California State University Laser Safety Manual

Steve Leland, LSO
sleland@csus.edu

Purpose

This manual is intended to reduce the risk of injuries associated with the use of lasers, support the teaching and research mission of CSUS with the safe use of lasers and to comply with ANSI standard Z136.1

Scope

This manual applies mainly to Class 3b and 4 lasers which must be used in a controlled area and also to embedded lasers that are Class 1, 2, or 3a under normal enclosed operating circumstances, but are Class 3b or 4 during service or maintenance procedures performed by CSUS employees.

Classes of Lasers

Class 1: (new IEC class 1 or 1M) Can't emit accessible laser radiation levels in excess of the acceptable emission limit (AEL) within the inherent design or intended use of the laser. Exempt, do not pose a hazard under normal operating conditions. These low powered lasers are incapable of producing injury when used as designed and intended and are exempt from engineering and administrative controls. A Class 1 laser could potentially have an embedded higher class inside of it. During service procedures with service panels removed and interlocks bypassed, it might be necessary to comply with higher class laser control measures during the service / repair procedure. Class 1 includes lasers that were formerly classified as Class 2a.

Class 2: (new IEC class 2 or 2M) **<1mWatt** or 0.1 Watt. Low power, visible spectrum (400-700nm wavelength) lasers can't cause eye injury in direct viewing of <.25 seconds, the natural aversion response time. Maximum Permissible Exposure limits can be exceeded only if the beam is viewed directly for extended periods beyond 0.25 seconds. Eye protection is the natural aversion response. Class 2M should not be viewed with optical aides such as telescopes, binoculars, magnifiers. A class 2 laser with a higher class of laser embedded inside of it might require higher class control measures during service or maintenance. A "CAUTION" label is required for these lasers warning users against staring directly into the beam.

Class 3: 1-5mWatts. Can be any wavelength, but can't produce a hazard from diffuse reflections. The output power is 0.5 Watts or less. Control measures center on direct intrabeam viewing. Can cause eye injury when viewed directly or from a specular (smooth mirror-like surface) reflection. Normally they are not a fire hazard.

Class 3 is divided into two sub-classes:

3a (new IEC class 3r) **1-5mWatts**.(**<.5W)** Have an accessible output between 1 and 5 times the Class 1 Accessible Emission Limit (AEL) for wavelengths shorter than .4um or longer than .7 um, or less than 5 times the Class 2 AEL for wavelength between 0.4 and .7 um. Some 3a lasers have a "CAUTION" label and normally wouldn't cause eye injury if viewed for less than the aversion response time of .25 s. Can be an eye hazard if used with collecting optics such as binoculars, microscopes. Class 3a lasers that are labeled "DANGER" are capable of exceeding maximum permissible exposure limits for the eye (and causing injury) within .25 s, but pose a low risk of injury. Laser pointers are in this category.

3b: (new IEC class 3b, no change**) 5mW to 500mWatts CW or, <10 J/cmsq for .25 s pulsed.** Ultraviolet (.18 to .4um) and infrared (1.4 um to 1mm) lasers which can emit accessible radiant power in excess of the Class 3a AEL during any emission duration within the maximum duration inherent in the design of the laser but which: 1) cannot emit an average radiant power in excess of 0.5 W for .25 s or more or, 2) cannot produce a radiant energy greater than..125 J within an exposure time of less than .25 s.

Visible (.4 to .7 um) or near- infrared (.7 to 1.4 um) lasers which emit in excess of the AEL of Class 3a but which 1) can't emit an average radiant power in excess of 0.5w for .25 s or more and, 2)cannot produce a radiant energy greater than .03 J per pulse.

Unsafe for intrabeam viewing and from direct, specular, reflections. Normally not a problem from diffuse (matte surface) reflection. Requires appropriate warning signs, a laser controlled area, eye protection.

Class 4: (New IEC class 4, no change) (**.5W CW or > 10 J/cmsq for .25 s pulsed)** Emit radiation in excess of the Class 3b AEL. May cause eye injury even from specular and diffuse reflection. Exposure to the direct beam is an eye, skin and fire hazard and can produce LGACS (laser generated air contaminants). May also produce hazardous plasma radiation. Use of Class 4 lasers requires administrative and engineering controls. Warning signs, a laser controlled area; controlled entry and eye protection are required.

Multi-wavelength lasers: For lasers that can be operated with more than wavelength, the classification is based on the most hazardous configuration.

Modified lasers: Lasers that are modified by the user must be re-classified by the laser safety officer.

Area Warning Signs

Class 1: none

Class 2: none

Class 3a: should be posted (ANSI 4.3)

Class 3b: shall be posted with laser warning signs (except laser pointers)

Class 4: shall be posted with laser warning signs

Temporary Laser Controlled areas

When lasers or equipment containing embedded lasers of class 3b or 4 are serviced or repaired and protective housing and interlocks are removed or bypassed, "notice" and warning signs shall be posted. The area outside of the service area cannot exceed the MPE. The work is done behind appropriate barriers or inside a laser controlled area.

Manufacturers Labeling

Must meet the CDRH (FDA Center for Devices and Radiologic Health) labeling standard and comply with 21 CFR 1040. The labeling must include the manufacturer's certification, identity, date of manufacture, hazard class, radiation output information and warnings, aperture dimensions, wavelength and power.

Safety Control Measures

NOTIFY THE LSO BEFORE INSTALLING CLASS 3B OR 4 LASERS

Class 2

Don't overcome the eyes natural aversion response or stare directly into the beam.

Don't point the laser directly at a person's eye.

Class 3

Don't aim the laser at a person's eye.

Use appropriate laser safety eyewear if there is a chance of intrabeam or specular reflection viewing.

Avoid placing the unprotected eye along the axis or near the beam. Some alignment procedures might require close proximity to the beam.

Keep the laser beam path above or below normal eye levels for either sitting or standing positions.

Don't look directly at the beam with optical instruments without an adequate protective filter is in place within the optical train.

Eliminate unnecessary specular surfaces from the vicinity of the laser beam path, and avoid aiming at such surfaces.

Don't aim at doorways or windows. Keep the beam path confined to the optical table or laser controlled area.

Class 3b

All of the above.

Class 3b lasers can only be operated in a laser controlled area by those trained in laser safety and who are authorized users and who must maintain direct visual surveillance and access of laser controlled areas during all conditions of operation.

Never leave the operating laser unattended if there is a chance that an unauthorized user may attempt to operate the laser. A key switch should be used if untrained persons may gain access.

The key should not be left in unattended lasers.

A warning light or buzzer is necessary to indicate when the laser is operating.

Enclose as much of the beam as practical.

Terminate primary and secondary beams with non-combustible material at the end of their useful paths.

Use low power settings, beam shutters and laser output filters when the full output power is not required.

Assure that spectators are not potentially exposed to hazardous conditions.

Keep manufacturer's operating manual and SOP's in the laser area.

Operate the laser only in indoor controlled areas with controlled access.

Appropriate warning signs are required.

Written standard operating procedures (SOP's) are recommended.

Can only be operated in a laser controlled area approved by the LSO.

Written alignment procedures are required.

New or modified laser controlled areas must be assessed by the LSO.

Class 4

All of the above.

Enclose the entire beam path if possible.

Confine the beam in light-tight rooms only.

Interlock the entrances if the NHZ extends to the entrances.

Insure that all personnel wear appropriate eye protection, or ensure that a suitable shield is present between the laser beam(s) and all present.

Use remote firing and video monitoring or remote viewing through a laser safety shield where feasible.

Use lower power settings, a beam shutter or laser output filters to reduce the beam irradiance to a less hazardous level whenever full beam power isn't required.

Make sure that the laser has a key-switch master control to permit only authorized personnel to operate the laser.

Don't leave the key in the control panel in unattended lasers.

Install all appropriate signs and labels.

Install an appropriate warning system such as a light or audible signal when the laser is in operation.

Optical pump systems may be hazardous to view. Charged optical pumping systems for pulsed lasers can be spontaneously discharged, causing the laser to fire unexpectedly.

Use dark, absorbing, diffuse, fire resistant target and backstops.

Written standard operating procedures (SOP's) are required.

Can only be operated in laser controlled areas approved by the LSO.

GLOSSARY

Accessible Emission Limit (AEL): Maximum accessible emission level permitted within a particular laser class.

Aperture: opening through which the laser radiation passes.

Average power: total energy of exposure divided by the duration.

Aversion response: closing (blinking) of the eye and movement of the head to avoid exposure to laser light

Beam diameter: diameter of the beam where the power per unit area of the beam is 1/e of the peak power

CW laser: continuous output of more than .25 s

Diffuse reflection: beam reflection from a matte surface with irregularities greater than the wavelength of the beam.

Infrared: electromagnetic wavelengths from 700 nm to 1 mm.

Irradiance: power per unit of area in Watts per square centimeter.

Laser: light amplification by stimulated emission of radiation

MPE: maximum permissible exposure level of laser radiation to which a human can be exposed without adverse reactions to the eye or skin

NHZ, nominal hazard zone inside of which the laser radiation from the direct, reflected or scattered beam exceeds the MPE.

NOHD, nominal ocular hazard distance along the axis of the direct beam to the human eye beyond which the MPE is not exceeded.

Pulsed laser: laser delivers energy in single or multiple pulses less than or equal to .25 s duration.

Radiant Energy: laser energy in joules (J).

Radiant exposure: radiant energy per square centimeter

Radiant power: emitted power in watts (W)

Repetitively pulsed laser: Multiple pulses with a repetition frequency equal to or greater than 1 Hz.

Specular Reflection: reflection of a beam from a mirror-like surface with surface irregularities smaller than the wavelength of the laser.

UV radiation: electromagnetic range of 180nm to 400nm

Visible radiation: 400 to 700 nm

CSUS LASER INVENTORY

For Class 3b and 4 Lasers, AND Class 1 or 2 laser laboratory equipment that may contain an embedded 3b or 4 laser IF CSUS employees may be required to service them. The information requested in on the equipment label and / or in the user manual and specifications.
Directions: Complete the required information and mail to Steve Leland, LSO, mail stop 6145, or email the completed document to sleland@skymail.csus.edu

Department:	Date:
Name of Contact Person:	Building/Room #:
Laser Information:	
Manufacturer:	Model:
Serial #:	
Type of Lasing Media (e.g. Argon, CO_2, HeNe, etc.):	
Wavelength(s) in nm:	Class:
Output Power(s) in W or J	Embedded? Yes No
Pulsed? Yes No	
Energy Pulse in J:	Pulse Width
Repetition Rate in Hz:	Pulse Time Envelope in seconds:
Q-Switched? Yes No	
Aperture (exit beam) Diameter in mm or cm:	
Divergence in mRad:	
Output Irradiance if listed in the specifications in E (w/cm sq)	
Used with dyes or solvents? Yes No	

Sample Laser Standard Operating Procedure

Laser:	Date:
Department:	Location:

1. LASER SAFETY CONTACTS

Primary Laser Operator:_____ Phone:_____
Laser Safety officer _____ Phone:_____
Maintenance/Repair _____ Phone:_____
Medical Emergencies _____ Phone:_____

1. LASER DESCRIPTION
   - Location of laser or laser system (site, building, room).
   - Diagram of area layout with beam path, include locations of emergency shut-off's, fire extinguishers, protective equipment (eye-wear), barriers.(attachment).
   - Description of each laser, including classification, lasing medium, and beam characteristics (divergence, aperture diameter, pulse length, repetition rate, and maximum output, as applicable.)
   - Purpose/application of beam(s).

2. LASER SAFETY PROGRAM

Clearly outline each category below:
   - Responsibilities of the laser operator(s)
   - Security / warning system activation / key control
   - Safety Procedures
   - Laser Training Requirements
   - Personnel Protective Equipment Requirements

3. OPERATING PROCEDURES
   - Initial preparation of laboratory environment for normal operation (key position, outside status indicator on, interlock activated, warning sign posted, personnel protective equipment available, other):
   - Target area preparation:
   - Special Procedures (**ALIGNMENT PROCEDURES**, safety tests, maintenance tests, other):
   - Operating procedures (power settings, Q-switch mode, pulse rate, other) are as follow:
   - Shutdown procedures are as follows:

CONTROL MEASURES

LASER/LASER SYSTEM CONTROLS		
Check if applicable	CONTROL	COMMENTS
[ ]	Entryway (door) Interlocks or controls	
[ ]	Laser Enclosure interlocks	
[ ]	Laser Housing Interlocks	
[ ]	Emergency Stop/Panic button	
[ ]	Master Switch (operated by key or code)	
[ ]	Laser secured to base	
[ ]	Beam Stops/Beam Attenuators	
[ ]	Protective Barriers	
[ ]	Warning Signs	
[ ]	Reference to Equipment manual	
[ ]	Extra Eyewear Available	
[ ]		

COMMENTS:

HAZARDS AND CONTROLS		
Check if applicable	HAZARD	CONTROLS
[ ]	Unenclosed beam/ Access to direct or scattered radiation	
[ ]	Laser at eye level of person sitting or standing	
[ ]	Ultraviolet Radiation/ Blue Light Exposure	
[ ]	Reflective Material in Beam Path	
[ ]	Hazardous Materials/Waste(dyes, solvents, other)	
[ ]	Fumes/Vapors	
[ ]	Electrical	
[ ]	Capacitors	
[ ]	Compressed Gasses	
[ ]	Fire	
[ ]	Housekeeping	
[ ]	Trip Hazard	

COMMENTS:

4. PERSONNEL PROTECTION EQUIPMENT

A. Eyewear

LASER EYEWEAR					
For this laser….			…Wear this eyewear		
Acquisition#	Type	Wavelength(s) (nm)	Wavelength(s) Attenuated (nm)	Optical Density(OD)	Remarks
Example	Nd:YAG	1064,532	1064,532	5+	UVEX

B. Other Protective Equipment Required within Nominal Hazard Zone

ITEM	LOCATION	USAGE CONDITION
_____	_____	_____
_____	_____	_____

5. OPERATOR REVIEW

I have read and understood this procedure and its contents, and agree to follow this procedure each time I use the laser or laser system.

Name (print)	Signature	Date
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

_____

Table 1: Administrative and Control Measures for Classes of Lasers					(From ANSI Z136.1)	
Control Measures	Class of laser					
	1	2	3a	3b	4
Written Standard Operating Procedures	no	no	no	o	x
Education and Training	no	o	o	x	x
Use by Authorized Personnel Only	no	no	no	x	x
Written Alignment procedures	no	x	x	x	x
Protective Equipment	no	no	no	o	x
Calculate MPE for Service / Maintenance	MPE*	MPE*	MPE*	x	x
Laser Optical Fiber Systems	MPE*	MPE*	MPE*	x	x
Eye Protection	no	no	no	o	x
Protective Windows	no	no	no	MPE*	NHZ
Skin Protection	no	no	no	MPE*	NHZ
Warning Signs and Labels	no	o	o	x	x
Protective Housing	x	x	x	x	x
Interlocks on Protective Housing	MPE*	MPE*	MPE*	x	x
Service Access Panel	MPE*	MPE*	MPE*	x	x
Key Control	no	no	no	o	x
Viewing Portals	no	MPE*	MPE*	MPE*	MPE*
Collecting Optics	MPE*	MPE*	MPE*	MPE*	MPE*
Open Beam Path	no	no	no	NHZ	NHZ
remote Interlock Connector	no	no	no	o	x
Enclosed Beam Path		none if the LSO approves			
Beam Stop Attenuator	no	no	no	o	x
Activation Warning System	no	no	no	o	x
Emission Delay	no	no	no	no	x
Indoor Laser Controlled Area	no	no	no	x	x
Laser Outdoor Controls	no	no	no	x	x
Temporary Laser Controlled Area	MPE*	MPE*	MPE*	no	no
remote Firing and Monitoring	no	no	no	no	o
Labels	x	x	x	x	x
Area Posting	no	no	o	x	x

no=	no requirement
x=	required
o=	recommended
*MPE =	required if the MPE is exceeded, contact the LSO for the determination or find it in the equipment specifications.
NHZ=	Nominal Hazard Zone Determination