Laser Safety Plan

Sonoma State University
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Section One

Introduction

1.1 Purpose

The objective of this Laser Safety Plan (LSP) is to provide specific guidance to individuals who work at or attend Sonoma State University (SSU) for the control of potentially hazardous non-ionizing light exposures to lasers in the laboratory environment. This LSP is a "living" document, which will need to be updated from time to time to best reflect specific, current conditions and practices. Environmental Health and Safety (EH&S) will work with the SSU Laser Safety Officer to keep this document current so that the specific guidance provided herein is operationally accurate and useful.

1.2 Policy

It is SSU's policy to provide its employees with a safe and healthful work environment and to comply with all pertinent SSU, federal, state, and local regulatory requirements. Further, SSU is committed to the protection of school property from damage or loss caused by accidents/emergencies, and to the prevention of harm to the general public or the environment resulting from SSU activities.

SSU's management recognizes that unique hazards may be found in laboratories utilizing lasers. This LSP is designed to address those hazards by stating laser-specific EH&S requirements and guidelines. It is a requirement that all instructors, students, laboratory workers, contractors, and visitors who work in SSU laser laboratories be familiar with and follow the requirements of this document.

1.3 Background

The Federal Occupational Safety and Health Administration (OSHA) promulgated an important standard entitled, "Non-ionizing Radiation" (29CFR 1926.54). This Standard addresses the potential hazards and safe use of non-ionizing radiation. Cal-OSHA subsequently adopted a parallel standard in the California Code of Regulations (CCR) Title 8, Section 1801 with the same title. The regulation adopts by reference the American National Standards Institute (ANSI) Z136.1-1993 Standard. This requires that SSU determine the applicability of the standard to its operations and, where applicable, develop and implement a written Laser Safety document.

1.4 Scope & Application

The scope of this LSP applies to all SSU laser operations. While the focus of this LSP is on Class 3b and 4 laser operations, many of the control recommendations, administrative procedures, and required uses of personal protective equipment (PPE) apply to Class 2 and 3A lasers as well. Therefore, all SSU operations that find this document (or portions thereof) pertinent shall use it for reference and guidance.

This Plan does not include radioactive materials or hazardous chemicals. The University's radiologic license governs the use of radioactive materials and is available through EH&S or the Radiation Safety Officer within the School of Science and Technology. Further, the Chemical Hygiene Officer and associated plan addresses hazardous chemical use in laboratories although some overlap is expected with the Chemical Hygiene Plan. If radioactive materials, hazardous chemicals or other hazards are encountered the appropriate Plan must be referenced and adhered to.

Section Two

Responsibilities

Consistent with SSU policy, responsibility for laser safety in the laboratory is shared by administrators, managers, faculty, laboratory workers, and any other persons directly or indirectly involved with laboratory operations. Specific responsibilities are described below.

2.1 Plan Administrator

The Plan administrator, The Dean of The School of Science and Technology, is responsible for the overall management and administration of the LSP. This is consistent with the responsibility section in the SSU Injury and Illness Prevention Program. The Plan Administrator is also responsible for:

1. Ensuring that appropriate technical and administrative human resources, budget, and equipment are provided to achieve the objectives of this document.
2. Providing leadership and direction to the School of Science and Technology with regards to laser safety within the laboratory.

2.2 Principal Investigator/Laboratory Director

Principal Investigators for Research Grants and Laboratory Directors have the same responsibilities as faculty and staff listed below with the addition of the following:

1. Any and all laser equipment that is Class 3 or higher shall have a completed and Laser Safety Committee approved Laser Registration Form prior to start-up or operation of equipment. This completed registration form shall include safe work practices and maintenance procedures and must include, at a minimum the components outlined in Section 6.2.

2.2 Faculty and Staff

Faculty and Staff are responsible for:

1. Implementing the pertinent requirements of this document in their respective areas.
2. Providing specialized training, or ensuring that students working under their direction in their laboratory area or with their laser equipment are trained specifically on the hazards associated with that equipment. This training must take place at the on-set of use of new equipment, new lab assignment, or changed lab assignment and must comply with the requirements of Section Seven of this document.
3. Ensuring that Safe Work Practices are developed for all Class 2 and higher laser operations. The guidelines for the development of Safe Work Practices are provided

in Section 6.2 of this document. A current listing and copies of all Safe Work Practices are maintained by the Laser Safety Officer (LSO).

4. Suggesting solutions to improve the safety of the process, equipment, production materials, and training.
5. Knowing safety and emergency equipment locations and operating procedures.
6. Regularly communicating safety information to students as necessary.
7. Ensuring that students are aware of, and familiar with, emergency procedures and the proper use of emergency equipment.
8. Ensuring that all safety training of students is documented and maintained in Department files.
9. Reinforcing training by monitoring the activities of students for unsafe acts and implementing corrective action as necessary.
10. Issuing Facility work orders to the Department Technician to initiate safety corrective actions.
11. Placing defective or unsafe equipment out of service and contacting the Department Technician to arrange for servicing of equipment that is in need of maintenance and/or repair.
12. Maintaining personal work areas in accordance with housekeeping guidelines.

2.3 Laser Safety Officer

The ANSI Z136.1 standard requires the appointment of a Laser Safety Officer for operations with lasers above class 2. This officer is qualified either through training or experience to oversee the development and implementation of the LSP. This designated officer may hold another job title provided he or she is technically competent to fulfill the responsibilities of both job titles. The Laser Safety Officer (LSO), is responsible for:

1. Providing technical guidance and assisting the Plan Administrator in the development and implementation of the Laser Safety Plan.
2. Assisting in the development and documentation of Safe Work Practices for their laboratory.
3. Assisting in the inspection of the laboratories for continual compliance on an annual basis and more frequently as necessary.
4. Reviewing the LSP annually or more frequently as necessary to keep plan current.
5. Responsible for resolution of appropriate laser safety management issues through SSU’s EH&S.
6. Making certain that Safety Data Sheets if chemicals are stored or used and other related information are available to all employees anytime the lab is accessible.

2.4 Associate Laser Safety Officer

The Associate Laser Safety Officer will work closely with the LSO to ensure continuity and implementation of the Plan for any newly appointed LSOs. The Associate LSO has the same responsibilities as the LSO, and will complete laser safety assignments as directed by LSO. The Associate LSO shall also adhere to the following responsibilities:

1. Notifying lab faculty and staff of the location of this LSP in laboratory areas for reference.
2. Investigating all accidents within their area of supervision and submitting a completed Incident Investigation Report to the Director of EH&S within 24 hours.
3. Ensuring that area-specific safety self-inspection Plans occur in all laboratories with lasers and potentially dangerous electrical energy at least quarterly. If the audit demonstrates a lack of compliance, notify Department Plan Administrator and EH&S.

2.5 Laser Safety Committee

The Laser Safety Committee is advisory to the Dean of Science and Technology (Plan Administrator), on matters related to the campus Laser Safety Plan. The Committee is comprised of faculty members representing various laser use areas of research and teaching, and members who represent the campus administration including the Director of Environmental Health & Safety.

The Laser Safety Committee has the authority to oversee the use of lasers throughout the campus. Thus, the Laser Safety Committee provides recommendations to the Plan Administrator and EH&S to permit, deny or revoke authorization for individuals to obtain and use lasers on the Sonoma State University campus.

The responsibilities of the Laser Safety Committee include the following:

1. Review proposals for unusually hazardous uses of lasers and establish criteria for equipment and procedures to ensure employee, student and public safety.
2. Review cases, which involve repeated infractions of the rules and regulations for laser safety.
3. Review accidents, which may involve injury or serious economic loss, and other cases for which reports to outside regulatory authorities are required.
4. Review appeals from laser users to modify rules or the decisions of EH&S.
5. Meet formally as often as necessary to review campus laser safety with EH&S.
6. Recommend the establishment or modification of campus laser safety policies.

2.6 Environmental Health and Safety

Environmental Health and Safety is responsible for certain elements of the LSP. These elements include:

1. Overseeing the education and training of faculty and staff before using lasers.
2. Ensuring that medical consultative services are available to those employees requesting or needing such services.
3. Responsible for resolution of appropriate laser safety management issues.

2.7 Facilities Department

The Facilities Department is responsible for:

1. Reviewing and approving laboratory equipment installations for compliance with pertinent building codes and regulations.
2. Maintaining and servicing facilities-related equipment which services laboratories including local exhaust ventilation systems and emergency/life safety equipment (e.g. building fire alarms and fire extinguishers).
3. Providing guidance to Laboratory management, researchers, and the LSO regarding appropriate engineering control installations for chemical and physical hazards.
4. Testing the performance of laboratory exhaust hoods biennially.

Section Three

Preplanning and Approval of Proposed Laboratory Operations

3.1 Approval Process

All proposed new or modified laboratory equipment/operations which use equipment that poses the potential for unique physical hazards (e.g. non-ionizing radiation, high voltage) require review and approval of the Laser Safety Committee, Plan Administrator, EH&S, and LSO prior to use and/or installation. This approval is accomplished by submitting the completed Laser Registration Form and Safe Work Practices to the LSO for review by the Laser Safety Committee. The Committee will recommend necessary modifications, deny or approve and provide rationale as warranted. ONLY after approval by the Laser Safety Committee, LSO, EH&S and the Plan Administrator may equipment be placed in service. New equipment shall be pre-approved for purchase by LSO. This requirement does not include newer replacement equipment or equipment with Underwriters Laboratory (UL) or other safety inspected and certified equipment. This review is required for **all** class 3 and 4 lasers whether lasers are embedded or not.

3.2 Laboratory Safety Support Equipment

Laboratory areas shall be equipped with the following as determined necessary by Campus Engineering, EH&S and LSO:

1. Fire sprinkler system
2. Fire extinguisher(s)
3. Eyewash and Safety shower (where corrosive chemicals are used)
4. Eye wash (where hazardous materials are used)
5. Respirators (if required by EH&S)
6. Safety glasses/goggles (appropriate for specific laser strength/intensity/wavelength)
7. Face shields (appropriate for specific laser strength/intensity/wavelength)
8. Lab protective clothing
9. Lab entry postings/signage
10. Fume hood(s)
11. Safety signage
12. Other equipment as may be deemed necessary by the Plan Administrator, EH&S or LSO including but not limited to interlocking devices.

Section Four

Laser Classifications

Lasers and laser systems are classified by potential hazard according to a system described in the American National Standards Institute (ANSI) standard Z136.1, and in 21 CFR part 1040. A laser's classification is based on several factors including its wavelength, power output, accessible emission level, and emission duration. The level of hazard associated with each class of lasers is listed below.

4.1 Class 1

Lasers in this class are incapable of causing eye or skin damage. These lasers are exempt from labeling requirements.

- Not capable of emitting in excess of the Class 1 Accessible Emission Limit (AEL).
- Most lasers in this class are lasers which are in an enclosure prohibiting or limiting access to the laser radiation.

4.2 Class 2

Lasers in this class emit visible light only. They are only capable of producing eye damage if the beam is stared at directly for longer than the normal human aversion response time (blink reflex) to bright light (0.25 second). This means a person would naturally turn away from the beam before any damage is done.

- All Class 2 lasers are in the visible region of the spectrum.
- Continuous wave lasers which can emit accessible radiant power which exceeds the Class 1 AEL for the maximum duration inherent in the laser, but do not exceed 1 mW.
- Pulsed lasers which can emit accessible radiant power which exceeds the Class 1 AEL for the maximum duration inherent in the laser, but not to exceed the Class 1 AEL for an exposure of 0.25 s and not to exceed an average radiant power of 1 mW.

4.3 Class 3a

Lasers in this class are capable of causing eye damage from short-duration (<0.25s) viewing of the direct beam.

- Have output that is less than 5 times Class 2 AELs for wavelengths between 400 to 700 nm.
- Have an accessible output between 1 and 5 times the Class 1 AEL for wavelengths shorter than 400 nm or longer than 700 nm.

4.4 Class 3b

Class 3b lasers are capable of causing eye damage from short-duration (<0.25s) viewing of the direct or specularly-reflected beam. Diffuse reflections from these lasers are generally not hazardous, except for intentional staring at distances close to the diffuser.

- Continuous wave - between the Class 3a limits and 500 mW.
- Repetitively pulsed - radiant energy between 30-150 mJ per pulse for visible and infrared, otherwise greater than 125 mJ per pulse; average power less than 500 mW .

4.5 Class 4

Lasers in this class are high powered and capable of causing severe eye damage with short-duration exposure to the direct, specularly-reflected, or diffusely-reflected beam. They are also capable of producing severe skin damage. Flammable or combustible materials may ignite if exposed to the direct beam.

Limits exceed Class 3b limits.

4.6 Embedded Lasers

A laser system of one class may contain a laser of a higher class. For example, a class 3a system might contain a class 4 laser in an interlocked protective housing which incorporates design features to limit the accessible emission level to the class 3a level.

If a laser or laser system has been manufactured by or modified at Sonoma State University, the principal investigator or laboratory director is responsible for determining the laser's proper classification. This classification may be accomplished using one of the following tables (taken from ANSI Z136.1 -- 2000) depending if the laser is pulsed or continuous. Regardless of listed classification for procedural and safety purposes the actual class of the embedded laser will be used to determine safety requirements.

4.7 Typical Classification Table for Continuous Wave (CW) Small-Source Lasers

Wavelength (μm)	Laser type	Wavelength (μm)	Class 1* (W)	Class 2* (W)	Class 3** (W)	Class 4* (W)
Ultraviolet 0.180 to 0.280	Nd:YAG (Quadrupled)	0.266	≤9.6 x 10^{-9} for 8 hours	None	>Class 1 but ≤0.5	>0.5
	Argon	0.275				
Ultraviolet 0.315 to 0.400	He-Cd	0.325	≤3.2 x 10^{-6}	None	>Class 1 but ≤0.5	>0.5
	Argon	0.351, 0.363				
	Krypton	0.3507, 0.3564				
Visible 0.400 to 0.700	He-Cd	0.4416 only	<4 x 10-5	> Class 1 but <1 x 10-3	> Class 2 but <0.5	>0.5
	Argon (visible)	0.457	≤5 x 10^{-5}			
		0.476	≤1 x 10^{-4}			
		0.488	≤2 x 10^{-4}			
		0.514	≤4 x 10^{-4}			
	Krypton	0.53				
	Nd:YAG (doubled)	0.532				
	He-Ne	0.543				
	Dye	0.400 - 0.500	≤0.4C_B x 10^{-4}			
	He-Se	0.460 - 0.500				
	Dye	0.550 - 0.700	≤4 x10^{-4}			
	He-Ne	0.632				
	InGaAIP	0.67				
	Ti:Sapphire					
	Krypton	0.6471, 0.6764				

<table>
<tr><th>Wavelength (µm)</th><th>Laser type</th><th>Wavelength (µm)</th><th>Class 1* (W)</th><th>Class 2* (W)</th><th>Class 3** (W)</th><th>Class 4* (W)</th></tr>
<tr><td>Near Infrared 0.700 to 1.400</td><td>GaAlAs</td><td>0.78</td><td><5.6 x 10-4</td><td rowspan="15">None</td><td rowspan="15">> Class 1 but ≤0.5</td><td rowspan="15">>0.5</td></tr>
<tr><td></td><td>GaAlAs</td><td>0.85</td><td>≤7.7 x 10^{-4}</td></tr>
<tr><td></td><td>GaAs</td><td>0.905</td><td>≤9.9 x 10^{-4}</td></tr>
<tr><td></td><td>Nd:YAG</td><td>1.064</td><td>≤1.9 x 10^{-3}</td></tr>
<tr><td></td><td>He-Ne</td><td>1.08</td><td>≤1.9 x 10^{-3}</td></tr>
<tr><td></td><td></td><td>1.152</td><td>≤2.1 x 10^{-3}</td></tr>
<tr><td></td><td>InGaAsP</td><td>1.31</td><td>≤1.5 x 10^{-2}</td></tr>
<tr><td>Far Infrared 1.400 to 1000</td><td>InGaAsP</td><td>1.55</td><td rowspan="6">≤9.6 x 10^{-3}</td></tr>
<tr><td></td><td>Holmium</td><td>2.1</td></tr>
<tr><td></td><td>Erbium</td><td>2.94</td></tr>
<tr><td></td><td>Hydrogen Fluoride</td><td>2.600 - 3.00</td></tr>
<tr><td></td><td>He-Ne</td><td>3.390 only</td></tr>
<tr><td></td><td>Carbon Monoxide</td><td>5.000 - 5.500</td></tr>
<tr><td></td><td>Carbon Dioxide</td><td>10.6</td><td rowspan="3">≤9.5 x 10^{-2}</td></tr>
<tr><td></td><td>Water Vapor</td><td>118</td></tr>
<tr><td></td><td>Hydrogen Cyanide</td><td>337</td></tr>
<tr><td colspan="7">* Assumes no mechanical or electrical design incorporated into laser system to prevent exposures from lasting to T_{max} = 8 hours (one workday); otherwise the Class 1 AEL could be larger than tabulated.</td></tr>
<tr><td colspan="7">** Class 3a lasers and laser systems include lasers and laser systems which have an accessible output between 1 and 5 times the Class 1 AEL for wavelengths shorter than 0.4um or longer than 0.7 um, or less than 5 times the Class 2 AEL for wavelengths between 0.4 and 0.7 um.</td></tr>
</table>

4.8 Typical Classification Table for Single Pulse Small Source Lasers

Wavelength (µm)	Laser type	Wavelength (µm)	Pulse Duration (s)	Class 1 (J)	Class 3b (J)	Class 4 (J)
Ultraviolet 0.180 to 0.400	Excimer (ArF)	0.193	20×10^{-9}	$\leq 2.4 \times 10^{-5}$	> Class 1 but ≤ 0.125	> 0.125
	Excimer (KrF)	0.248	20×10^{-9}	$\leq 2.4 \times 10^{-5}$		
	Nd:YAG Q-switched (quadrupled)	0.266	20×10^{-9}	$\leq 2.4 \times 10^{-5}$		
	Excimer (XeCl)	0.308	20×10^{-9}	$\leq 5.3 \times 10^{-5}$		
	Nitrogen	0.337	20×10^{-9}	$\leq 5.3 \times 10^{-5}$		
	Excimer (XeF)	0.351	20×10^{-9}	$\leq 5.3 \times 10^{-5}$		
Visible 0.400 to 0.700	Rhodamine 6G (Dye laser)	0.450 - 0.650	1×10^{-6}	$\leq 1.9 \times 10^{-7}$	> Class 1 but ≤ 0.03	> 0.03
	Copper vapor	0.510, 0.578	2.5×10^{-9}			
	Nd:YAG (doubled) (Q-switched)	0.532	20×10^{-9}			
	Ruby (Q-switched)	0.6943	20×10^{-9}			
	Ruby (Long pulse)	0.6943	1×10^{-3}	$\leq 3.9 \times 10^{-6}$		
Near Infrared 0.700 to 1.400	Ti:Sapphire	0.700 - 1.000	6×10^{-6}	$\leq 1.9 \times 10^{-7}$		
	Alexandrite	0.720 - 0.800	1×10^{-4}	$\leq 7.6 \times 10^{-7}$	> Class 1 but ≤ 0.033	> 0.033**
	Nd:YAG (Q-switched)	1.064	20×10^{-9}	$\leq 1.9 \times 10^{-6}$	> Class 1 but ≤ 0.125	>0.125

Wavelength (μm)	Laser type	Wavelength (μm)	Pulse Duration (s)	Class 1 (J)	Class 3b (J)	Class 4 (J)
Far Infrared 1.400 to 1000	Erbium:Glass	1.54	10×10^{-9}	$\leq 7.9 \times 10^{-3}$	> Class 1 but $\leq$0.125	> 0.125
	Co:Mg-Fl	1.8 - 2.5	80×10^{-6}	$\leq 7.9 \times 10^{-4}$		
	Holmium	2.1	250×10^{-6}	$\leq 7.9 \times 10^{-4}$		
	Hydrogen Fluoride	2.600 - 3.000	0.4×10^{-6}	$\leq 1.1 \times 10^{-4}$		
	Erbium	2.94	250×10^{-6}	$\leq 5.6 \times 10^{-4}$		
	Carbon Dioxide	10.6	100×10^{-9}	$\leq 7.9 \times 10^{-5}$		
	Carbon Dioxide	10.6	1×10^{-3}	$\leq 7.9 \times 10^{-4}$		

* Assuming that both eye and skin may be exposed, i.e., 1.0 mm beam (area of limiting aperture = 7.9×10^{-3} cm^2)

** Class 3b AEL varies from 0.033 to 0.480 J corresponding to wavelengths that vary between 0.720 and 0.800 um.

Section Five

Laser and Laser System Hazards

5.1 Eye

Different structures of the eye can be damaged from laser light depending on the wavelength. Retinal burns, resulting in partial or complete blindness, are possible in the visible (400 - 700 nm) and near-infrared (700 - 1400 nm) regions. At these wavelengths, the eye will focus the beam or a specular reflection on a tiny spot on the retina. This focusing increases the irradiance of the beam by a factor of about 100,000.

Laser emissions in the ultraviolet (< 400 nm) and infrared to far-infrared (> 1400 nm) regions are primarily absorbed by and cause damage to the cornea. In the near-ultraviolet range (315 - 400 nm), some of the radiation reaches the lens of the eye.

5.2 Skin

Skin damage can occur from exposure to infrared or ultraviolet light. For infrared exposure, the results can be thermal burns or excessively dry skin depending on the intensity of the radiation. In the 230 - 380 nm range of ultraviolet light, erythema (sunburn), skin cancer, or accelerated skin aging are possible. The most damaging region of ultraviolet is 280 - 315 nm, also known as UV-B.

5.3 Electrical

Many lasers contain high-voltage components, which can present a potentially lethal hazard. Proper lockout/Tagout and electrical safety procedures shall be followed when working on high-voltage components. Contact EH&S for proper procedures and equipment.

5.4 Fire

Many class 4 lasers are capable of igniting combustible materials. Care should be taken when choosing beam stops and shielding material.

5.5 Hazardous Materials

Laser laboratories contain many of the same hazards found in many chemical laboratories and therefore the same precautions should be taken. In addition, most laser dyes are considered to be hazardous materials and should be handled accordingly. Laser interactions with certain materials may produce toxic fumes, which must be properly vented. Therefore, all areas that use hazardous chemicals must also adhere to all Chemical Hygiene Plan requirements.

Section Six

Safe Laboratory Work Practices and Procedures

6.1 General Principles

This section describes administrative, procedural and engineering measures, which can reduce the chance of a laser-related incident. These measures shall be considered when evaluating a class 2 and higher laser operations. Although some items are appropriate for all facilities (e.g. posting proper warning signs), others may not be practical for some operations. Primary control measures are *italicized* for emphasis. In most cases, implementing these measures will provide the most effective safety considerations.

6.1.1 Beam Control

Enclosure of the laser equipment or beam path is the preferred method of control, since the enclosure will isolate or minimize the hazard. As a minimum, beam stops must be used to ensure no direct or specularly reflected laser light leaves the experiment area.

Laser beams height should be maintained at a level other than the normal position of the eye of a person in the standing or seated position. Securely fasten the laser and all optics on a level, firm, and stable surface.

6.1.2 Reflections

Remove unnecessary reflective items from the vicinity of the beam path. Do not wear reflective jewelry such as rings or watches while working near the beam path.

Be aware that lenses and other optical devices may reflect a portion of the beam from their front or rear surfaces.

Avoid placing the unprotected eye along or near the beam axis. The probability of a hazardous specular reflection is greatest in this area.

6.1.3 Power Level

The minimum laser radiation required for the application should be used. Operate a laser at the minimum power necessary for any operation. Beam shutters and filters can be used to reduce the beam power. Use a lower power laser when possible during alignment procedures. *Ensure that key or code controls are in place for all class 3b and 4 lasers and must ALWAYS be under control of supervisory personnel ANSI Z136.1 Section 4.3.4.*

6.1.4 Sign and Labels

The entrance to a class 3b or 4 laser facility must be posted with the appropriate warning sign. Each laser must be labeled as required by 21 CFR part 1040. These labels show the classification of the laser and identify the aperture(s) where the laser beam is emitted. Signs and labels may be obtained through EH&S. Warning signs are required for class 2 and higher lasers, refer to ANSI Z136.1 Section 4.7.

6.1.5 Warning Devices

Class 4 laser facilities where the beam is not fully enclosed should have a visible warning device (e.g. a flashing red light) at the outside of the entrance, which indicates when a laser is in operation.

6.1.6 Control of Area

Except for fully enclosed and interlocked systems, an authorized user must be present or the room kept locked during laser operations.

6.1.7 Interlocks

Many laser systems have interlocked protective housings, which prevent access to high-voltage components or laser radiation levels higher than those accessible through the aperture. These interlocks should not be bypassed without the specific authorization of the Principal Investigator. Additional control measures must be taken to prevent exposure to the higher radiation levels or high voltage while the interlock is bypassed.

6.1.8 Personal Protective Equipment

Eye protection designed for the specific wavelength of laser light should be available and worn when there is a chance that the beam or a hazardous reflection could reach the eye. The manufacturer should mark protective eyewear with the wavelength range over which protection is afforded and the minimum optical density within that range. Eyewear should be examined prior to each use and discarded if there is damage, which could reduce its effectiveness.

Protective eyewear generally will not provide adequate protection against viewing the direct beam of a high-powered laser. Wearing protective eyewear should not be used as an excuse for performing an unsafe procedure.

6.1.9 Operating Procedures

Written operating procedures shall be prepared prior to initial operation and be made available. These procedures shall include applicable safety measures for all class 3 and higher lasers.

6.1.10 Maintenance/Service

Only a knowledgeable person who has been specifically authorized by the LSO's designated lead for each lab should perform maintenance, servicing, or repair of a laser. Whenever such work involves accessing an embedded laser of a higher class, the controls appropriate to the higher class must be applied.

Any laser, which is significantly modified, must be re-evaluated to determine its classification.

6.1.11 Other Considerations

The following general safety principles should be observed by all personnel when working with lasers and associated chemicals:

1. Substitute less toxic materials whenever possible (e.g., toluene may be substituted for benzene).

2. Minimize all exposures through the use of engineering (e.g., lab-hoods, interlocks), administrative (e.g. Safe Work Practices), and personal protective (e.g. gloves, eye protection) controls.
3. Obtain and read the Safe Work Practices, SDS and other hazard information on equipment, solids, liquids, and gases used to support laboratory operations.
4. Confine long hair and loose clothing in the laboratory.
5. Be knowledgeable in the use of laboratory emergency equipment such as eyewashes, showers, emergency shutoffs, fire extinguishers, and receive information about how to obtain additional help in an emergency.
6. Carefully label or cross-reference every secondary container with the identity of its contents. Appropriate hazard warnings will be required if more than one person will be using the secondary container or if the container is to be left unattended for more than half an hour.
7. Utilize equipment only for its designed purpose.
8. Keep the work area clean and orderly.
9. Provide a means of containing the materials if equipment or containers should break or spill their contents (secondary containment). A pre-determined spill abatement procedure should be part of the Safe Operating Procedure, which covers the use of the chemical.
10. Limit the volume of volatile or flammable materials to the minimum needed for short operation periods.
11. All chemical storage cabinets and racks, and all laboratory equipment using hazardous materials shall be seismically braced in accordance with best structural engineering practices.
12. Consider the appropriateness of engineering design controls for systems that can generate or operate at high or low pressure.

6.2 Safe Work Practices

The most important administrative controls for hazardous operations are the safe work practices that are developed and used in the Laboratory. **Safe work practices** are those practices used in a laboratory operation, which have been communicated via on-the-job training, through reading of equipment and process specifications, and through reading of general safety information.

Written safe work practices are required for Class 3 and higher laser operations and recommended for other potentially hazardous operations. Safe work practices should be developed by the appropriate technician and maintained as discussed in Appendix Three of this document. A list of "high hazard" operations requiring Safe Work Practices by classification is provided below.

Example High Hazard Operations Requiring Written Safe Work Practices

1. Equipment and processes which use carcinogenic, mutagenic, or teratogenic substances.
2. Equipment or processes which use more than 1 pint/ 1 pound of organic solvents, acids, bases, oxidizers, heavy metals, toxic materials.

3. Equipment or processes which involve accessible hazardous electricity or ionizing and non-ionizing radiation, including laser light.
4. Powered machining areas and equipment.
5. Any other area/operation as deemed appropriate by the Plan Administrator, LSO or EH&S.

6.3 Health and Hygiene

1. Contamination of food, drink, and smoking materials is a potential route for exposure to toxic substances. Food shall be stored, handled, and consumed in areas free of hazardous substances.
2. Food and drink shall not be permitted in areas where chemicals or chemical equipment are being used.
3. Glassware or utensils that have been used for laboratory operations should never be used to prepare or consume food or beverages. Laboratory refrigerators and ice chests shall not be used for food storage.
4. Thoroughly wash hands and remove contaminated lab coats etc. prior to leaving laboratory.

6.4 Unattended Operations & Working Alone

6.4.1 General

Precautions should be taken for unattended laboratory operations that are carried out continuously or overnight. Unattended operations should be designed to be safe, and plans should be made to avoid hazards in case of failure. If possible, make arrangements for routine surveillance (e.g., each hour) of the operation, leave the lights on, and leave an appropriate sign on the door to indicate that the operation is going but has been left unattended.

1. Names and telephone numbers of lab operator(s) are to be posted on the entrance door for unattended operations.
2. Operations requiring cooling water shall employ monitoring devices that will shut the operation down in the event of water supply failure.
3. In general, it is imprudent to work in laboratories alone. Arrangements should be made between individuals working in separate laboratories to crosscheck with one another periodically.
4. **Laboratory work known to be hazardous must not be undertaken by faculty/staff alone in a laboratory. At least two persons must be present. Safe Work Practices shall specify this requirement.**
5. Students shall not be left unsupervised while conducting potentially hazardous work in the laboratory.

6.4.2 Working Alone

SSU employees should not work alone in laboratories when involved in highly hazardous operations. Examples of highly hazardous operations follow:

1. Working with Class 3b or 4 lasers.

2. Confined space entry.
3. Conditions requiring the use of Self-Contained Breathing Apparatus (SCBA), air line respirators, or Supplied Air Breathing Apparatus (SABA).
4. Work on energized high voltage (600 volts or more) electrical equipment.
5. Work involving the potential for atmospheres Immediately Dangerous to Life or Health (IDLH). (e.g., those operations where engineering controls are not in place to preclude IDLH atmospheres from occurring).
6. Work on unguarded moving equipment or machinery.
7. Work on energized high-pressure systems or vessels.
8. Work with high-energy materials (i.e., oxidation, polymerization, radioactive, etc.).
9. Work in laboratories involving the handling and processing of bulk chemicals (e.g., greater than 1 gallon containers).
10. Any other work activity identified by the Plan Administrator, LSO or EH&S as being too hazardous to be performed alone.

6.5 Housekeeping

The following housekeeping practices should be observed at all times in the laboratory:

1. There is a definite relationship between safety performance and orderliness in the laboratory. Work areas should be kept clean and free from obstructions. Cleanup should be completed following any operation or at least, the end of each day.
2. Stairways and hallways shall not be used as storage areas.
3. Spilled chemicals shall be identified, isolated, safely as soon as feasible, cleaned up and disposed of properly. Only trained personnel shall perform spill clean-ups. Spills of large quantities of chemicals where there is the potential for personal injury, for environmental impact, and for property damage shall be reported to EH&S for response.
4. Old containers and chemical wastes should be disposed of promptly and not be allowed to accumulate in the laboratory. Wastes shall not be accumulated for more than 90 days except in designated satellite accumulation areas. Waste containers shall be labeled for contents and dated with lids tightly closed except when filling. See Chemical Hygiene Plan for further information.
5. Non-hazardous materials spills (e.g. water) are to be cleaned up immediately.
6. Access to exits, emergency equipment, and essential equipment shut downs and controls shall never be blocked.
7. Equipment and chemicals all should be stored properly; clutter should be minimized.

6.7 Fiber Optics

The following safe work practices should be observed at all times in the laboratory:

1. Do not operate the fiber cleaving or the fusion splicer unless you have been properly instructed by the appropriate faculty or laboratory technician.
2. Safety glasses must be worn at all times while cleaving fibers.
3. The cut ends of optical fiber are dangerous. They are basically glass needles that will penetrate flesh then break off and become nearly impossible to remove. Once in your body, it will likely become infected.
4. Find and dispose of all cut fiber fragments immediately after cutting. Proper disposal means placing them in an approved fiber disposal unit (not a trash can).
5. Handle cut fiber fragments with tweezers only.
6. It is the operator's responsibility to ensure that no fiber fragments 'escape' and injure someone. If you lose a fiber fragment you must look until you find it or it is sure to stick someone (maybe you a few minutes later).
7. Fiber fragments can stick to the cover of the cleaver. Move slowly when opening the cover. Always look on the inside of the cover if you don't see your fragment on the shelf. Fragments can also fall down by the diamond wheel.
8. If you can't find your fragment, get more light on the subject and work area. Do not move the cleaver until the fragment has been found. Use a magnifying glass if you need to but FIND THAT FRAGMENT.

6.8 Access to SSU Laboratories

Access to SSU Laboratories is controlled by Faculty and Technicians. SSU requires that every employee, visitor, contractor, or other person performing work at the site be familiar with, and observe the applicable SSU EH&S requirements. New employees and, where appropriate, contractors, students and visitors are required to receive safety and hazard training matched to their responsibilities and duties. The responsible Faculty and or Principal investigator ensures that this requirement is met in their areas.

6.9 Safety & Emergency Equipment

6.9.1 Equipment Guarding

1. All machining, test and mechanical equipment shall be adequately furnished with guards that prevent access to hazardous electrical connections, pinch points or moving parts.
2. All guards should be inspected before using equipment.
3. Faculty/Staff shall not turn on, use, repair, or operate any hazardous laboratory equipment unless trained and authorized by the responsible lab technician or faculty member.

6.9.2 Shields

Safety shields must be used for protection against possible explosions or uncontrolled reactions. Laboratory equipment must be shielded on all sides so that there is no line-of sight exposure to personnel. The sash on a chemical fume hood is a readily available partial shield. However, a portable shield must also be used, particularly with hoods that have vertical-rising sashes rather than horizontal-sliding sashes for operations having the potential for explosion such as:

1. Whenever a reaction is attempted for the first time (small quantities of reactants should be used to minimize hazards); and
2. Whenever a familiar test or reaction is carried out on a larger than usual scale.

6.9.3 Pressure

Standards for the use of pneumatic and high-pressure hydraulic equipment are available in American Society of Mechanical Engineering (ASME) documents however; the following are additional requirements for laboratory operations:

1. Reactions should never be carried out in, nor heat applied to, an apparatus that is a closed system unless it is designed and tested to withstand pressure.
2. Pressurized apparatus shall have an appropriate relief device.
3. If the reaction cannot be opened directly to the air, an inert gas purge and bubbler system should be used to avoid pressure buildup.
4. All pressurized gas cylinders and systems shall be installed and used in accordance with Safe Operating Procedures developed by faculty or lab technicians and approved by EH&S for safe equipment usage, handling, and storage.

6.9.4 Eyewash & Showers

1. Eyewash fountains are <u>required</u> if the substance in use presents an eye hazard (e.g., any corrosive). The eyewash fountain must provide a soft stream or spray of aerated water.
2. Safety showers must be provided in areas where a corrosive chemical or rapid fire hazard exists, for immediate first aid treatment of chemical splashes and for extinguishing clothing fires. The shower must be capable of drenching the victim immediately in the event of an emergency.
3. Eyewash fountains and safety showers should be located close to each other so that, if necessary, the eyes can be washed while the body is showered. Access to these facilities must remain open at all times and within ten seconds of travel distance. In case of accident, flush the affected body part for at least 15 minutes. Report the accident to 911 from an internal phone for assistance.
4. Eyewash and showers shall be tested and flushed by Facilities personnel at least monthly to ensure that they are operating properly. Inspection tags must be filled out to document testing. Faulty equipment shall be repaired by Facilities, when problem is identified or upon request.

6.9.5 Fire Extinguishers

Laboratories using hazardous chemicals should have a BC or ABC rated, dry chemical or CO2 fire extinguisher in close proximity of any exit for use on ordinary combustibles, flammable liquids, and electrical fires. If additional extinguishers are needed for an area, contact EH&S for information concerning recommendations and requirements.

Section Seven

Training and Employee Information

7.1 Introduction

Principal Investigators, Laboratory Directors, Faculty and Staff must be provided area-specific training on the hazards to which they may be exposed and the means to avoid these hazards prior to using equipment. Training must be updated when a new hazard is introduced into the workplace. Training must be approved by the LSO with the assistance of EH&S. New Faculty or Staff must receive "On the Job Training" by the LSO or an approved designee.

Further, all trainers whether training other faculty, staff or students must demonstrate the appropriate understanding of the system to be used and prepare the appropriate training including a written quiz that must be passed (80% minimum pass) by ALL users and students that will demonstrate minimal understanding of hazard and safe operating principles.

For additional information on Hazard Communication, refer to the SSU Hazard Communication Program. For additional information on Training Requirements, see the SSU "Injury and Illness Prevention Program".

As a minimum, area-specific training must include:

1. The use of safe work practices,
2. An indication of which operations involve hazardous materials;
3. Potential chemical, physical, and/or biological hazards;
4. Applicable health and safety standards;
5. Purpose and results of exposure monitoring for chemical and physical hazards;
6. Purpose and use of control measures;
7. Requirements for use of personal protective equipment;
8. Detection systems, light head turn response, odor and irritation threshold for chemicals, monitors, alarms, odors, symptoms, etc.;
9. Safety Data Sheet-location and how to use;
10. The requirements of Laser Safety Plan and Chemical Hygiene Plan (where applicable);
11. Non-routine tasks; and
12. Labeling, Postings, and Signage Requirements.

13. When working with Hazardous Materials in the lab, information regarding the material and its possible reproductive effects shall be provided. (See Chemical Hygiene Plan)
14. While working in the lab, all should be cognizant of the existence of special hazards concerning pregnant women, women of childbearing age, and for those planning to have children. (See Chemical Hygiene Plan)

7.2 Responsibilities

It is the faculty or staff member's responsibility to work safely and ensure that the students work safely to prevent harm to themselves, the general public and environment. SSU safety standards must be observed. To assist Faculty and Staff, general health and safety training is coordinated by EH&S upon request. Any condition that may lead to a violation of these standards must be reported immediately to the LSO or EH&S. Faculty and Staff are obligated to stop work under unsafe conditions. Report any injuries received on the job. In addition, Faculty and Staff are obligated to respond to emergencies by following laboratory emergency procedures.

Faculty and Staff must be instructed about potential hazards involved in the lab, proper safety precautions to follow and emergency procedures to use if an accident should occur. Examples of training required for Faculty and Staff includes:

1. Laser Safety
2. Hazard Communication
3. Chemical Hygiene & Safety in the Laboratory
4. Hazardous Waste Generator Training
5. Emergency Procedures
6. Lockout/Tag-out and Electrical Safety

Other training that may be required depending on lab assignments, chemical agents and/or physical hazards includes:

1. Radiation Safety
2. Respirator Use
3. Specialized Chemical Safety Training
4. Hearing Conservation
5. CPR
7. First Aid
8. Fire Extinguisher Use

7.3 Emergencies and Incidents

7.1 Emergencies

For any emergency requiring Police, fire or ambulance, call 911 or 707-664-4444.

7.2 Emergencies or Incidents Involving Lasers

In the event of an accident or incident involving a laser: TURN OFF THE LASER

If there is a serious injury or fire, call 911.

Notify Environmental Health & Safety at 664-2932. If after work hours contact University Police at 664-4444 and have the dispatcher contact EH&S. EH&S will contact Laser Safety Officer.

Notify the Laboratory supervisor, Principal Investigator or Laboratory Director.

Section Eight

Medical Consultations and Monitoring

9.1 Criteria for Selection

SSU has established a Medical Surveillance Program to monitor the health status of faculty and staff with respect to the hazards of the materials and process equipment they use. This Section summarizes those requirements.

Medical consultation and examinations are provided under the direction of consulting physician(s) at a contract medical services facility. The primary objectives of the Medical Consultation and Monitoring program are:

- To ensure that staff and faculty are assigned duties they are physically able to perform.
- To provide medical care and rehabilitation of the occupationally ill or injured.
- To provide emergency treatment of serious illnesses or injuries.
- To encourage staff and faculty to maintain their physical and mental health.
- To assist in maintaining a healthful and safe work environment.
- The primary medical monitoring required for all Principal Investigators Laboratory Directors, Faculty and staff is laser eye exams, which are required prior to working with lasers. This is required for users of Class 3 and 4 lasers and is initial and at the time of separation with the University.

9.2 Exposure Incidents

ANSI Z136.1 Table 5 and Table 7 present maximum permissible exposure limits for ocular exposure and skin exposures, respectively. If these limits are exceeded or may be exceeded, potential exposure limits should be measured or calculated. If a potential or known exposure occurs, please complete the Supervisor's report of injury and other steps as described at http://web.sonoma.edu/hr/payroll/workers-compensation/incident-reporting.html

Section Nine

Recordkeeping

Accurate documentation and recordkeeping of exposure monitoring, medical surveillance and health and safety training is an important component of this LSP. This section defines the recordkeeping requirements for important aspects of the Plan.

9.1 Specific Recordkeeping Responsibilities:

Current Safe Work Practices, chemical inventories and Safety Data Sheets for each laboratory shall be readily available for staff and faculty access and reference in the event of an emergency. *Responsibility: Principal Investigator, Laboratory Director, Faculty and Staff using laboratories.*

Exposure records for hazardous laser operations, hazardous chemicals and harmful physical agents will be maintained for 30 years from end of employment per 29 CFR 1910.20. *Responsibility: Medical Monitoring Administrator, EH&S and LSO*.

Medical records for staff or faculty exposed to hazardous laser operations, hazardous chemicals and harmful physical agents will be maintained for the duration of employment plus 30 years per 20 CFR 1910.20. *Responsibility: EH&S*.

Additionally, the following records must be kept for a minimum of three years:

1. Staff and Faculty Training Records-will be held by EH&S and LSO or LSO designee, while Student Records are held by faculty. Student records must be held until class is completed, the semester ends or a student is no longer enrolled. This must include completed safety quizzes.
2. Area Sponsored or Area Specific Classes including Training on Safe Work Practices presented to students by faculty or staff; *Responsibility: Principal Investigator, Laboratory Director and Faculty*.
3. Accident Investigations. *Responsibility: School Dean of Science and Technology, EH&S and LSO*.
4. Laser Safety Committee Meetings; *Responsibility: LSO*.

Appendix One

Sonoma State University Laser Registration Form

Sonoma State University

LASER REGISTRATION FORM

Required for all class 3b or 4 lasers

Upon completion of this form return to:

Laser Safety Officer, Salazar 2003

Principal Investigator/Laboratory Director:	**Date:**
Department:	**Laser system location:** **Building/Room#**

I. LASER SAFETY CONTACTS:	**Name:**	**Phone:**
Principal Investigator/ Laboratory director:		
Laser Safety Officer:		
Service Contractor: In-house (Y / N)		
Emergencies:		

2. LASER DESCRIPTION

Type:	Wavelength(s):	Classification:
Manufacturer:	Model:	Serial #:

Description: (He-Ne, Nd-YAG, CO_2, etc.)

<u>Continuous Wave Laser</u>

Maximum Power(W):

<u>Pulsed Laser</u>

Maximum Energy(J):	Pulse Duration(ns):
Pulse Repetition Frequency(Hz):	

Beam Properties:

Emerging Beam Divergence (mrads):
Emerging Beam Dimensions (mm):

<u>Date Place in service:</u>

<u>Use of the laser system</u>: _____ Analysis	______ R&D	_____ Demo	____ Other
<u>Status of Unit:</u>	_____ Operable	_____ Inoperable	______Stored

3. OPERATING PROCEDURES:
a. Laboratory preparation and start-up procedures.
b. Target area preparation
c. Normal operating procedures.
d. Shut down procedures
e. Special operating procedures, including alignment, interlock bypass, maintenance and service.
f. Emergency procedures.

4. CONTROL MEASURES:

Y/N/NA	CONTROL	COMMENTS
	Entryway interlocks or controls are present.	
	Protective housing interlocks are present.	
	Enclosure interlocks are present.	
	Emergency stop/panic button is present.	
	Master switch is present .	
	Laser and associated equipment is secured to base.	
	Beam stops or attenuators are present.	
	Protective barriers are present.	
	Warning signs are posted.	
	Personal protective equipment is available and used.	
	Nominal Hazard Zone is defined.	
	Manufacturer's operating program is available.	

ADDITIONAL COMMENTS:

5. HAZARDS AND CONTROLS:

Y/N/NA	HAZARD	CONTROL MEASURES
	Unenclosed beam.	
	Potential exposure to direct beam or reflections.	
	Laser positioned at eye level.	
	Reflective materials in beam path.	
	Exposure to ultraviolet or blue light. .	
	Hazardous materials are used. (Dyes, solvents, etc.)	
	Hazardous waste is generated.	
	Laser generated air contaminants are generated.	
	Exposure to high voltage.	
	Compressed gases are used.	
	Fire hazards are present.	
	Plasma radiation is generated.	

ADDITIONAL COMMENTS:

6. PERSONAL PROTECTIVE EQUIPMENT (PPE) Laser Eyewear

FOR THIS LASER		WEAR THIS EYEWEAR		
Laser	Wavelength(s) (nm)	Wavelength(s) Attenuated (nm)	Optical Density	Manufacturer

Other PPE Required

7. Personnel who will use this laser system:

NAME:	**SSU ID#**	**Status (student or staff)**

8. OPERATOR REVIEW:

I have read this procedure and understand its contents.

Name:	Signature:	Date:

Appendix Two

Glossary of Terms

Accessible laser radiation

Laser radiation to which the human eye or skin may be exposed for the condition (operation, maintenance or service) specified.

Accessible Emission Level or Limit (AEL)

The magnitude of laser radiation to which human access is possible. Usually measured in watts for continuous wave lasers and in joules for pulsed lasers.

American National Standard for Safe Use of Lasers (ANSI Z136.1-2000.)

Document that provides guidance for the safe use of lasers and laser systems by defining control measures for each of four laser classifications. The University of Pennsylvania has adopted this standard as a minimum standard for laser safety.

Aperture

An opening through which laser radiation can pass. This term usually refers to the opening on the laser (or a protective housing) where the beam is emitted.

Attenuation

The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Authorized personnel

Individuals approved by the Principal Investigator or Laboratory Director to install, operate or service laser equipment.

Average power

The total energy in an exposure or emission divided by the duration of the exposure or emission.

Aversion response

Closure of the eyelid or movement of the head to avoid an exposure to a noxious stimulant or bright light. Aversion response to an exposure from a bright laser source is assumed to occur within .25 s, including the blink reflex time.

Collateral radiation

Any electronic radiation, except laser radiation, emitted by a laser or laser system that is physically necessary for its operation.

Collecting optics

Lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars or loupes.

Continuous wave (CW)

The output of a laser that is operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser operating with a continuous output for a period > 0.25 s is regarded as a CW laser.

Controlled area

An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation and related hazards.

Diffuse Reflection

A reflection where different parts of the beam are reflected over a wide range of angles, such as when hitting a matted surface. Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Embedded Laser.

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

Enclosed Laser System.

Any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure.

Erythema

Redness of the skin due to congestion of the capillaries.

Failsafe interlock

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

Fiber Optics

A system of flexible quartz or glass fibers with internal reflective surfaces that pass light through thousands of glancing (total internal) reflections.

Fluorescence

The emission of light of a particular wavelength resulting from absorption of energy typically from light of shorter wavelengths.

Incident personnel

Individuals working in areas where there is a potential for exposure to laser radiation from a Class 3b or Class 4 laser, but do not operate the laser.

Infrared Radiation (IR)

Invisible Electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 micrometers (1mm).

Intrabeam viewing

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

Irradiance or Intensity

The optical power per unit area reaching a surface (W/cm^2).

Laser

A device which produces an intense, coherent, directional beam of light. Also an acronym for Light Amplification by Stimulated Emission of Radiation.

Laser controlled area

See Controlled Area.

Laser operator

See Authorized Personnel.

Laser Safety Officer (LSO)

One who has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser System

An assembly of electrical, mechanical, and optical components which includes a laser.

Maintenance

Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product.

Maximum permissible exposure (MPE)

The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure (joules/cm2) or irradiance (watts/cm2). The criteria for MPE are detailed in Section 8 of ANSI Z136.1.

Nominal hazard zone (NHZ)

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

Operation

The performance of the laser or laser system over the full range of its intended functions (normal operation.)

Optical Density (OD)

A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter. OD = log10 (I_i/I_t) where I_i is the incident irradiance and I_t is the transmitted irradiance. Logarithm to the base ten of the reciprocal of the transmittance. The higher the optical density, the lower the transmittance.

Protective Housing

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

Pulsed Laser

A laser that delivers its energy in the form of a single pulse or a train of pulses, with a pulse duration of less than 0.25 s.

Q-switch

A device for producing very short (10-250 ns) intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Service

The performance of those procedures or adjustments described in the manufacturer's service instructions that may affect any aspect of the performance of the laser or laser system. These are usually performed by qualified technical personnel provided by the manufacturer or other service companies.

Repetitive pulse laser

A laser with multiple pulses of radiant energy occurring in sequence.

Reversible bleaching

The absorbing filter of laser eyewear may become temporarily saturated from an ultrashort laser pulse, causing the beam to pass through.

Scanning Laser

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

Shall

The word “shall” is to be understood as mandatory.

Should

The word “should” is to be understood as advisory.

Specular Reflection

A mirror-like reflection. The exact definition of a specular surface is one in which the surface roughness is smaller than the wavelengths of the incident light; a mirror-like reflection.

Tunable Laser

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

Ultraviolet (UV) Radiation

Electromagnetic radiation with wavelengths smaller than those of visible radiation. For the purpose of this Plan, wavelengths between 0.18 to 0.4 µm, specifically soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).

Visible Radiation (light)

Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths which lie in the range between 400 nm and 700 nm (or 0.4 to 0.7 µm).

Ultraviolet radiation

Electromagnetic radiation with wavelengths smaller than those of visible radiation.

Wavelength

The distance between two successive points on a periodic wave which have the same phase, which determines its color. Common units of measurement are the micrometer (micron) and the nanometer (nm).