WAYNE STATE UNIVERSITY

Laser Safety Guide

April 2012

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PREFACE

The purpose of this manual is to provide individuals using lasers information on laser hazards, laser-related policies, and procedures, recommendations for the safe use of lasers, and laser safety training. It has been designed to provide the basis for safe laser use in the research and teaching environment without placing excessive burdens of cost or use restrictions on those responsible for laser operations. Much of the information contained herein is based on the American National Standard for Safe Use of Lasers, ANSI Z136.1-2007. The ANSI standard is the accepted standard for laser safety in the United States.

Many lasers are capable of causing eye injury to anyone who looks directly into the laser output beam, or even at a specular reflection of the beam. In addition, diffuse reflection of a high-power laser beam can produce permanent eye damage. High-power laser beams can also burn exposed skin, ignite flammable materials, and cause the release of hazardous fumes, gases, and debris. Other hazards associated with the equipment and optical apparatus required to produce the lasing action and control the beam can include high-voltage, high pressure, compressed gases, cryogenics, noise, ionizing and non-ionizing radiation, and toxic materials.

Despite the potential hazards, laser equipment can be operated safely if the proper procedures and necessary precautions are followed. To this end, the Wayne State University Laser Safety Committee has developed this manual. If you need additional information or assistance, contact the Laser Safety Officer at the Office of Occupational and Environmental Health at 313-577-1200.

This guide adopted in large part from Purdue University.

CHAPTER 1

INTRODUCTION TO LASER SAFETY

Is my laser dangerous?

- Locate the class label on the laser (Figure 1). All lasers sold in the US have one. This will tell you if it is class 1, 2, 3a (3R), 3b, or 4 laser.
- Dangers of a class 1, 2, or 3a (3R) laser are much less significant than those of a class 3b or 4 laser. Even for these low power class lasers, direct exposure of the eye to the output beam can be dangerous. In addition, many of these lasers, regardless of class, have high-voltage power supplies that can be hazardous.
- If you have a class 3b or class 4 laser; it is dangerous, and you need to be especially careful.
- Refer to APPENDIX A for information on laser classification.

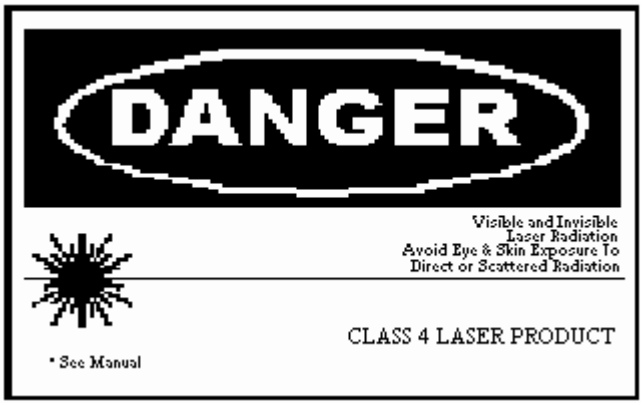

Figure 1. Laser Identification label

I have a class 3b or class 4 laser. What makes it dangerous to me?

- Of foremost concern is the danger the laser poses to your eyesight. Irreparable damage to parts of your eye, and permanent partial or full loss of vision are possible. Lack of knowledge and training in laser safety is easily remedied and immensely valuable to helping you work safely.
- High-power lasers usually have large power supplies designed to deliver large currents, often at high voltages. Accidents during troubleshooting can be fatal. Untrained personnel should stay out of the high voltage power supplies.
- There have been incidents where high-power lasers have ignited laboratory equipment, leading to fire and smoke damage to the laboratory.
- There may be a risk of skin damage from direct exposure to the beam.
- Excimer lasers make use of reactive gases requiring special safety precautions and procedures to prevent exposure.
- How each of the above risks affects you depends on the type of laser, the wavelength, pulse energy (or power for a continuous wave laser), pulse duration (or exposure duration for a continuous wave laser), and the type of application.

I'm new to lasers. How do I figure out what to be concerned about in my lab?

- Ask your Principle Investigator about it.
- Ask about the laser safety training through the Office of Environmental Health and Safety located at 5425 Woodward Avenue, 3rd floor, 313-577-1200.
- See the OEHS website, www.oehs.wayne.edu for additional information.
- Read on to learn a more.

What is the danger to me?

- Depending on the wavelength of the laser light, your cornea, lens, or retina may absorb the light. When there is too much absorption, the cells are burned, leading to damage.

CHAPTER 1

- Effects on the skin are both photochemical and thermal depending on the wavelength of the laser light. Symptoms range from mild reddening (erythema) to blistering and charring. Also, there are possible carcinogenic effects.
- Non-beam hazards include fumes, compressed gases, cryogenic materials, noise, electrical hazards, fire, explosion, and collateral radiation.

How do I know how much is too much?

- Refer to the American National Standard for Safe Use of Lasers, ANSI Z136.1, for hazard analysis of several different laser types. This ANSI standard is available for reference at OEHS.
- Refer to APPENDIX B for information on common types of lasers and check the laser identification label. If the data you are looking for is not there, contact OEHS at 313-577-1200.

How can I avoid accidental exposure?

- Follow the safety procedures for your laboratory. OEHS can help you formulate such procedures if they do not exist or are outdated.
- Use correct approved laser safety goggles when appropriate. The lenses in laser safety eyewear are for a specific wavelength range, and do not protect you outside of this range. Even with safety eyewear, consider direct exposure to a laser beam to be dangerous.
- One simple rule of thumb is to keep the beam horizontal and at waist level so when you are standing in the laboratory your eyes are well above the beam plane.
- Question practices which appear unsafe to you. Are they necessary or outdated? Can the same function be performed in a manner, which is less dangerous? Can the unsafe practices be replaced by some other diagnosis or measurement? Are work practices designed for expediency at the expense of safety?

Where can I get more laser safety information at Wayne State University?

- Laser safety information is available in this guide, at the OEHS website , www.oehs.wayne.edu and through OEHS at 313-577-1200.

Where can I find out about procedures at Wayne State University?

- Procedures for the safe operation of a laser are outlined in the next two chapters of this guide. In Chapter 2 we discuss safety features that should be designed into the laser and the laboratory, as well as information on procedural and administrative policies.
- Procedures at Wayne State University are based on many of the guidelines developed by professional organizations such as the American National Standards Institute (ANSI). Several sections of the American National Standard for Safe Use of Lasers, ANSI Z136.1, are referenced in the following sections and are denoted by parenthesis.

CHAPTER 2

CONTROL MEASURES

I. Introduction

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

- **A.** Eye exposure during alignment
- **B.** Misaligned optics and upwardly directed beams
- **C.** Available eye protection not used
- **D.** Equipment malfunction
- **E.** Improper methods of handling high-voltage circuits
- **F.** Intentional exposure of unprotected personnel
- **G.** Operators unfamiliar with laser equipment
- **H.** Lack of protection from ancillary hazards
- **I.** Improper restoration of equipment following service
- **J.** Eyewear worn not appropriate for laser in use
- **K.** Failure to follow Standard Operating Procedures (SOPs)

Control measures are classified as engineering control measures (ANSI Z136.1, Section 4.3) and administrative and procedural control measures (ANSI Z136.1, Sections 4.4 and 4.5). Engineering controls are those that are incorporated into the laser system and the laser laboratory. Administrative and procedural controls are methods or instructions, which specify rules and/or work practices to supplement engineering controls and may require use of personal protective equipment. An example of an engineering control measure would be a laser beam stop, and an example of an administrative and procedural control measure would be the SOPs. When feasible, engineering controls are always the preferred method to provide for safety in a laser laboratory.

Laser controls are designed to ensure skin and eye exposures do not exceed the applicable Maximum Permissible Exposure (MPE) limit. The MPE defines the maximum safe exposure without hazardous effect or adverse biological changes in the eye or skin. The MPE depends upon the wavelength and exposure duration.

An important consideration when implementing control measures is to distinguish among operation, maintenance, and service. Control measures are based on normal operation of the laser system. When either maintenance or service is performed, it is often necessary to implement additional control measures.

II. Engineering Controls

Engineering controls for Class 3b and 4 lasers are listed below. All Class 3b and 4 lasers at Wayne State University are covered by this policy, and should have the listed design features unless otherwise approved by the Laser Safety Officer (LSO). If the system is purchased in the United States, the system has as part of the design features the controls stated below. This is often indicated on the laser by a "statement of certification".

- **A.** A protective housing shall be provided for each laser system. The protective housing shall be interlocked such that removal of the protective housing will prevent exposure to laser radiation. Interlocks shall not be defeated or overridden during normal operation of the laser (ANSI 4.3.1).
- **B.** Service access panels that allow access to the beam during operation shall either be interlocked or require a tool for removal and have an appropriate warning label (ANSI 4.3.3).
- **C.** A Class 3b laser should have a key controlled master switch. A Class 4 laser shall have a key controlled master switch. The authority for access to the key shall be vested to the Principal Investigator. (ANSI 4.3.4).

CHAPTER 2

D. All viewing portals, display screens, and collecting optics shall be designed to prevent exposure to the laser beam above the applicable MPE for all conditions of operation and maintenance (ANSI 4.3.5).

E. A laser controlled area shall be designated for all unenclosed beam paths. The laser control area is defined as the area where laser radiation is in excess of the MPE. The appropriate control measures must be implemented in the laser controlled area (ANSI 4.3.6).

F. A Class 3b laser should be provided with a remote interlock connector. A Class 4 laser shall have a remote interlock connector. The remote interlock connector will decrease the laser beam power to safe levels when activated (ANSI 4.3.7).

G. A Class 3b laser should have a permanent beam stop in place. A Class 4 laser shall have a permanent beam stop in place (ANSI 4.3.8).

H. An alarm (for example, an audible sound such as a bell or chime), a warning light (visible through protective eyewear), or a verbal "countdown" command should be used at start-up of a Class 3b laser, and shall be used with Class 4 lasers. For Class 4 laser systems, the warning should allow sufficient time to take appropriate actions to avoid exposure to the laser beam (ANSI 4.3.9).

I. Whenever possible, Class 4 lasers should be operated and fired from a remote location (ANSI 4.3.13).

III. Administrative and Procedural Controls

A. Approval is required for each laser facility. The application should be filed for approval before work begins.

B. Standard operating procedures, with safety controls, shall be readily available for operation of the laser system (ANSI 4.4.1). Refer to APPENDIX D for a guide to assist in the development of SOPs.

C. Each laser operator shall have the education and training level commensurate with degree of hazard and responsibility (ANSI 4.4.3). Refer to Section IV of Chapter 3.

D. Alignment procedures shall be developed to ensure that eye exposure to the primary beam or to a diffuse or specular reflection does not exceed the MPE (ANSI 4.4.5).

E. The laser facility shall be designed in such a way to limit spectator access to the laser controlled area (ANSI 4.4.6).

F. Service personnel must comply with appropriate control procedures for the laser system and have education and training commensurate with the laser system (ANSI 4.4.7).

G. Proper eye protection devices, specifically designed for the laser radiation, shall be worn when engineering or other administrative and procedural controls are inadequate to eliminate exposures above the MPE (ANSI 4.6.2).

IV. Class 3b and 4 Laser Controlled Area

A. The area designated as the controlled area for Class 3b laser facilities shall have the following adequate control measures (ANSI 4.3.10.1).

1. Operation only by qualified and authorized personnel. Refer to Section I of Chapter 3.

2. Appropriate warning signs at all entryways and within the area. Refer to Section VI of Chapter 3.

3. Appropriate beam stops for terminating potentially dangerous beams.

4. Only diffuse-reflective surfaces on non-optical structures in or near the beam path.

5. Appropriate eye protection for all personnel within the area.

6. Laser beam positioned well above or below eye level.

7. All windows, doorways, and open portals covered to prevent the laser radiation above the applicable MPE outside the laser facility.

8. Secured storage of laser equipment.

CHAPTER 2

B. In addition to the above control measures for Class 3b laser facilities, the controlled area for Class 4 laser facilities (Figure 2) **shall** have the following control measures (ANSI 4.3.10.2).

1. All entryway controls designed to allow rapid egress.

2. A "Panic Button" or "Shut Off" shall be clearly marked and readily accessible to the laser personnel. When activated the "Panic Button" will reduce the output power of the laser to levels below the MPE. The following are acceptable examples of "Panic Buttons".

a. Key switches to deactivate the laser.

b. Master switch on power source to turn off power.

c. Red mushroom-type button on control panel or other readily accessible location within the area.

3. Limited Access Entryway. The PI shall implement one of the following mechanisms to protect personnel. The LSO will be available for consultative services.

a. Non-Defeatable (non-override) Entryway Safety Controls

Non-Defeatable entryway controls will reduce the output power of the laser to levels below the MPE when the door is opened unexpectedly.

b. Defeatable Entryway Safety Controls

Defeatable entryway controls, with an override for safety latches and/or interlocks, may be used if it is clearly evident that there is no laser radiation hazard at the point of entry. Only adequately trained and authorized personnel may operate the overrides to enter the facility.

c. Procedural Entryway Safety Controls

i. All authorized personnel shall be trained, and proper personal protective equipment (PPE) shall be available upon entry.

ii. A secondary barrier (laser curtain) shall be used to block the laser radiation at the entryway.

iii. At the entryway there should be a visible or audible indication that the laser is in operation.

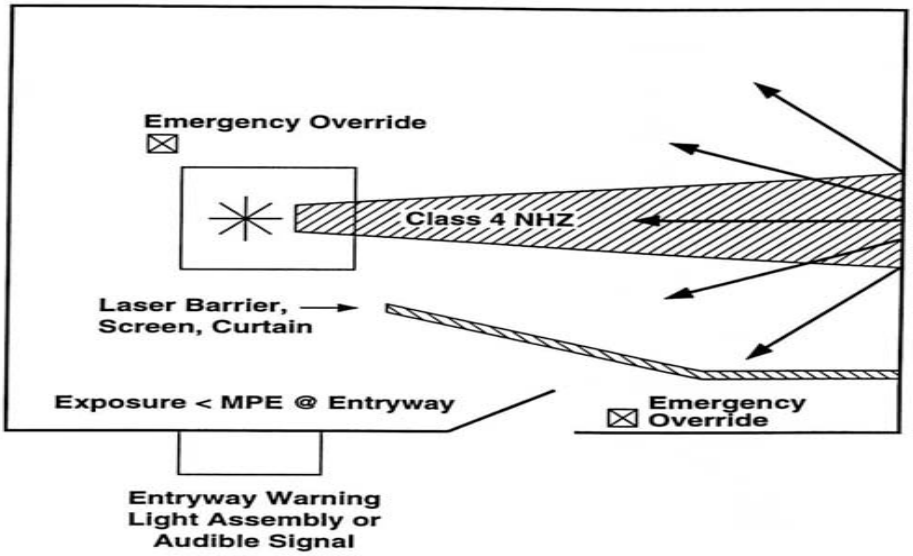

Figure 2. Class 4 Laser Controlled Area

CHAPTER 2

V. Equipment Labels

All lasers (except Class 1) shall have appropriate warning labels with the laser sunburst logo and the appropriate cautionary statement (Figure 1). The labels shall be affixed to both the control panel and the laser housing.

Ancillary hazards shall also be appropriately labeled, but the sunburst logo is not required.

VI. Area Posting Signs

Areas which contain Class 2 or 3a laser systems should be posted with appropriate area postings as described in Figure 3. Areas which contain Class 3b or 4 laser systems shall be posted with appropriate area postings as described in Figure 4. Also, the laser controlled area should be indicated with the appropriate warning sign.

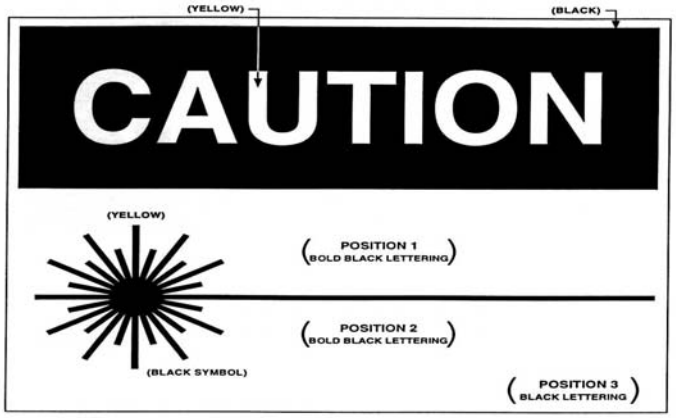

Figure 3. Area Posting for Class 2 and 3a Lasers

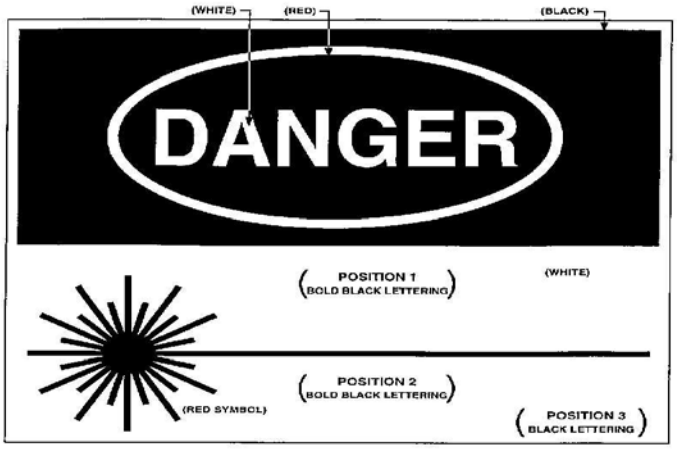

Figure 4. Area Posting for Class 3b and 4 Lasers

CHAPTER 3

LASER SAFETY PROGRAM

This chapter was developed to inform supervisors and operators of their roles and responsibilities to help provide a safe laser environment at Wayne State University.

I. RESPONSIBILITY OF EMPLOYEES AND STUDENTS WORKING WITH OR NEAR LASERS

A. Authorization

An employee or student shall not operate a class 3b or 4 laser system unless authorized to do so by the PI for that laser. The PI should give system specific laser safety training, including this document, and provide the users with the Standard Operating and Alignment Procedures.

B. Compliance

All employees and students shall comply with the safety rules and regulations prescribed by the PI, LSO, and Laser Safety Committee. Employees and students shall know the operating procedures applicable to their work.

C. Accident Reporting

All injuries and accidents involving lasers and laser systems shall be reported to the PI and the LSO. However, the treatment of injured personnel and the preservation of property shall be the first priority.

II. RESPONSIBILITY OF THE PRINCIPAL INVESTIGATOR

A. Prerequisite

The PI shall know the educational and training requirements, the potential laser hazards and associated control measures, and all OPERATING procedures pertaining to laser safety for lasers and laser systems under the PI's control.

B. Training

The PI shall ensure that all laser users under his/her control are trained.

C. Authorized Users of Laser Systems

The PI shall submit a Laser Registration Usage form for each laser. The PI shall determine which students and employees are authorized to operate a laser system under his/her control. PI's are required ensure users have appropriate training; machine specific and Laser Safety Training.

D. Accidents and Injuries

The PI shall notify the LSO of known or suspected laser-related accidents and injuries. The PI shall ensure that their departmental business office is promptly notified. If necessary, the PI will assist in obtaining appropriate medical attention for any employee or student involved in the laser accident. The PI shall cooperate with the LSO and/or LSC during the course of their investigation and implement recommendations to prevent a recurrence. A written incident report shall be prepared by the PI within 1 month.

E. Approval of Laser System Operation

Lasers should be registered with the LSO and review of the registration and SOP's approved before class 3b or 4 lasers are used. The LSO will forward registration documents and SOP's to the committee for comments and approval.

CHAPTER 3

F. Approval of Planned Installations

The PI shall assure that plans for laser installations or modifications of installations are submitted to the LSC for approval. The LSO will act as a consultant, in conjunction with Facilities Planning, for the installation of new laser facilities.

G. Operating Procedures

For Class 3b and 4 laser systems, the PI shall ensure standard operating procedures (SOPs) are developed and provided in order to prevent the operation of a laser if exposure to employees, students, visitors, or the general public could exceed the MPE. SOPs shall also be necessary for alignment, maintenance and/or service, and emergency response.

III. RESPONSIBILITY AND AUTHORITY OF LASER SAFETY COMMITTEE

A. Policies and Practices

The committee shall establish and maintain policies, procedures, and guidance for the control of laser hazards.

B. Approval of Class 3b and 4 Laser Facilities

Approval of a laser or laser system for operation will be given by the LSC. Each laser registered will be evaluated for appropriate safety and control measures. The evaluation will include a review of the standard operating procedures (SOPs), engineering controls for the laser, engineering controls for the laboratory or area, and administrative and procedural controls for the laser facility. Standard operating procedures for alignment, maintenance and/or service, and emergency response shall be provided as necessary.

Temporary approval for operation can be given by the LSO, who will then seek final approval at the next LSC meeting.

C. Standards

The committee will review all applicable new or revised laser safety standards.

D. Membership of Laser Safety Committee

The Wayne State University Laser Safety Committee shall consist of faculty and staff who by their knowledge and experience are qualified to make judgments and recommend policy in the area of laser safety. Committee members shall be appointed by the Vice President of Research.

E. Authority

The LSC and the LSO have the authority to suspend, restrict, and terminate the operation of a laser project if it is deemed that the laser hazard controls are inadequate.

IV. RESPONSIBILITY AND AUTHORITY OF LASER SAFETY OFFICER

A. General

The LSO will work with the individual PI to ensure the safety standards of each laser laboratory are adequate. The LSO shall be designated by the LSC and has the authority to monitor and enforce the control of laser hazards.

B. Consultative Services

The LSO will provide consultative services on laser hazard evaluation and controls, and personnel training programs.

C. Training Programs

Training shall be provided to each employee and student routinely operating a Class 3b or 4 laser or laser system. A comprehensive laser safety training program is available from OEHS. Training programs provided by the vendor are encouraged. The LSC should be informed of the content of these alternative programs. Training should be completed at the time work begins.

CHAPTER 3

D. Records

The LSO will ensure that the records are maintained indicating that appropriate training has been provided and all users of laser systems are listed on the appropriate projects.

The LSO shall periodically contact the PIs to ensure the laser application is current.

E. Surveys and Inspections

The LSO will survey all areas where Class 3b and 4 laser equipment is used. Surveys shall be performed on a regular basis, when modifications to the laser and/or laser system have occurred, before the initial operation of a new laser, or as deemed necessary.

The LSO will accompany regulatory agencies inspecting the laser facility. The LSO will ensure that corrective action is taken where required.

F. Accidents and Injuries

Upon notification of a known or suspected laser-related accident or injury, the LSO shall investigate and document the accident or injury and take appropriate action. The LSO shall perform a hazard evaluation of the laser facility to determine the cause of the accident, interview individuals involved in the accident, and make certain that necessary controls have been implemented before operation resumes.

APPENDICES

APPENDIX A

LASER CLASSIFICATION

Class	Power Output	Description
1	<0.4 μW	Considered safe for continuously viewing or are designed in such a way that prevents human access to laser.
2	0.4 μW-1 mW	Visible light lasers will not cause eye injury if viewed momentarily. They can possibly present an eye hazard if viewed directly for a long period of time.
3a	1 mW-5 mW	Cannot damage the eye within 0.25 second of the aversion response or blink reflex. Injury is possible if the beam is viewed with collecting optics or by staring at the direct beam.
3b	5 mW-500 mW	Present an eye and skin hazard from viewing the direct beam or a specularly reflected beam. No production of a hazardous diffuse reflection except when viewed with collecting optics. No fire hazard is presented.
4	>500 mW	These are the **most hazardous lasers** and may cause an eye and skin injury from the direct viewing, specular reflection, and diffuse reflection. These lasers can produce fire and generate hazardous airborne contaminants.

APPENDIX B
COMMON LASER TYPES AND WAVELENGTHS

TABLE B1: Ultraviolet (180 nm – 400 nm)

Laser Type	Wavelength (nm)
Argon Fluoride	193
Krypton Fluoride	248
Neodymium:YAG (4th harmonic)	266
Argon	275, 351, 363
Xenon Chloride	308
Helium Cadmium	325
Nitrogen	337
Xenon Fluoride	351
Neodymium:YAG (3rd harmonic)	355

TABLE B2: Visible (400 nm – 700 nm)

Laser Type	Wavelength (nm)
Helium Cadmium	442
Rhodamine 6G	450, 650
Argon	457, 476, 488, 514
Copper Vapor	510, 578
Krypton	530
Neodymium:YAG (2nd harmonic)	532
Helium Neon	543, 632
Indium Gallium Aluminum Phosphide	670
Ruby	694

TABLE B3: Near-infrared (700 nm – 1400 nm)

Laser Type	Wavelength (nm)
Ti-Sapphire	700 – 1000
Alexandrite	720 – 800
Gallium Aluminum Arsenide	780, 850
Gallium Arsenide	905
Neodymium:YAG	1064
Helium Neon	1180, 1152
Indium Gallium Arsenic Phosphide	1310

TABLE B4: Mid-infrared (1400 nm – 3000 nm)

Laser Type	Wavelength (nm)
Erbium:Glass	1540
Homium	2100
Hydrogen Fluoride	2600 – 3000
Erbium	2940

TABLE B5: Far-infrared (3000 nm – 1 mm)

Laser Type	Wavelength (nm)
Helium Neon	3390
Carbon Monoxide	5000 – 5500
Carbon Dioxide	10600

APPENDIX C

Laser Registration Form

WSU Laser Safety Program
5425 Woodward Ave., Suite 300:
Attention: Laser Safety Officer
Fax # 313-993-4079

1. Principal Investigator: _____ 2. Department: _____

3. Phone number: _____ 4. Email:_____

5. Office address: _____

6. Location of Laser: Room _____ Building _____

Laser Information: Laser is Active _____ Laser is Inactive/Storage_____

Laser Manufacturer _____

Model # _____ Serial #_____ _____

Laser Class (3a (3R), 3b, 4) _____ Beam: ☐ Open ☐ Closed ☐ Partially Closed

Laser Type: _____

Beam Diameter _____ millimeters Beam Divergence _____ mill radians

Beam diameter and divergence measured at ☐ 1/e ☐ $1/e^2$

How many simultaneous wavelengths? _____ List: _____

CW
Wavelength (nm) _____

Maximum Operating Power (W) _____

Average Operating Power (W) _____

Pulsed
Wavelength (nm) _____

Maximum Pulse Duration (sec.) _____

Maximum Pulse Frequency (Hz) _____

Maximum Operating energy (J) _____

Average Operating Energy (J) _____

Please check all that apply for this laser

___ Use of cryogens
___ Use of compressed gases
___ Use of high voltage supplies
___ High voltage > 30kVp
___ Dye laser
___ Turnable laser
___ Used as a pumping laser
___ Laser is water-cooled
___ Airborne contaminants generated
___ Exposed beam path
___ Use of beam focusing optics
___ Use of frequency doubling crystal
___ High noise level
___ Laser cutting/welding
___ Self-modified laser

Laser Registration Form

Safety & Compliance Items:

_____Entryways are properly identified with Caution or Danger Laser (for Class 3b and 4) Signage

_____Entryway control: (Required for Class 4) ___Undefeatable interlock _____Defeatable interlock _____ Procedural

_____Beam stops & curbs used where needed

_____Standard Operating Procedures (SOP)

_____Emergency procedures

_____Users have laser specific training – hands on given by PI

_____Users have had Laser Safety Training- theory and safety practices given by OEHS

_____Safety Eyewear is available

_____Windows covers and barrier curtains

_____Audible and visual warning light (Class 4)

_____Written Alignment Procedures (Class 4)

_____Key Control for unauthorized laser use

Attach a copy of the Standard Operating Procedures and Alignment Procedures

Principle Investigator Signature_____Date_____

Contact for additional information:

Wendy Barrows, Laser Safety Officer at 313-577-9505 or wbarrows@wayne.edu for questions. Lasers should be registered with the LSO. The Laser Safety Committee will review the laser registrations and make comment on any necessary safety concerns regarding the use or the laser. Please refer to WSU Laser Safety Manual for additional laser program specifics.

Committee Approval date:_____

APPENDIX D

GUIDELINES FOR LASER OPERATING PROCEDURES

These guidelines are intended to assist lasers users in preparing standard operating procedures (SOPs) for laser facilities. The information should be used as a guide to allow you to develop SOPs specific to your laser systems.

Anyone writing operating procedures should be familiar with laser safety and the Wayne State University Laser Safety Policy. The Wayne University Laser Safety Policy and ANSI Z136.1 require **all** SOPs for laser facilities to be approved by the LSO.

I. INTRODUCTION

A. Describe the laser location.

B. Describe the laser(s) by type, classification, and technical specifications (wavelength, power/energy, pulse length, repetition rate, beam diameter and divergence, etc.).

C. Briefly describe the purpose of the operation.

II. HAZARDS

Identify and analyze the specific hazards associated with this laser operation; include beam hazards as well as any non-beam hazards (electrical, hazardous chemicals, high pressure, plume emissions, etc.).

III. HAZARD CONTROLS

Describe the means used to mitigate each of the hazards listed above in the HAZARDS section. Please refer to ANSI Z136.1, the Wayne State University Laser Safety Policy, or the LSO for assistance.

IV. TRAINING REQUIREMENTS

Describe the training requirements for the laser operator and incidental personnel. The laser operator shall have formal training in laser safety as well as hands on training with the specific laser system. Incidental personnel shall be made aware of the specific hazards associated with the laser operation.

V. OPERATING PROCEDURES

List the sequential events that describe the complete operation, including when to implement the hazard control measures. The procedures shall be written for the benefit of the laser operator who must read and understand them to perform the operation safely.

VI. ALIGNMENT PROCEDURES

List the steps used to perform beam alignment on a laser or laser system. Special attention should be given to control measures that can reduce the potential for exposure. Examples for control measures are shutting down the main laser and using an alignment laser, reducing the power/energy of the laser, use of beam dumps for the primary beam, etc.

Most laser accidents from the beam occur during the alignment operation.

VII. EMERGENCY PROCEDURES

Describe your planned actions in case of an accident, injury, fire, or other emergency. Include names and phone numbers of those that must be contacted in case of an emergency. The procedures shall include OEHS at 313-577-1200 and Wayne State University Police at 313-577-2222. Post the emergency procedures in the laboratory.

Standard Operating Procedures (Example 1)
Class 3b or 4 Lasers

I. Scope

A. This document provides safety guidance for laser operators and spectators within the laser controlled area.

B. Procedures reflected herein are in accordance with applicable regulation parameters impacting the operation of the laser laboratory.

II. Responsibilities

A. _____ is responsible for the safety of this laboratory operation in conformance with this Standard Operating Procedure (SOP). In the absence of _____, _____ shall assume these responsibilities.

B. Only trained laboratory personnel listed on the end of this document and maintenance personnel from manufacturers may energize the laser or laser system.

III. Beam Alignments

A. Secure all entrances into the laser area.

B. Locate all equipment and materials needed prior to starting alignment.

C. Use laser protective eyewear with proper OD and wavelength for alignment. Use skin covers (labcoat, gloves, and UV face shield) to protect users from UV laser beam scatter. * see below

D. Intrabeam viewing must always be avoided. Whenever possible use a low power alignment laser (class 2 or 3a), if none is available, use the lowest beam power available.

E. If there are others in the room make sure they are aware of the alignment in progress.

F. Keep optical table(s) clear of objects which may cause unwanted reflections. Close laser shutter if entering the beam path necessary.

G. Insure all beam blocks, enclosures, and beam barriers are replaced when the alignment is complete.

* Visual Light Transmission (VLT). The concept of VLT is simple. The desire is to block out the dangerous wavelengths and to allow sufficient visual light to pass through for good vision. Multi-wavelength applications present a problem; the percentage of VLT can range from 4 percent to 30 percent. VLTs below 20 percent in a well-lit room can still yield a dark field of view. Therefore, one needs to be aware of the lighting conditions in which the eyewear will be used. If the room lighting is dim for experimental or process reasons, even a 30 percent VLT may present safety issues, pushing the needs for stronger engineering controls or local task lighting.

Optical density. (OD) The protective goal of laser eyewear is such that if laser radiation strikes the lens portion of the eyewear, the lens will completely block or reduce any transmitted radiation to below the maximum permissible exposure (MPE) level. This filtration or protection level is called optical density.

For ultra-violet and infrared radiation, the OD selected should offer full protection. For visible wavelengths, it is common to select less than full protection OD to allow some visibility of the beam for alignment purposes or beam manipulation. This becomes a challenge when beam output is less than 100 mW (milliwatt) or the beam is expanded.

IV. Laser Controlled Areas

A. The laser hazards associated with this laboratory have been analyzed, and the controls specified for these hazards will reduce the risk to employees and the environment to acceptable levels.

B. All entries into the laser controlled area must be posted with the proper warning sign.

1. Do not rely on a closed door as adequate security. Use key locks or activated interlocks on doorways into the laser area.
2. When the laser is energized, all entrances into the laser controlled area must be secured to prevent unauthorized access. If there is a "laser on" indicator it must be used.

C. An emergency procedure sign must be posted inside the laser controlled area along with this laser safety plan/standard operating procedures near the laser or laser system.

D. The laser beam shall be contained in the immediate area using non-reflective and non-flammable beam blocks and/or partitions.

E. It is the discretion of the laser operator to allow or deny entry into the laser area while the laser is energized.

F. If there are windows in the laser area, they must be blocked with opaque material that is non-reflective and non-flammable.

G. If possible, position the laser so it is not at standing or sitting eye level.

H. If the laser/laser system is key operated; do not leave the key in the laser when the experiment is finish.

V. Non-beam Hazards

A. Laser dyes should be handled with care and proper protective equipment must be used (labcoat, safety glasses and gloves). If dyes are to be mixed, it must be done in a well ventilated fume hood. Dye pumps and storage must be in secondary containers.

B. When working with high voltage, the "buddy" system should always be used. Trained CPR laboratory personnel are highly recommended.

C. Compressed gas cylinders must be secured properly and staff should be trained with the proper hazards and handling of the various gases.

D. Attention should be given to protect against fire, especially with class 4 laser/laser system. Flammable solvents may be used in laser dyes or to clean components. Fire extinguishers (charged properly) should be kept in the laser area and staff should know how to use them.

E. Good general house keeping can greatly improve safety from physical hazards. Cables should be secured to keep trip hazards to a minimum.

VI. Laser Maintenance

A. Only properly trained and PI approved personnel may service laser systems.

B. All enclosures, interlocks, and safety devices must be replaced and verified operational prior to returning the laser to service.

VII. Training

A. Individuals who use this equipment are required to take the WSU Laser Safety Class and shall be trained to recognize the intrinsic hazards, are aware of basic safety information that relates to their job duties, and know the safe operating requirement for this activity.

B. All operating personnel shall read and understood this standard operating procedure (SOP) and all applicable references stated in this SOP. Signatures of all authorized operators are required at the end of this SOP.

VIII. Emergency Procedures

A. In an event of a laser emergency refer to the Laser Emergency Procedure posted in the laser controlled area.

B. In an event of fire or other emergency, evacuate and notify the WSU police department by dialing 313-577-2222.

XI. Additional Safety Measures

_____

_____

_____

Standard Operating Procedure Signature Form

The responsible individual shall verify and document that personnel working under the direction of this SOP understand and agree to comply with the safety plan before beginning work.

All individual listed below affirm that they have read and agreed to comply with the attached SOP.

Print Name	Signature	Date

LASER SOP (Example 2)

Scope: These procedures apply to all activities in the Laser Controlled Area when to a class 4 laser beam is accessible.

Laser Descriptions

Ti:Sapphire Laser (class 4):
Wavelength: 800 nm
Maximum Average Power: 1 W
Beam Diameter: 1.5 mm
Beam Divergence: 0.81 mrad

Nd:YAG Laser (class 4):

Fundamental Wavelength: 1064 nm	Double Wavelength: 532 nm
Maximum Average Power: 2.5 W	Maximum Average Power: 1 W
Beam Diameter: 1.2 mm	Beam Diameter: 1.0 mm
Beam Divergence: 1.24 mrad	Beam Divergence: 0.75 mrad

Hazards

The primary hazard associated with these lasers is an eye hazard from direct or reflected beams. Invisible, open beams may be present and must be controlled by the laser operator. Diffuse reflections may be a hazard, but the Diffuse Reflection NHZ is typically less than 20 cm.

Eyewear

Approved laser safety eyewear with the following optical densities is available in the laboratory:

Ti:Saph @ 800 nm	OD 7
Nd:YAG @ 1064 nm	OD >5.5
Nd:YAG @ 532 nm	OD >5.5

All personnel in the Laser Controlled Area are required to wear the appropriate eyewear during laser operation except in the following circumstances.
During sample change eyewear may be removed if the laser shutter is closed. During work at the computer workstation eyewear may be removed for brief periods after authorization by the LSO if the person who will work without eyewear has performed a safety check to verify that there are no stray reflections in the area of the workstation immediately before removing eyewear. If IR beams are in use, a thorough safety check using an IR viewer is required.

Additional Laser Control Measures

A. The Laser Controlled Area is bounded by a laser barrier curtain. Only **Authorized Laser Operators** and approved visitors are allowed inside the Laser Controlled Area during laser operation. **Visitors** may enter the Laser Controlled Area only upon approval of the laser operator after they have received a safety briefing.
B. Laser beams will be initiated in a controlled manner with the beam terminated on a specific target or a diffuse reflecting surface. Safety checks will be performed regularly and following any optical path change to confirm that no stray reflections leave the laser tables.
C. Only Authorized Laser Operators are allowed in the Laser Controlled Area during **laser and optical alignment**. Alignment will be accomplished using the lowest practical power. A safety check must be performed after beam alignment. All stray reflections will be blocked as near their source as possible with diffuse reflecting beam blocks.

Required Training: Laser Safety training is required of all personnel before they will be authorized to operate the lasers. Authorization by the LSO is required.

Emergency Procedures

In case of emergency turn off all lasers and notify the Laser Safety Officer.

Authorized Personnel

The following personnel are authorized to operate class 4 lasers in this laboratory

_____ _____ _____ _____
_____ _____ _____ _____

APPENDIX E

WAYNE STATE UNIVERSITY

Office of Environmental Health & Safety
5425 Woodward Avenue 3rd floor
(313) 577-1200 office (313) 993-4079 office fax

Laser Safety Self-Audit Checklist

Building: ---------- Room: ---------- PI: ----------

Audit Performed by: ----------Date: ----------

Contact Information:----------

Instructions: Please complete, send a copy to the above address. Complete for active lasers only	Y	N	NA	COMMENTS
A. Administrative				
1. Lasers are classified appropriately (3B, 4)				
2. Standard operating procedures are available				
3. Alignment procedures are available				
4. Viewing cards are used for alignment				
5. Laser users attended appropriate training (via OEHS)				
6. Laser users have received laser specific training				
7. Lasers are registered with OEHS				
B. Labeling and Posting				
1. Certification label present				
2. Class designation and appropriate warning label present				
3. Radiation output information on label				
4. Aperture label present				
5. Appropriate warning/danger sign at entrance to laser area				
6. Warning posted for invisible radiation				
C. Control Measures				
1. Protective housing present and in good condition				
2. Beam attenuator present				
3. Laser table below eye level				
4. Beam is enclosed as much as possible				
5. Beam not directed toward doors or windows				
6. Beams are terminated with fire-resistant beam stops				
7. Surfaces minimize specular reflections				
8. Controls are located so that the operator is not exposed to beam				

	Y	N	NA	COMMENTS
D. Personal Protective Equipment				
1. Eye protection is appropriate for wavelength				
2. Eye protection has adequate OD				
3. Warning/indicator lights can be seen through protective filters				
E. Class 3b and 4 Lasers				
1. Interlocks on protective housing				
2. Service access panel present				
3. Limited access to spectators				
4. Nominal hazard zone determined				
5. Operators do not wear watches or reflective jewelry				
6. Viewing portals present where MPE is exceeded				
F. Class 4 Lasers				
1. Failsafe interlocks at entry to controlled area				
1a. Defeatable interlocks at entry to controlled area				
1b. Procedural entryway control with: ➢ Properly trained authorized personnel ➢ Activation warning light indicating laser is energized ➢ Protective equipment provided at the door such as: Blocking barrier, screen, curtain, eyewear				
2. Area restricted to authorized personnel				
3. Laser may be fired remotely				
4. If present, curtains are fire-resistant				
5. Area designed to allow rapid emergency egress				
6. **Pulsed-** interlocks designed to prevent firing of the laser or dumping the stored energy into a dummy load				
7. **CW-** interlocks designed to turn off power supply or interrupt the beam by means of shutters				
8. Operators know not to wear ties, scarfs, and dangling clothing or jewelry.				
G. Non-Beam Hazards				
1. High voltage equipment appropriately grounded				
2. High voltage equipment located away from wet surfaces or water sources				
3. High voltage warning label in place				
4. Compressed gases secured				

APPENDIX F

WAYNE STATE UNIVERSITY

Office of Environmental Health & Safety
5425 Woodward Avenue
Detroit, MI 48085
(313) 577-1200 main (313) 993-4079 fax

Confocal Microscopy Hazard Checklist

PI:_____ Contact #_____ Date: _____

Laser Location: _____Laser Class: _____

This checklist is a summary of key points for the evaluation of a laser microscopy workstation. This form needs to be completed only once, unless there are changes to the system. Please keep a copy of this document on file and submit one to the address above. This form is given to guide and we only request a copy so we know you have performed a self-review of your laser system.

Do you know your wavelengths? ( )

Laser light may be visible (400 to 700 nm) or invisible (180 to 399 nm or 701 nm to 10,000 nm). Sometimes you can see laser light "outside" the visible range. An 800 nm laser will be visible and appear very dim; creating the impression, it is not a risk of eye injury. The retinal hazard zone is 400 to 1400 nm. Know the wavelengths and power levels you are potentially exposed to!

Is the laser pathway entirely fiber optic? Yes ( ) No ( ) If yes, go to step C. If no, complete the entire form.

A. Be sure you understand the beam path.
   Is there potential for human exposure? Yes ( ) No ( )
   Specifiy:_____

B. Consider what the beam can interact with on its way to the intended target.

   Note: How well an item can scatter light can be deceptive. It has little to do with how an item may appear to you. It is related to the surface structure of the material and wavelength of the incident light. All unnecessary items need to be kept out of the beam path.

   - Are there any upwardly directed beams? Yes( ) No ( )
   - Are there any computer monitors potentially in line with the beam? Yes( ) No( )
     This could be a source of reflection with potential human exposure.
   - Is the beam at eye level with respect to the operator's position at any time?
     Yes ( ) No ( )
   - Are there any objects/items in the path of the beam that may cause scatter?
     Yes ( ) No ( )
     Look for scatter off mirrors and items that are a necessary part of the optics table. It may be necessary to put beam stops in place to minimize potential exposure.

C. Are there filters or a beam stop present to prevent a user from viewing laser light through the eyepieces? Yes ( ) No ( )
If not, what methods will be used to prevent exposure?_____

Note: How well an item can scatter light can be deceptive. It has little to do with how an item may appear to you. It is related to the surface structure of the material and wavelength of the incident light. All unnecessary items need to be kept out of the beam path.

D. Is protective eyewear needed and is it available? Yes ( ) No ( )

E. Is there a user log? Yes ( ) No ( )

F. Have all users had function specific training? Yes ( ) No ( )
Is it documented? Yes ( ) No ( )
Function specific training should be given by PI or experienced user.

G. Is the laser used with lights on, off or dimmed? Lights on ( ) Lights off ( ) Dimmed ( )
Low light conditions result in a larger pupil opening. This could increase exposure and is important to know.

H. Who performs maintenance on the lasers?
_____
_____

I. If infectious agents or materials are used, is a HEPA filter system in use ? Yes ( ) No ( )
If yes, provide Manufacturer, Model, and Serial Number
_____
_____
Who Performs maintenance on the HEPA filtered system?
_____
_____

APPENDIX G

Laser Safety Committee Member List

Name	Department	Phone	Email
Marcis Jansons, Chair Assistant Professor	Mechanical Engineering	313-577-3887	**mjansons@wayne.edu**
Ivan Avrutsky Associate Processor	Electrical & Computer Engineering / Physics & Astronomy	313-577-4801	**ivan.avrutsky@wayne.edu**
Kamir Moin Associate Professor	Pharmacology	313-577-2199	**kmoin@med.wayne.edu**
Ashis Mukhopadhyad Associate Professor	Physics	313-577-2775	**ashis@wayne.edu**
Arthur Suits Professor	Chemistry	313-577-2597	**asuits@chem.wayne.edu**
Annette Tremonti Research Assistant	OEHS	313-577-3579	**ad8831@wayne.edu**
Tom Perez Director	OEHS	313-577-1200	**tperez@wayne.edu**
Lorry Sabo Manager, Export Controls & Regulatory Compliance	VP for Research	313-577-5046	**lsabo@wayne.edu**
Rob Moon Associate Director	OEHS	313-577-1200	**ds9835@wayne.edu**
Wendy Barrows Laser Safety Officer & Assistant Radiation Safety Officer	OEHS	313-577-9505	**wbarrows@wayne.edu**