be posted. For systems already in use without a hazard evaluation having been performed, the evaluation shall be completed as soon as practicable. The PI is responsible for the applied hazard evaluation of the laser installation and proper posting of laser warning signs. Contact the LSO for guidance on hazard evaluation and to perform the numerical hazard evaluation.

For laser systems with open beam paths, the hazard evaluation must include the potential hazards that may be encountered from reflective surfaces. Reflective surfaces shall be excluded from the beam path at all points where the laser radiation exceeds the MPE, if practical. No individual may be exposed to levels of laser radiation higher than the MPE. Measurements and calculations performed to determine MPE limits shall be made in a manner consistent with the criteria contained in ANSI Z136.1.

No laser may be operated or made ready for operation until the area along all points of the beam path where the laser radiation will exceed the MPE is clear of individuals, unless the individuals are wearing appropriate protective devices. In crowded laboratories this may require the use of curtains designed to block laser radiation. Properly evaluated and installed laser-rated barrier curtains are satisfactory for use at the University. If curtains or enclosures that have been tested and labeled by the manufacturer with damage threshold and test time are not used, the PI is responsible for ensuring that adequate tests are performed to ensure that the laser radiation is suitably attenuated and that the barrier does not ignite or rapidly decompose when struck by reasonably foreseeable levels of radiant power or energy.

Alignment of laser optical systems shall be performed in a manner that ensures that no one is exposed to laser radiation above the MPE. A controlled area must be established when exposure to laser radiation in excess of the MPE limit is possible. Access to the controlled area shall be only by permission of an experienced trained operator.

The laser system shall be operated at all times under the direct supervision or control of an experienced, trained operator who maintains visual surveillance of conditions for safe use and can terminate laser emission in the event of any unsafe condition of use. Unattended use of the laser system can be permitted only when the PI has implemented control measures that provide adequate protection and has provided laser safety training to those who may enter the laser controlled area during times of unattended use. Engineered control measures are always preferred over procedural controls.

8.0 Warning Signs and Labels

A controlled area, in which access is restricted for the purpose of protection from laser radiation, must be conspicuously posted with laser warning signs as prescribed for the class of the laser in ASNI Z136.1. Because the warning sign must have certain prescribed wording at specific locations depending on the class and type of laser, these signs should be obtained from ORS.

Additional labeling requirements may apply for user-constructed enclosures as well as beam guides such as optical fiber and tubes. Check with the ORS for guidance on these requirements.

9.0 What to do in Case of Accidental Exposure

The PI must notify the LSO immediately as discussed in Section 10. If the laser is a retinal hazard (400-1400 nm), even perceived ocular exposure must be reported to ORS. The PI must ensure that the appropriate medical treatment is provided per the requirements of the ORS Emergency Procedures for the Evanston and Chicago campuses.

10.0 Notifications and Reports

Each laser investigator must notify ORS immediately by telephone at 1-5581 of any incident involving exposure to laser radiation that has caused injury to an individual in the course of use, handling, operation, manufacture or discharge of a laser system.

The State requires registrants to notify them immediately if the exposure is at least 100 times the MPE or if there is vision loss. The State requires notification within 24 hours if the exposure is 5 times the MPE or there are second or third degree skin burns. Hence, it is critical that the PI contact ORS immediately so that this requirement is satisfied. A written report must be filed with the State within 30 days of the incident.

After the initial notification, the PI must prepare a written report of the incident and submit it to

the LSO within two weeks after the incident. Use the ORS Incident Report form for the written report. The report must include:

- the full name of each exposed individual,
- an estimate of each individual's exposure (in multiples of MPE), if possible,
- the levels of laser radiation involved in radiant energy (J/cm^2) or radiant power (W/cm^2),
- the cause of the exposure,
- a description of any injuries, and
- corrective actions to prevent a recurrence.

11.0 Enforcement Policy

The policies set forth in this Handbook are intended to ensure that Northwestern University is in compliance with all regulatory requirements regarding the safe use of lasers. Failure to comply with these policies could jeopardize all research involving laser radiation. The State of Illinois, through the Illinois Emergency Management Agency, is authorized to assess civil penalties for violations of their regulations amounting to $10,000 per violation. Each day of a continuing violation is considered a new violation.

Any non-compliance identified by the LSO must be corrected promptly. Failure to correct a violation in a timely manner is considered a willful disregard for University safety policies and, according to the Safety Enforcement Policy of the Office for Research, may result in the loss of laboratory privileges.

Appendix A

Sample Procedures

Sample Procedure #1

Laser Safety

Purpose: To define the area in which control measures shall be applied and to describe the control measures necessary in order to maintain a safe environment for use of the laser system.

Policy: Class 3B and Class 4 lasers shall be operated in areas where traffic flow and compliance with all safety procedures can be monitored. No individual's exposure may exceed the Maximum Permissible Exposure (MPE) for the wavelength and power of the beam.

Procedure:

1. Appropriate warning signs shall be posted at eye level on all doors that access a room where a laser is to be operated. These signs shall state all required information, along with an indicator such as a lighted sign to show when a laser is being operated.

2. Laser eye protection labeled with the appropriate wavelength and optical density shall be available at the entry where each door sign is posted.

3. Glass windows shall be covered with shades or filters of appropriate optical density whenever a laser system is operational.

4. All safety procedures shall be followed during service, maintenance and demonstrations.

5. No one shall be allowed into a laser room unless properly authorized and protected.

6. Laser keys shall be kept in a secured area and signed out only by those authorized to do so.

7. During an emergency, STOP and ask for help if you are not sure how to proceed. Above all, do no harm.

Sample Procedure #2

Ocular Safety

Purpose: To prevent ocular injuries to personnel working with Class 3B and Class 4 lasers.

Policy: Within the controlled area, all personnel shall adhere to appropriate eye protection procedures during all laser applications.

NOTE: Under some conditions, the controlled area may include the entire room in which the laser procedure is performed. Under those conditions, the ocular safety procedures listed below apply to the entire room. In health care facilities, ocular safety procedures shall also apply to the patient receiving laser treatment.

All personnel involved in maintenance and demonstrations of laser systems shall follow all ocular safety procedures whenever a laser is in operation in the facility.

Procedure:

1. Appropriate laser eye protection shall be worn by everyone in the controlled area while the laser is in operation. Appropriate laser eye protection consists of glasses or goggles of sufficient optical density to prevent ocular damage at the laser wavelength in use. An exception to this may occur when the operator is looking through an attached microscope with a lens, where the lens or a filter has the appropriate optical density for the laser in use.

2. Prior to use, the operator and ancillary personnel shall be responsible for selecting and examining laser eye protection for comfort, proper fit, and presence of labels describing both wavelength and proper optical density.

3. If laser eye protection is damaged, it shall not be worn and a report shall be made to the Laser Safety Officer.

4. Contact lenses are not acceptable as protective eyewear. Prescription lens wearers shall use appropriate laser eye protection.

5. All laser eye protection shall have side shields to protect from peripheral injury and impact.

6. Any articulated arm that is not shuttered shall be capped when not connected to the hand piece or the operating microscope.

7. The laser system shall be placed in standby mode when delivery optics are moved away from the target.

8. In health care facilities, patients shall be fitted with appropriately labeled eyewear, or have their eyes covered with wet cloth pads or towels. Metal, hard plastic or similar materials shall be placed on the patient's face or eyes only when indicated.

Appendix B

Laser Classification

Classification is a system used to describe the potential hazard posed by a laser, laser system, or laser product. There are three organizations that publish classification systems: the Center for Devices and Radiological Health (CDRH), the International Electrotechnical Commission (IEC), and the Accredited Standard Committee Z136 (ANSI Z136.1). These systems are not identical and are included in the tables below.

Table B-1 – IEC / ANSI Classification System[A]

Class	Wavelengths	Description
1	180 nm – 1 mm	No known hazards for this class; exempt from control measures
1M	302.5 – 4000 nm (IEC)[B] 302- 2800 nm (ANSI)	"M" stands for magnification; Class 1 unless the beam is viewed with collecting optics (e.g., binoculars, telescope, microscope)
1C[C]	Unspecified	Used for laser products intended to be in contact with human skin or internal body tissues for medical, diagnostic, therapeutic, or cosmetic purposes.
2	400 – 700 nm	Safe exposure for visible wavelengths for the human aversion response time, 0.25 s.
2M	400 – 700 nm	Class 2 unless viewed with collecting optics.
3R	180 nm – 1 mm	"R" stands for reduced requirements; Exposure to the direct beam will produce an overexposure but the probability of injury is relatively low.
3B	180 nm – 1mm	Hazardous for direct ocular exposure; low probability of injury for diffuse reflection; may produce minor skin injuries and may ignite certain materials (e.g., explosive dusts)
4	180 nm – 1mm	Hazardous to the eye and skin for direct exposure and to the eye for exposure to diffuse reflection; fire hazards as well.

[A] – Based on IEC 60825-1-2014 and ANSI Z136.1-2014.
[B] - The difference on the boundary in the infrared spectral region is because the IEC recognizes special optical materials used in infrared astronomy while the ANSI standard does not because the use of such materials is not common.
[C] – This class is only in the IEC standard and is new with the 2014 standard.

Table B-2 – CDRH Classification System

Class	Wavelengths	Description
I	180 nm – 1 mm	No known hazards for this class; exempt from control measures
IIA	400 – 710 nm	Safe for exposure durations up to 1000 seconds
II	400 – 710 nm	Safe exposure for visible wavelengths for the human aversion response time, 0.25 s.
IIIa	400 – 710 nm	Low irradiance Class IIIa lasers are a chronic exposure hazard while high irradiance Class IIIa lasers are an acute exposure hazard.
IIIb	180 nm – 1 mm	Acute hazard to the skin and eyes from direct beam exposure.
IV	180 nm – 1 mm	Acute hazard to the skin and eyes from both the direct beam and scattered radiation.

Laser product manufacturers who sell laser products in the United States must conform to the requirements of the CDRH. This includes classification of the laser product. Beginning in 2000,

the CDRH allowed laser product manufacturers to use most provisions of the IEC 60825-1 standard to meet U.S. requirements, including the classification system. This was reaffirmed by the CDRH with the publication of the revised IEC standard in 2007. However, the CDRH has not extended this to the 2014 IEC standard. Hence, it is possible that laser products may be classified by either or sometimes both classification systems.

With respect to interpretation of the hazard class, it is important to note that there are three activities performed with lasers: operation, maintenance and service. Lasers are always classified for operation, which is the full range of intended tasks of the device.

In research and development, it is common to have open-beam applications with access to high hazard class number lasers, e.g., 3B and 4. In some applications, however, a high class number laser is embedded within a protective housing that decreases the accessible radiant power to Class 1 levels. In this case the laser device will be classified Class 1, indicating that it is safe to operate, but may pose hazards to individuals who maintain or service the laser system.

Appendix C

Safe Alignment Practices

The following information includes common, safety guidelines for beam alignments and is not an alignment procedure.

Beam alignment is the most hazardous task that is performed with lasers and laser systems. Estimates are that approximately two-thirds of laser laboratory accidents occur during beam alignment. A number of these have occurred when the operator is not wearing laser eye protection. Hence, the fundamental approach is laser safety is to turn down the output power or energy to safe levels that do not require the use of laser eye protection. If this is not possible, then the approach is to use laser eye protection with sufficient optical density to momentarily block a stray or errant beam, and use some device to indirectly view the beam, as discussed below.

1. Ensure that there is a current written alignment procedure for the laser or laser system to be aligned. Note, that the ORS requires a written alignment procedure for all Class 4 lasers and laser systems.
2. Reduce the output power or energy to the lowest level practical.
3. Use laser eye protection and insure that it has the required level of optical density.
4. If the alignment is performed on a laser system that emits multiple wavelengths or is aligned at more than one set of output conditions (e.g., low and high power) and these factors require the use of more than one pair of laser eye protection, ensure that there is a clear understanding of when eyewear must be changed.
5. Use devices to indirectly view the location of the beam. Such devices often shift an invisible wavelength into the visible part of the spectrum, or shift a visible wavelength to another part of the visible spectrum. This allows the user to wear relatively high optical density eyewear, and still see the location of the beam. A partial list of these devices follows.
    a. Ultraviolet radiation – UV viewing scopes; business cards/3x5 paper cards; yellow/orange highlighter on paper cards; yellow/orange Post-It® notes on paper cards; phosphor-coated viewing cards; thermal paper; View-It®
    b. Visible wavelengths – Business cards/3x5 paper cards; construction paper (complimentary color of beam); phosphor-coated viewing cards; cameras with false color or B&W; night-viewing goggles; thermal paper; fluorescing alignment disks
    c. Near infrared (IR-A) – IR viewing scopes; digital cameras (e.g., those with unfiltered CCD detectors); ceramic disks and other fluorescing alignment disks; View-It®; liquid crystal paper; thermal paper; night-viewing goggles
    d. Far infrared (IR-B & -C) – Fire bricks (can emit silicates); thermal image plates; thermal paper; mid-IR (MIR) detector card; liquid crystal paper, certain thermal cameras
6. Ensure the area is clean and uncluttered (housekeeping!).
7. Use tools that have matte-black finishes and non-rollable handles, when possible, and keep tools on a near-by cart.
8. Review the workplace and personnel for devices that can produce specular reflections including intentional (e.g., optical mirrors, Brewster windows, prisms, harmonic generating crystals, periscopes) and opportunistic (e.g., jewelry, articles in shirt pockets, tools, glassware, films, plastic baggies, measurement detector, solar cell material) mirrors. (Note that many of the items just mentioned here have been involved in documented laser injuries.)
9. Use table curbs, beam blocks, screens, and other blackout materials as well as beam dumps to control the beam and minimize the potential for errant or stray beams. If the beam must be

transmitted away from its normal location (e.g., a far-field alignment), cordon off the area, post warning signs, and communicate the unique hazard to people who may routinely access this area.

10. If low-optical density, alignment eyewear was used during most or all of the alignment, be sure to replace these with laser eye protection for operational levels of power/energy when returning the laser to normal output conditions.
11. If multiple individuals are involved in the alignment, ensure that individual alignment tasks are clearly understood prior to beginning the alignment and that communication is maintained throughout the alignment. This is especially important if the beam is transmitted from the laser head into a different location (e.g., room-to-room).