National Institutes of Health

Laser Safety Program

2019

Authored by the Laser Safety Officer (LSO) and Deputy LSO with additional input, review, and the concurrence of the Laser Safety Advisory Committee (LSAC).

CONTENTS

ACRONYMS

DOHS	Division of Occupational Health and Safety
DLSO	Deputy Laser Safety Officer
LCA	Laser Controlled Area
LSAC	Laser Safety Advisory Committee
LSO	Laser Safety Officer
NIH	National Institutes of Health
OMS	Occupational Medical Service
ORS	Office of Research Services
PI	Principal Investigator
SOP	Standard Operating Procedure
TAB	Technical Assistance Branch

INTRODUCTION

Over time, the applications for lasers in biomedical research and in clinical treatments have grown exponentially. This spectrum is on display at NIH, with lasers in use from optical imaging, where super-resolution microscopy can pinpoint single molecules, to laser therapies of the eye, where laser treatments may help reduce the probability of vision loss in some patients. As the number of novel techniques involving lasers grows, so too does the number of personnel who work directly with or around lasers; the majority of institutes at NIH use lasers. Full realization of the benefits of lasers necessitates their safe use by everyone.

I. PURPOSE

The Laser Safety Program (LSP) has been developed to provide guidance and oversight for the safe use of lasers at NIH.

II. SCOPE

The LSP applies to all NIH employees, contractors and students working directly with or around Class 3B and Class 4 lasers and laser systems at official NIH facilities, hereinafter referred to as lasers.

III. RESPONSIBILITIES

Laser Safety Advisory Committee (LSAC):

a) Develop and manage the LSP;
b) Verify safety practices and control methods by personnel using lasers;
c) Investigate all incidents and accidents involving the use of lasers in NIH facilities; and
d) Maintain an accurate inventory of lasers.

Laser Safety Officer (LSO):

a) Assist with laser hazard evaluation and classification;
b) Provide and/or facilitate laser safety training;
c) Determine required safety practices and control measures critical for the implementation of a laser laboratory as specified by ANSI Z136.1 – 2014 *American National Standard for Safe Use of Lasers* and compliance with applicable laws and regulations;
d) Consult on the purchase of necessary laser safety materials (signs, labels, safety eyewear, etc.);
e) Monitor and enforce program requirements; and
f) Conduct periodic reviews of the LSP.

Deputy Laser Safety Officer (DLSO):

a) Assist the LSO with the performance of his or her duties; and
b) As deputy, will carry out the duties of the LSO when authorized.

Supervisors/Principal Investigators (PIs):

a) Register new lasers online at https://go.usa.gov/xReGv (accessible to users connected to the NIH network);
b) Identify all laser hazards and implement all appropriate hazard controls. Correct any unsafe or non-compliant conditions in the laboratory;
c) Identify all personnel who may operate, maintain, or work in close proximity to lasers and ensure training is completed at intervals specified by the LSP;
d) Monitor all authorized personnel for compliance with the LSP;
e) Ensure maintenance is conducted at proper intervals to keep lasers in safe working order;
f) Maintain a copy of this written program in the workplace; and
g) Complete a Standard Operating Procedure (SOP) for each laser and location (lasers which share substantially similar procedures and/or locations can be combined into one SOP). SOPs shall be kept in locations so that personnel have access before entry into a Laser Controlled Area (LCA).

Laser Users:

a) Know all hazards and associated procedures for the safe use of lasers in the work area;
b) Complete required training(s) as specified by a supervisor/PI, LSO, or the LSAC;
c) Comply with the LSP and use good safety practices;
d) Use all personal protective equipment as specified in prescribed training or required by a supervisor/PI, LSO, or the LSAC; and
e) Immediately notify a supervisor/PI, LSO, or the LSAC of any hazards encountered.

IV. DEFINITIONS

Accessible emission limit (AEL): The maximum accessible emission level permitted within a particular laser hazard class.

Authorized personnel: Any individual approved to work with lasers by completion of required training(s).

Aversion response: An involuntary movement of either the head and/or eye to avoid exposure to a visible laser beam.

Blink reflex: The involuntary closing and opening of the eye(s) as a result of external stimulation.

Collecting optics: Lenses or optical instruments that use magnification to increase the power of a laser beam.

Continuous wave (CW): A laser beam with an output greater than 0.25 seconds.

Deputy Laser Safety Officer (DLSO): One who assists the LSO in the performance of his/her duties to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards. The LSO can delegate authority to the DLSO.

Diffuse reflection: The reflecting of a laser beam in many directions by a surface.

Divergence: The splitting of a laser beam so that the beam diameter increases with distance traveled.

Embedded laser: A laser of a specific class that is reduced to a lower class due to the mechanisms and devices (engineering controls) that remove potential for contact.

Fail-safe interlock: An engineering control 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.

Infrared: In this standard, the region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (about 0.7 m) and the shortest microwaves (about 1 mm).

Intrabeam viewing: The viewing condition whereby the eye is exposed to all or part of a laser beam.

Laser Controlled Area (LCA): A laser use area where the occupancy and activity of those within is controlled and supervised. This area may be defined by walls, barriers, or other means. Within this area, potentially hazardous beam exposure is possible.

Laser Safety Advisory Committee (LSAC): A group of individual members of the NIH community who have an inherent interest in laser safety due to their professional role, such as: using lasers in research, laboratory management, and/or safety responsibility. The group shall be composed of members from all NIH ICs operating lasers and will work together with the LSO and DLSO to shape and execute the LSP.

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

Maximum permissible exposure (MPE): The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

Nominal hazard zone (NHZ): The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

Non-beam hazard: A class of hazards that result from factors other than direct human exposure to a laser beam.

Protective housing: An enclosure that surrounds the laser or laser system and prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals, and may enclose associated optics and a workstation.

Pulsed laser: A laser which delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse is less than 0.25 s.

Q-switch: is a technique by which a laser can be made to produce a pulsed output beam. The technique allows the production of light pulses with extremely high (gigawatt) peak power, much higher than would be produced by the same laser if it were operating in a continuous wave (constant output) mode.

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

Safety latch: A device intended to provide a measure of safety that must physically be removed to allow exposure to a hazard.

Specular reflection: A mirror-like reflection.

Thermal effect: Temperature elevation caused by exposure to a laser beam.

Threshold limit (TL): The term is applied to laser protective eyewear filters, protective windows, and barriers. The TL is an expression of the "resistance factor" for beam penetration of a laser protective device. This is generally related by the Threshold Limit (TL) of the protective device, expressed in $W \cdot cm^{-2}$ or $J \cdot cm^{-2}$. It is the maximum average irradiance or radiant exposure at a given beam diameter for which a laser protective device provides adequate beam resistance. Thus, laser exposures delivered on the protective device at or below the TL will limit beam penetration to levels at or below the applicable MPE.

Ultraviolet radiation: In this standard, electromagnetic radiation with wavelengths between 180 and 400 nm (shorter than those of visible radiation).

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

V. PROGRAM

Laser Safety Program

The NIH LSP is administered by the Division of Occupational Health and Safety (DOHS) through the LSO and DLSO, in collaboration with the LSAC.

The LSP was developed to conform to *ANSI Z136.1 – 2014, the American National Standard for Safe Use of Lasers* as well as *ANSI Z136.8 – 2012, the American National Standard for Safe Use of Lasers in Research, Development, or Testing.* The LSP is supplemented with guidelines from other sources and is structured to ensure compliance with all applicable regulations (see references in section VI).

The control measures outlined herein shall not serve to restrict or limit in any way the use of laser radiation of any type which may be intentionally administered to an individual for diagnostic, therapeutic, or medical research purposes by or under the direction of qualified professionals engaged in health care. However, those administering and assisting in the administering of the laser radiation, as well as the patient, where applicable, shall be protected by the control measures as outlined herein and, as applicable, by the requirements as specified in *ANSI Z136.3 – 2011, the American National Standard for Laser Safety in Health Care.*

The LSP is also issued as NIH Policy Manual chapter 3036 – NIH Laser Safety Program. The manual chapter can be viewed online at https://policymanual.nih.gov/3036.

Laser Classification

Class 1

1. Understood to be a non-hazardous source during usage intended by manufacturer.
2. Not intended to be monitored by this LSP:
    a. No surveillance or audits; and
    b. No control measures for usage.

Class 1M

1. A Class 1 system that may become hazardous if viewed with an optical instrument.
2. Not intended to be monitored by this LSP:
    a. No surveillance or audits; and
    b. Control measures – ensure no optically aided viewing.

Class 2

1. A laser with power less than or equal to 1 milliwatt.
2. A laser within the visual spectrum (400 nanometers – 700 nanometers).
3. Not intended to be monitored by this LSP:
    a. No surveillance or audits; and

b. Control measures – understood that the natural aversion response is sufficient to protect the eyes from damage.

Class 2M

1. A Class 2 system that may become hazardous if viewed with an optical instrument.
2. Not intended to be monitored by this LSP:
    a. No surveillance or audits; and
    b. Control measures – ensure no optically aided viewing.

Class 3R

1. A laser with power less than 5 milliwatts.
2. May be dangerous from both direct viewing and specular reflections if natural aversion responses are not functioning properly.
3. Not intended to be monitored by this LSP:
    a. No surveillance or audits; and
    b. Control measures – ensure no optically aided viewing, avoid direct viewing of the beam or its specular reflection, and avoid unattended operation where the beam is directed into a location where it can be directly viewed by the public or personnel uninformed about the hazards.

Class 3B

1. A laser with power less than or equal to 0.5 watts.
2. May be dangerous from both direct viewing and specular reflections.
3. Not a fire hazard.
4. **Intended** to be monitored by this LSP:
    a. Minimum of an annual survey for compliance to the LSP; and
    b. Control measures – See section **V: Laser Hazard Control Measures** for more detailed information regarding specific control measures.

Class 4

1. A laser with power that exceeds a Class 3B.
2. Hazardous to both eyes and skin when beam makes direct contact or from specular reflection; may pose a hazard from diffuse reflection.
3. May be a fire hazard.
4. **Intended** to be monitored by this LSP:
    a. Minimum of an annual survey for compliance to the LSP; and
    b. Control measures – See section **V: Laser Hazard Control Measures** for more detailed information regarding specific control measures.

Laser Acquisition and Transfer

It is the sole responsibility of the PI to document and report to the LSO the purchase of a Class 3B or Class 4 laser or laser system. The PI may choose to delegate this function, however, the ultimate responsibility for success or failure of the reporting remains with the PI. PIs (or their designee) can register new lasers online at https://go.usa.gov/xReGv (accessible to users connected to the NIH network).

Laser Hazard Control Measures

Controls for Class 3B and Class 4 Lasers:

1. **Posting** – At minimum, the entryway of a laser safety area shall be posted for the class of laser, laser power, and laser wavelength(s). Additionally, it may be necessary to post inside the laser safety area to further define the hazard.

2. **Authorization** – Only individuals who have been trained by a designated official may utilize Class 3B and Class 4 lasers. No other individuals shall have the means to utilize the lasers.

3. **Beam trajectory and control** – The laser may only be utilized after the beam manner is well characterized and understood. The beam should be controlled to not be at either standing or sitting heights. Additionally, an appropriate beam stop shall be utilized to terminate the beam.

4. **Non-beam hazards** – All non-laser materials that have the potential to come into contact with the laser beam shall be analyzed to determine if any hazards are created upon contact over a period of time. When no written information is available to describe conditions created by contact, the responsible party should assume a hazardous product and ensure a proper means to eliminate the hazard. The most common means of controlling non-beam hazards is the use of local exhaust ventilation, essentially a mechanical means of purging an atmosphere through the use of controlled, directional air flow. Additional non-beam hazards are described in the next section.

5. **Personal Protective Equipment (PPE)** – All Class 3B and Class 4 laser usage areas shall have a written document providing the required PPE to be used while working with the laser. The most common PPE for use with lasers is protective eye wear. It is critical that eye wear be appropriate to the laser used. All PPE shall be inspected before use for conditions that would negate the effectiveness of the protective device.

6. **Containment** – All Class 3B and Class 4 laser(s) and laser system(s) should utilize a means of containment that fully encloses the beam path and any potential reflections of the beam from surfaces. Building materials utilized in a laser area(s)

should be analyzed for reflective potential, and when possible altered to decrease reflectance to as low a level as achievable. Windows to spaces outside of the laser area should be removed or covered to block transmission of the laser. Engineering controls like laser activation entry lights and key switches should be used at all times to ensure effective containment and control.

7. **Rapid Egress and Emergency Access** – All Class 4 laser area(s) shall have a controlled means of rapid egress and admittance for emergency conditions.

8. **Standard Operating Procedures (SOP)** – A standard operating procedural document shall be established for each laser laboratory and be made available to personnel before entry into an LCA (see appendix B). Submit SOPs to the LSO for review.

Non-Beam Hazards & Control Measures

A. **Electrical Hazards** – Many incidents and accidents related to laser(s) and laser system(s) stem not from the laser beam, but from user interaction with electrical components required for the laser to function. Most Class 3B and Class 4 lasers utilize high voltages and large capacitors which have a high potential for electrical accidents. Only highly trained users should be authorized by the PIs to complete work involving electrical components. Any work involving electrical components shall comply with the NIH Lockout/Tagout procedures and guidelines.

B. **Laser Dyes** – Dyes used as lasing mediums are often classified as toxic, carcinogenic and/or flammable. These chemicals shall be handled appropriately and safety data sheets (SDSs) for each shall be on file within the laser use area.

C. **Laser Generated Air Contaminants (LGAC)** – Contact between a laser beam and a material can cause specific, yet, sometimes unknown contaminants to be released into the atmosphere of the laser use area. Periodically this release of air contaminates may occur without noticeable signs, such as smoking of the material contacted. Proper room ventilation or local exhaust ventilation is critical in any laser use area and shall be evaluated before the installation of a Class 3B or Class 4 laser. The use of respiratory protection is not an accepted means of controlling the generated airborne hazard.

D. **UV and Visible-Radiation and Plasma Emissions** – Evaluations for the discharge of radiation, both visible and UV; and, plasma formation shall be completed before the use of a Class 3B or Class 4 laser. Identification of any of these conditions requires a review of the PPE used for skin protection to ensure adequate safety coverage. Additionally, laser and laser system components shall be periodically surveyed for damage from these conditions.

Laser Safety Training

All supervisors and users shall successfully complete the NIH Laser Safety training before using a Class 3B or Class 4 laser or laser system. Completion of an alternate training class shall be submitted to the LSAC for approval before laser usage may occur. Retraining is required biennially, after an incident or accident, and as required by the PI, LSO, DLSO, or LSAC.

Laser Safety Survey

A laser safety survey is completed annually for all Class 3B and Class 4 laser and laser systems. Safety surveys can be completed by the LSO, an appropriately trained Occupational Safety and Health Specialist, or a safety survey team involving personnel from the LSAC and the laser use area. The laser safety survey form is attached as appendix A. The laser safety self-reporting form, attached as appendix C, is an alternate survey method that can be used periodically and in lieu of the survey form. Deficiencies found will require a response by the PI or designee concerning modifications to make to resolve the issue. No usage of the laser(s) or laser system(s) should occur before the modifications are made unless the LSAC grants a written waiver to the PI.

Medical Surveillance and Laser Accidents

Individuals who believe that they require a medical evaluation concerning their use of laser(s) or laser system(s) shall make a request through their respective supervisor. All requests will be conducted by Occupational Medical Services (OMS). Standard annual medical evaluations will not be conducted for NIH laser users.

In the event of any accidents or incidents involving a Class 3B or Class 4 laser or laser system the user shall immediately notify their supervisor. The user shall undergo an immediate evaluation by OMS located on the sixth floor of building 10, Room 6C306. The phone number for OMS is (301) 496-4411.

VI. REFERENCES

ANSI Z136.1-2014, *American National Standard for Safe Use of Lasers*

ANSI Z136.3-2011, *Safe Use of Lasers in Health Care Facilities*

29 CFR 1910.132, *Personal protective equipment*

29 CFR 1910.133(a), *Eye and face protection*

STD 01-05-001, (*OSHA) Guidelines for Laser Safety and Hazard Assessment*

21 CFR 1040.10, *Laser Products*

21 CFR 1040.11, *Specific purpose laser product*

HHS Publication FDA 86-8260, *Compliance Guide for Laser Products*

VII. **APPENDICES**

Appendix A: Laser Safety Survey Form

Appendix B: Laser Safety General SOP

Appendix C: Program Evaluation and Improvement

National Institutes of Health
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NIH LASER SAFETY PROGRAM APPENDIX A: SURVEY FORM

ADMINISTRATIVE INFORMATION			
PI		Lab Manager	
IC		Campus/Bldg/Room	
SOP(s) Written?	YES NO	SOPs Available?	YES NO
LASER INFORMATION			
Manufacturer		Model	
Serial #		NIH Asset Tag #	
Medical Laser?	YES NO	Hazard Class	1 1M 2 2M 3R 3B 4
Notes:			
TECHNICAL SPECIFICATIONS			
Type		Wavelength(s) (nm)	
Power(s)		Pulsed	Energy (J): Length (s): Rate (Hz):
Equipment Grounded?		YES NO	
Alignment Done In-House?		YES NO	
If Yes, Additional Safety Procedures Established?		YES NO	
If Yes, Describe			
Notes:			
ENGINEERING AND ADMINISTRATIVE CONTROLS			
Warning Sign Visible?	YES NO	Warning System Type(s)	Audible Light Verbal
Key Control? (On/Off Switch)	YES NO (Required for Class 4)	Protective Housing?	YES NO
Complete Enclosure?	YES NO	Barriers, Curtains, Beam Stops, Etc.?	YES NO
Notes:			
PERSONAL PROTECTIVE EYEWEAR			
Manufacturer(s)		Model(s)	
OD @ λ			
CERTIFICATION			
Follow-Up Required?	YES NO	Surveyor	
Signature		Date	

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NIH LASER SAFETY PROGRAM APPENDIX B: GENERAL SOP

REMINDERS:

- *Lasers shall only be operated by authorized personnel who have completed training; and*
- *Laser users must periodically read and always follow the SOP.*

ADMINISTRATIVE INFORMATION			
PI		Lab Manager	
IC		Campus/Bldg/Room	
Phone #		DOHS #s	

LASER USE AND PROCEDURES			
Laser Use	Medical Research ◯	Type of Research	
Length of Use	Ongoing ◯ Limited ◯	Specify Limited Use	
List Step-By-Step Procedures for Laser(s) System(s) Use			

TECHNICAL SPECIFICATIONS							
Description	Individual Laser ◯	Commercially Embedded Laser System ◯	Custom-Built Laser System ◯				
Beam Characteristics	Fully Enclosed ◯	Partially Enclosed ◯	Open ◯	Beam Located Between Sitting & Standing Height ◯			
Reason for Incomplete Enclosure							
Alignment Done In-House?	YES ◯	NO ◯					
If Yes, Additional Safety Procedures Established?	YES ◯	NO ◯					
If Yes, Describe							

ENGINEERING AND ADMINISTRATIVE CONTROLS				
Windows Covered	YES ◯	NO ◯	N/A ◯	
Only Anodized, Dull, Non-Reflective or Matte Finished Instruments Used Near Laser Site	YES ◯	NO ◯	N/A ◯	
Watches and Reflective Jewelry Removed or Covered Prior to Operating the Laser	YES ◯	NO ◯	N/A ◯	
Grounded	YES ◯	NO ◯	N/A ◯	
Rapid Egress Paths Established	YES ◯	NO ◯	N/A ◯	
Restricted Room Access	YES ◯	NO ◯	N/A ◯	
Barriers, Curtains, Beam Stops, Etc.	YES ◯	NO ◯	N/A ◯	
Key Control (On/Off Switch) (Required for Class 4)	YES ◯	NO ◯	N/A ◯	
Laser Key Returned to Secure Storage When the Laser Is Not in Use	YES ◯	NO ◯	N/A ◯	
Fail-Safe Interlock(s)	YES ◯	NO ◯	N/A ◯	
Safety Latch(es)	YES ◯	NO ◯	N/A ◯	
Fire Extinguisher Available	YES ◯	NO ◯	N/A ◯	
Warning Signs Posted on All Laser Room Entrance Doors	YES ◯	NO ◯	N/A ◯	
Emergency Contact Information Included on Door Warning Signs	YES ◯	NO ◯	N/A ◯	
Warning System Type(s)	Audible ◯	Visible (Illuminated) ◯	Verbal ◯	

PERSONAL PROTECTIVE EYEWEAR				
Clean and Without Scratches	YES ◯	NO ◯	N/A ◯	
Stored in Case(s) When Not in Use	YES ◯	NO ◯	N/A ◯	
Optical Density and Wavelength Range Markings Visible	YES ◯	NO ◯	N/A ◯	
Optical Density Needs Verified (Online Calculator: https://www.lia.org/evaluator/od.php)	YES ◯	NO ◯	N/A ◯	

Number of Pairs	Location Kept (Room)	Manufacturer	Model	OD @ Wavelength(s)

CERTIFICATION			
Responsible Person			
Signature		Date	

APPENDIX C: PROGRAM EVALUATION AND IMPROVEMENT TEMPLATE

Laser Safety Program CY [Insert Calendar Year of Review]

For assistance with completing this table, visit

OSHA's webpage on Recommended Practices for Safety and Health Programs

Requirement	Not Implemented	Partially Implemented	Implemented with only Minor Deficiencies	Fully Implemented	Evidence of Implementation	Planned Improvements
Performance indicators are used to track progress toward program goals.				✓		
Performance is tracked using both lagging and leading indicators.				✓		
Performance data are analyzed and shared with workers.				✓		
Management does an initial review (and subsequent annual reviews) to evaluate the program and ensure that it is fully implemented and functioning as planned.				✓		
Workers are involved in all program review activities.				✓		
Program reviews examine key processes to ensure that they are operating as intended.				✓		
The program is modified as needed to correct shortcomings.				✓		