Radiation Safety Manual*
Part II
Requirements for Lasers

University of California, Riverside

Environmental Health & Safety

* Available from EH&S Radiation Safety and on the UCR EH&S web site www.ehs.ucr.edu/.

Part I, “Requirements for Radioactive Materials and Machines that Produce Ionizing Radiation”.

Part III, “Requirements for Machines that Produce Non-Ionizing Radiation”

Contact Information

EH&S Web Site .... www.ehs.ucr.edu

Radiation Safety Information & Services
EH&S Radiation Safety ....Extension 2-5529

Radioactive Waste Pickup
Integrated Waste Management ....Extension 2-5518

Emergencies (8:00 a.m. - 5:00 p.m.) ....Extension 2-5529

Emergencies (after-hours and on weekends)
Ask For EH&S Radiation Safety ....Dial 9-1-1 (campus phone)

Table of Contents

1.00 Overview

The requirements for lasers provide reasonable and adequate guidance to personnel for the safe use of lasers and laser systems. Both Federal Occupational Safety & Health Administration (OSHA) regulations (21 CFR 1010 & 1040) and Cal OSHA regulations (CCR Title 8) address issues of laser safety and recognize standards developed by the American Standards Institute (ANSI) as the accepted ones for the safe use of lasers. Therefore, the following requirements are based on the current ANSI standard (ANSI Z136.1-2000). Appendices VIII and IX give a summary of the required engineering and administrative/ procedural control measures described below.

2.00 Organization

Lasers used at UCR are governed by the policies and procedures approved by the Laser Safety Committee. The Laser Safety Officer is responsible for implementing the policies and procedures approved by the Laser Safety Committee. The Principal Investigator (PI) is responsible for using lasers according to these policies and procedures. See below for more details.

2.01 Laser Safety Committee (LSC)

The Laser Safety Committee is a part of the Radiation Safety Committee and develops/ reviews all policies and procedures related to the use of lasers and any matters referred by the Laser Safety Officer.

2.02 Laser Safety Officer (LSO)

The Laser Safety Officer is responsible for implementing the policies and procedures established and maintained by the LSC. This individual will maintain an inventory of lasers, review all laser operations, evaluate procedures/SOPs, maintain personnel laser training and medical surveillance records, investigate accidents, incidents or non-compliance and initiate appropriate action and reports.

2.03 Principal Investigator (PI)

The Principal Investigator is responsible for the operation of one or more lasers/ laser systems. This individual has the requisite knowledge and authority to assure that lasers are operated safely, personnel are properly trained, and controls are in effect to minimize exposure of personnel to the laser beam and its associated hazards.

3.00 Classification of Lasers

All laser systems must be classified according to the criteria in ANSI Z136.1-2000, (see Appendix II).

4.00 Registration of Lasers

All laser systems that include a laser categorized, as Class 3b or 4 must be registered with EH&S Radiation Safety. The PI can accomplish this by submitting a laser registration form to the LSO (see Appendix I). Purchasing will notify EH&S Radiation Safety whenever a Class 3b or 4 laser purchase request is received.

5.00 Standard Operating Procedures

Operating, maintenance, and service procedures must be available for inspection, and followed in every facility where class 3b & 4 lasers are used.

6.00 Training

Any individual who: uses, works in the area of, maintains, services or aligns any Class 3b or 4 laser, even if embedded in a Class 1 laser system, must be trained (training for users of embedded class I lasers can be limited and emphasize the fact that the user must never take the unit apart or alter it in any way). Training must be adequate to assure that assigned duties/ responsibilities can be performed properly and safely. Compliant training must be approved by the Laser Safety Officer and documented (date, class outline, trainer) at EH&S Radiation Safety by the trainer.

Training must include the following information as it applies to the duties and responsibilities of the particular individual:

a) Understanding laser warning signs
b) Identification of the hazards associated with laser use
c) Identification of basic methods to reduce the risks related to laser use
d) Following Standard Operating Procedures
e) Use of eye protection and other safety equipment
f) Electrical safety
g) Special safety features of the specific lab/ work area
h) Concerns related to the use of hazardous materials such as dyes and solvents
i) Required medical surveillance

7.00 Labels, Signs, and Warnings

7.01 Lasers, and Assemblies That Include Lasers

Each Laser or assembly that contains a laser must be labeled with the following information (see Table V):

a) Maximum power output of laser
b) Classification of laser (see Appendix II)
c) Classification of the assembly that contains a laser, (see Appendix II)

7.02 Laser Use Locations

Each area where a Class 3b or 4 laser is used must be labeled by ANSI Z136.1 as follows (see Appendix III and Table IV for sign specifications and requirements):

a) Routine Requirements:

All laser facilities must be clearly labeled to warn workers and other individuals of the potential risk. Normally, warning signs are posted at entryways (on doors) to laser hazard zones.

b) Temporary Setups:

Temporary setups must be labeled clearly with signs to prevent other individuals/ lab workers from inadvertent exposure to stray beams.

7.03 Protective Equipment

See Table VI for protective equipment labeling.

8.00 Maximum Permissible Exposures (MPE)

Maximum Permissible Exposures (MPE) for eye and skin depend on many factors that include the wavelength of emitted radiation, beam size, duration of exposure, etc. Section 8 of ANSI Z136.1-2000, "Criteria for Exposure of the Eye and Skin", contains detailed MPE information (see Appendix IV for selected values).

9.00 Medical Surveillance

Eye examinations are required prior to the start of work with Class 3b and 4 lasers to establish a baseline and whenever a laser injury is known or suspected.

The eye examination must include the following parameters in accordance with ANSI Z136.1-2000:

- Ocular history
- Visual acuity
- Color vision
- Macular function (Amsler grid)

If abnormalities are noted tests will be performed as recommended by a qualified Ophthalmologist/ Optometrist. Additional tests may include an examination of the ocular fundus with an ophthalmoscope and skin examination.

10.00 Engineering Controls

Protective housing is required for all lasers in operation. Operation of a laser outside of its protective housing requires approval of the LSO.

Interlocks that disable the beam or activate exhaust fans when a potential risk is present may be necessary to minimize the likelihood of unnecessary exposure to the beam or fumes/ vapors/ gasses (ozone) generated by it. Interlocks on doors to laser hazard areas must meet NFPA 101 requirements.

11.00 Maintenance and Repair

All maintenance and repair of lasers must be performed by individuals who can document training and education that is appropriate for the laser/ laser system in question.

Appropriate precautions, including lockout/ blockout (lockout/ tagout) must be taken by the laser repair person to assure his/ her own safety as well as the safety of others in the area (contact EH&S for details).

12.00 Eye Protection

Eye protection is required when there is a potential for eye injury due to projectiles, chemicals, the laser beam or scattered/ reflected radiation. When an individual who needs to wear prescription glasses is required to wear eye protection routinely, the required eye protection must accommodate the prescription glasses or be equipped with lenses that have the appropriate correction.

12.01 Safety Goggles

Safety goggles must be worn while performing any work that generates debris or chemical hazard to the eye. This includes the use of power tools, any construction, soldering, and the use of chemicals.

12.02 Laser Goggles

Laser goggles will be worn whenever any Class 3b or 4 system is operating in the laboratory/ work area. The laser goggles must be appropriate for the wavelength(s) and maximum intensity of the laser(s) being used, and suitable for the work being done (see Appendix VI, Tables II and III). One pair of goggles (prescription if necessary) must be assigned to each full-time member of the group.

Note:

a) Inexpensive plastic goggles may provide adequate protection for low-level ultraviolet radiation beams.

b) It is important that the attenuation provided by the goggles is adequate protection for the wavelength(s) of the laser(s) in use. The use of goggles with a greater attenuation than required will **not** increase protection and may actually compromise safety by making it unnecessarily difficult to see during beam alignment and other routine procedures.

12.03 Goggles for Visitors

Visitors to the laboratory must wear appropriate safety/ laser goggles. If no goggles are available the visitors should be turned away or the lasers should be blocked at the suitable points. Special care should be observed when admitting visitors who, due to height, may have their eye height in the same plane as the laser beam.

13.00 General Safety Considerations Regarding Laser Use

The following are considered basic to the safe operation of lasers but apply specifically to Classes 3b and 4:

a) Only individuals with proper qualifications and training can operate lasers and associated equipment

b) Follow approved safety/ operating procedures (required for classes 3b & 4)

c) Use all required safety features/ interlocks

d) Areas where lasers are used must be posted with standard laser warning placards, as required

e) The laser beam must not be directed at a person

f) Do not allow chairs or stools in the laser lab that place the eye at laser height

g) Use beam shutters/ caps or turned off the laser when laser transmission is not actually required

h) Lasers must be turned off when unattended for a substantial period of time

i) Beams of <1cm diameter should be kept 6" to 8" above the plane of the table (42" to 44" above the floor). Exceptions may occur when coupling to large apparatus such as vacuum chambers, where extra care and beam blocks should be used

j) When feasible, only remote or electronic means must be used to guide the laser beam during alignment

k) Stray beams must are not allowed to pass outside the lab through doors/ openings. The relevant doors/ openings must be closed whenever optical setups are changed and stray beams are created

l) When possible, design the optical setup so beams are parallel or perpendicular to the optical table. Tilted beams may reach eye height at other locations in the lab

m) When possible, beams should be contained in beam tubes or enclosures

n) When possible, any long-term optical setup (greater the one month) should be contained in a radiation tight enclosure (appropriately colored Plexiglas, Lexan, or metals are often adequate). To be most effective, the enclosure should be interlocked such that the beam is disabled when protection is not provided

o) All non-essential reflective material (jewelry, watches, belt buckles) must be eliminated from the beam area

p) Beams must be terminated with beam blocks that are constructed of a material that will minimize reflection and that is appropriate for the beam being stopped

q) Beam stops must be secured with strong mechanical mounts to avoid the possibility of beam blocks dropping and exposing individuals to high intensity beams

r) Unless personnel are out of range, lasers should not be used in areas where there is significant dust or mists

s) Safety review by the LSO or designee when a class 3b or 4 laser is significantly modified or moved to a new location that may require different control methods

14.00 Special Considerations for Outdoor Operations

Typical outdoor uses include atmospheric probes, remote sensing applications, range finding, communication, and survey/ alignment operations.

For outdoor applications involving Class 3b or 4 Lasers follow the applicable general requirements outlined above, but also consider the following:

- Establishment of controlled areas, when feasible
- Potential spectators exposed to hazardous conditions resulting from the use of

lasers

- Lasers are never permitted to track non-target vehicles or aircraft
- Environmental impact such as wildlife, plants, etc.

If Class 4 lasers are used outdoors, contact EH&S Radiation Safety for special requirements related to FAA and EPA.

15.00 Electrical Safety

The high voltages and electrical currents that may be associated with lasers present a serious hazard to personnel if proper safety precautions are not followed. The following basic principles apply:

a) Electrical circuit breakers must be clearly marked and each worker instructed as to the location and procedure for turning off specific breakers in an emergency situation

b) All modifications to power lines or power supplies must be performed with circuit breakers off. When live high current or high voltage power supplies are inspected, two members must be present in the laboratory. Both members should be trained in emergency procedures involving electrical hazards

c) Lockout/ blockout (lockout/ tagout) may be necessary in some circumstances (contact EH&S for details)

16.00 Hazardous Material/ Biohazard Safety

Hazardous and biohazardous materials are sometimes used in conjunction with laser operation or are produced during their use. Special safety precautions may be necessary to protect people from the risks associated with these special hazards. Examples:

- Hazardous materials such as dyes (often carcinogens) and solvents used during laser operation must be handled and disposed properly
- Fumes, gasses (ozone), and vapors generated during laser operation may be hazardous chemicals or biohazards that require special management such as exhaust fans, collection devices, personnel protective equipment, etc.

Refer to the UCR Chemical Hygiene Plan or contact EH&S for questions.

Appendices

I. Summary of Laser Classification from ANSI Z136.1 (2000)

Classification of lasers can be a complex process so reference to ANSI Z136.1 (2000) is essential. However, the basic considerations/ criteria are included below. It is important to note that classification of a laser system is based on the accessible radiant power, not on the power of the laser itself. This means that a laser system classified as 1 or 2 may contain a laser classified 2 or higher. Such systems must be identified since they require special precautions during service/ modifications that expose the laser/ laser beam.

Following is a summary of characteristics of the various classes of lasers (from Class 1, lowest hazard to Class 4, highest hazard):

A. Class 1:

1. Not known to be able to cause biological injury.
2. Visible or invisible radiation.
3. Cannot emit accessible laser radiation levels in excess of the applicable Class 1 AEL (see Table I) for any emission duration within the maximum duration inherent in the design or intended use of the laser or laser system.
4. Is exempt from all control measures or other forms of surveillance with the exception of applicable requirements for embedded lasers.
5. The maximum exposure duration is assumed to be no more than 30,000 s, except for infrared systems not intended to be viewed (> 0.7 μm), 100 s must be used.

B. Class 2:

1. Visible light only.
2. CW and repetitive-pulse lasers (not single-pulsed).
3. Can emit accessible radiant energy exceeding the appropriate Class 1 AEL (see Table I) for maximum duration inherent in the design or intended use of the laser or laser system, but not exceeding the Class 1 AEL (see Table I) for any applicable pulse (emission) duration < 0.25 s and not exceeding an average radiant power of 1mW.

C. Class 3a:

1. Ocular hazard for chronic viewing or viewing with collecting optics.
2. Visible and invisible radiation.
3. Accessible output between 1 and 5 times the Class 1 AEL (see Table I) for wavelengths shorter than 0.4 μm or longer than 0.7μm, or less than 5 times the class 2 AEL for wavelengths between 0.4 and 0.7 μm.

D. Class 3b:

1. Ocular and skin hazard from direct exposure to beam, or specular reflection.
2. Visible or invisible radiation.
    - Ultraviolet (0.18 – 0.4 μm) and infrared (1.4 μm – 1 mm): can emit accessible radiant power in excess of Class 3a AEL (see Table I) during any emission duration within the maximum duration inherent in the design of the laser or laser system, but cannot emit an average radiant power in excess of 0.5 W for ≥ 0.25 s or produce a radiant

energy greater than 0.125 J within an exposure time < 0.25 s.

- Visible (0.4 – 0.7μm) or near-infrared (0.7 – 1.4 μm): emit in excess of the AEL of Class 3a (see Table I), but cannot emit an average radiant power in excess of 0.5 W for≥ 0.25 s or produce a radiant energy greater than 0.03 J per pulse.

E. Class 4:

1. Ocular and skin hazard from exposure to both the direct beam and scattered radiation.
2. Possible fire hazards.
3. Laser systems that emit radiation that exceed the Class 3b AEL (see Table I).

II. Laser Warning Signs and Labels

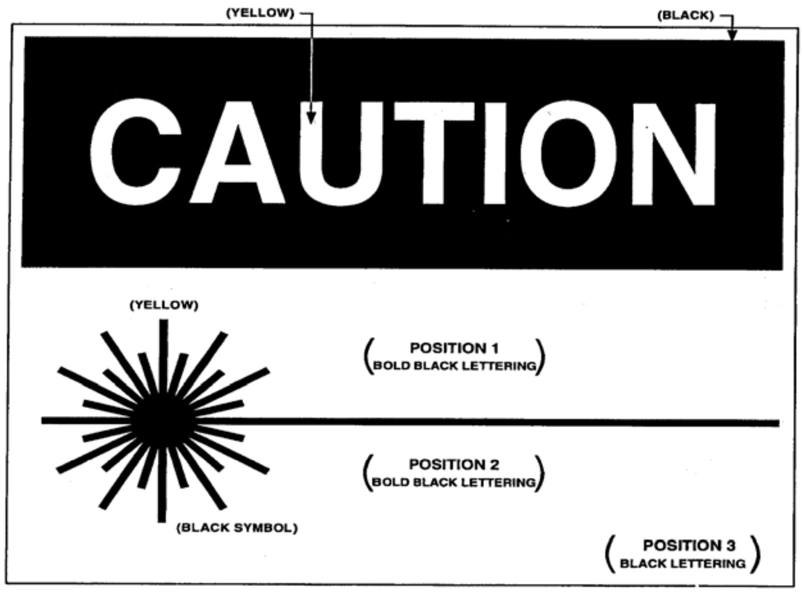

Figure 1
Sample warning sign for Class 2 and certain Class 3a lasers

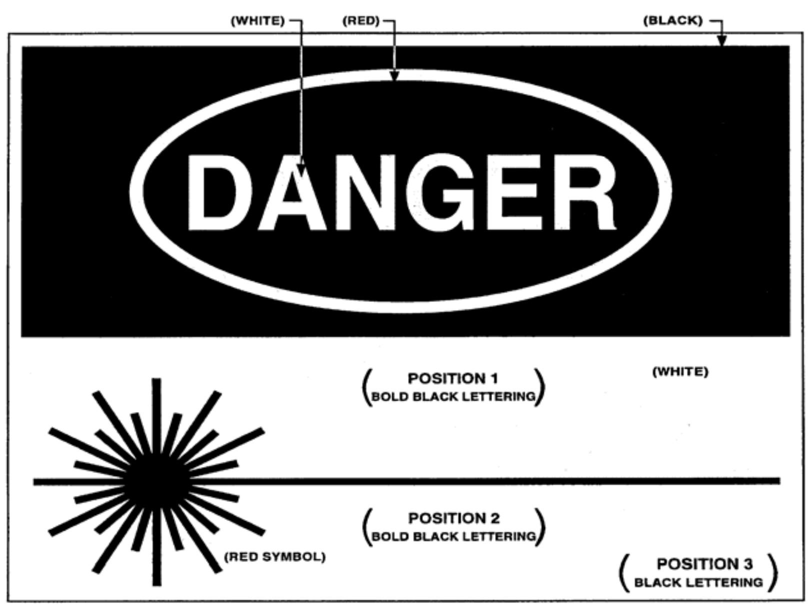

Figure 2
Sample warning sign for certain Class 3a lasers and for all Class 3b and Class 4 lasers

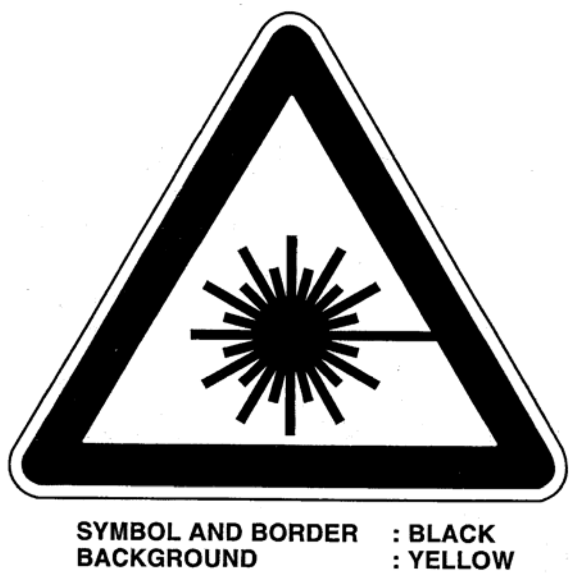

Figure 3
IEC Warning Logo - Hazard Symbol

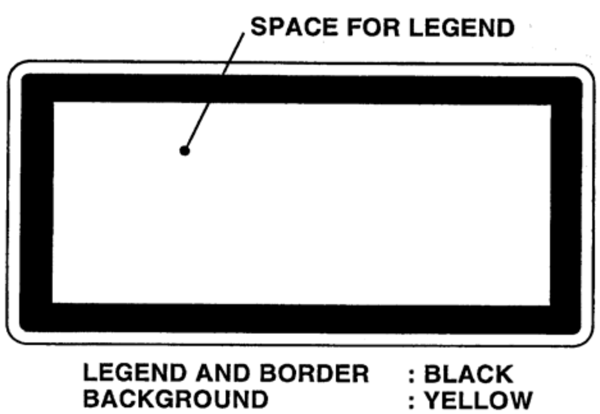

Figure 4
IEC Information Label - Label for explanatory wording

Figure 5
Sample Warning Sign for Temporary Controlled Area

III. Selected MPE Values from ANSI Z136.1(2000)

Intrabeam MPE for the Eye and Skin for Selected CW Lasers

Laser Type	Primary Wavelength(s) (µm)	Exposure Limit	
		Eye	Skin
Helium-Cadmium Argon	0.442 0.488 & 0.515	a) 2.5 mW·cm^{-2} for 0.25 s b) 10 mJ·cm^{-2} for 10 to 10^4 s c) 1µW·cm^{-2} for t>10^4 s	0.2 W·cm^{-2} for t>10 s
Helium-Neon	0.633	a) 2.5 mW·cm^{-2} for 0.25 s b) 10 mJ·cm^{-2} for 10 s c) 170 µW·cm^{-2} for t>453 s* d) 17 µW·cm^{-2} for t>10^4 s	0.2 W·cm^{-2} for t>10 s
Krypton	0.647	a) 2.5 mW·cm^{-2} for 0.25 s b) 10 mJ·cm^{-2} for 10 s d) 28 µW·cm^{-2} for t>10^4 s	0.2 W·cm^{-2} for t>10 s
Nd:YAG	1.064	1.6 mW·cm^{-2} for t>1000 s	1.0 W·cm^{-2} for t>10 s
Gallium-Arsenide	0.905	0.8 mW·cm^{-2} for t>1000 s	0.5 W·cm^{-2} for t>10 s
Helium-Cadmium Nitrogen	0.325 0.337	a) 1 J·cm^{-2} for 10 to 3 x 10^4 s b) 1 J·cm^{-2} for 10 to 3 x 10^4 s	a) 1 J·cm^{-2} for 10 to 1000 s b) 1 mW·cm^{-2} for t>10s
Carbon-dioxide	10.600	0.1 W·cm^{-2} for t>10 s	0.1 W·cm^{-2} for t> 10 s

* See T_1 in ANSI Z136.1 (2000), Tables 6&7 and Laser Institute of America "Laser Safety Guide, Table Ia.

Intrabeam MPE for the Eye and Skin for Selected Pulsed Lasers

Laser	Primary Wavelength(s) (µm)	Pulse Duration	Maximum Permissible Exposure	
			Eye	Skin
Normal-pulsed ruby	0.694	1 msec	10^{-5}J·cm^{-2}	0.2 J·cm^{-2}
Q-switched ruby	0.694	5-100 nsec	5x10^{-7}J·cm^{-2}	0.02 J·cm^{-2}
Rhodamine 6G dye laser	≈0.500-0.700	0.5-18 µsec	5x10^{-7}J·cm^{-2}	0.03 to 0.07 J·cm^{-2}
Normal pulsed Nd:YAG	1.064	1 msec	5x10^{-5}J·cm^{-2}	1 J·cm^{-2}
Q-switched Nd:YAG	1.064	5-100 nsec	5x10^{-6}J·cm^{-2}	0.1 J·cm^{-2}

IV. Some Useful Constants and Information for Laser Users

A. Constants and Units

1. Avogadro's number (N_A) = 6.025×10^{23} mol^{-1}
2. Speed of light (c) = 2.998×10^{8} m/sec
   = 3×10^{10} cm/sec
   = 3×10^{14} μm/sec
3. Planck's constant (h) = 6.626×10^{-34} J-sec
   = 6.626×10^{-27} erg-sec
   = 4.136×10^{-15} eV-sec

B. Optical Terms and Units

1. Energy (Q), typical units, Joule (J), erg and electron Volt (eV):

   Joule = kg-m^2/sec^2
   Joule = 107 erg
   Joule = 6.25 x 1018 eV

2. Energy of a photon, typical unit, eV:

   Q = hν
   Where:
   ν = frequency (e.g., Hz, sec-1)
   h = Plancks constant
   Q(eV) = 1.24/λ
   Q(J) = 1.987 x 1014/λ
   Where:
   λ = wavelength in μm

3. Frequency (ν), typical unit, Hz:

   ν = c/λ
   Where:
   ν = frequency (e.g., Hz, sec-1)
   λ = wavelength in μm
   c = speed of light (3 x 1014 μm/sec)
   ν(Hz) = (3 x 1014 μm/sec)/λ

4. Irradiance (E), typical unit, Watts/cm^2

   E = power/area
   $E_{(circular\ beam)}$ = $4P/\pi D^2$
   Where:
   D = beam diameter in cm.
   P = power in Watts

5. Power (P), typical unit, Watt:

   P = Q/t

6. Wavelength (λ), typical unit, μm:

$\lambda = c/\nu$

7. Wave number (k or cm^{-1}), typical unit, 1/cm:

$k = 1/\lambda$

$k_{(1/cm)} = 10^4/\lambda(cm)$

8. Optical density of laser protective eye-wear at a specific wavelength

$D_\lambda = \log_{10}(H_0/MPE)$

Where:

D_λ = Optical density of laser protective eye-wear at a specific wavelength

H_0 = Anticipated worst case exposure (usually expressed as W/cm^2 for CW sources and J/cm^2 for pulsed sources)

MPE = "Maximum Permitted Exposure" expressed in units identical to H_0

C. Conversion Factors

1 Joule (J)	=	1 kg m^2/sec^2
	=	6.25×10^{18} eV
	=	10^7 erg
1 Watt (W)	=	1 J/sec
1 eV	=	1.602 x 10-19 Joule
1 Hz	=	1 cycle/sec
1 μm	=	10-6 m
1 nm	=	10-9 m
	=	10^{-3} μm

V. Sample Calculations

1) Find the Output Irradiance of a 10 W laser with a 1 cm beam diameter.

Applicable equations:

$E = P \div A$

$A = \pi\, r^2 = \pi\, d^2 \div 4$

Where:

A = area of beam
d = diameter of beam
E = beam energy
P = beam power
r = radius of beam

Given:

P = 10 W
d = 1 cm

Calculation:

$E = 10\ W \div [\pi\ (1cm)2 \div 4]$

$E = 10\ W \div 0.785\ cm2$

E = 12.7 W/cm2

2) Find the Ocular Maximum Permissible Exposure (MPE) for a continuous wave Argon Laser (λ = 0.488 µm) for an exposure duration of 0.25 sec.

Applicable Equation:

$MPE = 1.8\ t^{3/4}\ mJ/cm^2$ (see Appendix IV)

Given:

λ = 0.488 µm
t = 0.25 sec

Calculations:

$MPE = 1.8\ (0.25)^{3/4}\ mJ/cm^2$
$= 0.64\ mJ/cm^2$

To convert to mW/cm^2 divide by the exposure time:

$MPE = 0.64\ mJ/cm^2 \div 0.25\ sec = 2.55\ mW/cm^2$

3) Find the optical density required for laser protective eye-wear for the MPE calculated in question # 2 above (CW operating at λ = 488 nm) if the worst case exposure is 3.8 mW/cm^2?

Applicable Equation:

$D_\lambda = \log_{10} (H_0/MPE)$

Where:

$D\lambda$ =	Optical density of laser protective eye-wear at a specific wavelength
H0 =	Anticipated worst case exposure (usually expressed as W/cm2 for CW sources and J/cm2 for pulsed sources)
MPE =	"Maximum Permitted Exposure" expressed in units identical to H0

Given:

MPE =	2.55 mW/cm^2
H_0 =	3.8 W/cm^2 = 3,800 mW/cm^2

Calculations:

$$D_\lambda = \log_{10} (3{,}800\ mW/cm^2/cm^2/2.55\ mW/cm^2)$$

$$= \log_{10} (1{,}490.2)$$

$$= 3.2 \text{ (at } \lambda = 0.488\ \mu m)$$

VI. A Summary of Good Practices for Laser Users

The principal hazards associated with lasers are electrocution, fires caused either by the laser energy source (usually electrical) or radiation emitted from the laser involving flammable/ combustible materials in the laser (such as laser dye solutions) or surrounding area (such as paper or squeeze bottles of flammable solvent). In addition, movement of the heavy optical benches found in laser labs can cause injury, death, and property damage if they move during an earthquake, and air contaminants arising when a laser beam strikes an object may be hazardous. Spaces housing class 3b or 4 lasers will need to have interlocked entrances, spaces to store PPE, be compatible with beam enclosures and beam routing over/ under eye height, and have provisions for dealing with hazardous materials such as toxic gasses, dyes, and excimer gas mixtures. A time delay is required for Class 4 lasers. Per Z136.1 and 21 CFR 1040, Class 4 lasers must have provisions for connection to room interlock systems.

The requirements and guidance items that follow are accompanied by references to relevant regulatory and guidance sources. In addition, there may be comments that should give practical insights into the implications of the requirements or methods for implementing them.

A. Provisions for Controlling Access to Laser Areas

1. Doors to spaces containing Class 3b or 4 lasers may require interlocks that will prevent emission from the lasers if the door is opened.

   ANSI Z136.1-2000

   A lab containing a number of lasers, interlocked optical benches or beam paths may require a programmable logic controller to coordinate interlock functions and warning annunciations at entrances from public areas.

2. All doors to laser areas must be posted with warning signs that will be seen before anyone reaches the doorway.

   Good practice.

   The signs are specified in ANSI Z136.1-2000. Format modifications were made in the 2000 revision to the Z136.1, so laser warning signs fall into agreement with ANSI Z535 series specifications for safety warning signs. Electronic displays may be preferred for clarity and to relate complex instructions for labs with complex laser setups inside. Electronic displays may be as simple with on/off switch controls or range to announcements for systems interfacing laser, room access, and beam enclosure interlocks. Electronic displays may also be used in addition to conventional warning signs.

3. People must be allowed to put on appropriate laser eyewear before entering spaces where beam hazards exist/ could exist or, preferably, before they enter the lab.

   Good practice

   Laser eyewear is moderately or very expensive so provision should be made to store it so that the filter material is not sitting in water/ solvents (some “glass” filters are vulnerable to water damage), pressing against surfaces, or vulnerable to scratching and damage. A multi-pouch plastic shoe bag is enough for storing laser eyewear.

4. Barriers must be provided to assure that Class 3b or 4 laser beams can never leave the confines of a laser lab by entering hallways, leave the building via windows, etc. Barriers should also be provided for Class 2 or 3a lasers.

   ANSI Z136.1-2000

   Z136.1 recommends barriers for Class 3b lasers and requires them for Class 4 lasers. An “incident” is guaranteed if a laser beam gets into a hall and somebody simply sees it or, worse, is injured by it. Laser labs with windows would need to covered them to prevent beams from escaping. A simple metal plate with a matte finish on the inside would be best. Filters that work at specific bands of wavelengths are available, but are usually expensive. Cheaper materials, such as shaded glass and plastic, have been used in specific cases, but design can be tricky and fire safety is always a concern.

B. Controlling Beam Paths

1. Beam paths from Class 3b or 4 lasers that must cross-occupiable areas must pass either over or under the eye height of standing and sitting people.

   ANSI Z136.1-2000

   This is a basic, highly effective precaution.

2. Eye level beam paths from Class 3b or 4 lasers must be housed in interlocked enclosures.

   ANSI Z136.1-2000

3. Avoid shiny surfaces, matte finishes must be used wherever possible.

   ANSI Z136.1-2000

   Matte textures break up laser beams while shiny surfaces act as mirrors that allow the beam to bounce into unexpected places at almost full power.

C. Fire Safety

1. Flammable materials must be avoided in spaces housing Class 4 lasers. Curtains must be flame-retardant or preferably flame proof.

   NFPA115, Recommended Practice on Laser Fire Protection

   ANSI Z136.1-2000

   NFPA 115 advises that laser beams with irradiances above 2 Watts/cm^2 should be regarded as fire hazardous. Curtains are sometimes used to partition the interiors of laser labs.

2. Laser dye solutions, solvents, and other flammable materials must be safely stored.

   NFPA115, Recommended Practice on Laser Fire Protection

D. Electrical Safety

1. Electrical components must be grounded.

   ANSI Z136.1-2000

Some of these components may be on optical benches so provisions for grounding optical benches will also be needed.

2. Electrical systems must show voltage, frequency, and power.

   ANSI Z136.1-2000

E. Class 4 Laser labs

1. Red mushroom type emergency shutoffs must be installed so people inside the lab can shut off power to lasers in an emergency.

   ANSI Z136.1-2000

   Z136.1 does not specify red mushrooms, but these have become very common and well recognized. They should be clearly marked and protected from inadvertent operation but still be easily accessible.

2. Class 4 laser labs must have easy exits.

   ANSI Z136.1-2000

   Crash bar hardware on outward-swinging doors can be used.

3. There must be a time delay before a Class 4 laser beam is allowed to emerge from the laser.

   ANSI Z136.1-2000

F. Optical Benches

Optical benches must be secured to prevent large movements in an earthquake.

Good practice

This is done installing a sturdy frame close to, but not touching, the optical bench. These are commercially available. Traditional optical benches are slabs of solid granite about a foot thick and 4 feet wide by a higher number of feet long.

G. Excimer lasers

1. Gas mixtures should be stored in gas storage cabinets.

   Laser Institute of America (LIA) Guide to Non-beam Hazards Associated with Laser Use

   Conventional gas storage cabinets will effectively contain the dilute halogen and hydrogen halide in inert gas mixtures used in excimer lasers if the delivery lines are kept bone dry. Gas storage cabinet hardware allows this to be done using bone-dry nitrogen purge gas.

2. The gas discharge from an excimer laser and associated gas storage cabinet must be connected to an appropriate exhaust ventilation system.

   LIA Guide to Non-beam Hazards Associated with Laser Use

H. Laser Generated Air Contaminants

Places where beam irradiances exceed 10,000,000 Watts/cm^2 (typically at the beam focus of a tool or surgical instrument) must be evaluated by an Industrial Hygienist to define controls for laser generated air contaminants. These places must be ventilated and enclosed to the maximum practical extent.

ANSI Z136.1-2000

LIA Guide to Non-beam Hazards Associated with Laser Use

Organic materials, including polymers and tissue, will produce potentially carcinogenic plumes. Polymers will pyrolyze to form toxic gasses. Metals and inorganic materials will form fume clouds. These can be treated as common hot gas air contaminant sources in accordance with ACGIH and ASHRAE criteria. The interiors of the enclosures should be easy to clean/ decontaminate. HEPA filtration of the effluent may be needed.

VII. Summary of Engineering Control Measures for Lasers

From ANSI Z136.1 – 2000, Table 10

Feature*	Classification				
	1	2	3a	3b	4
Protective housing (4.3.1)	R	R	R	R	R
Without protective housing (4.3.1.1)	LSO	LSO	LSO	LSO	LSO
Interlocks on protective housing (4.3.2)	∇	∇	∇	R	R
Service access panel (4.3.3)	∇	∇	∇	R	R
Key control (4.3.4)	N	N	N	S	R
Viewing portals (4.3.5.1)	N	MPE	MPE	MPE	MPE
Collecting optics (4.3.5.2)	MPE	MPE	MPE	MPE	MPE
Totally open beam path (4.3.6.1)	N	N	N	R, NHZ	R, NHZ
Limited open beam path (4.3.6.2)	N	N	N	R, NHZ	R, NHZ
Enclosed beam path (4.3.6.3)	None is required if 4.3.1 and 4.3.2 fulfilled				
Remote interlock connector (4.3.7)	N	N	N	S	R
Beam stop or attenuator (4.3.8)	N	N	N	S	R
Activation warning systems (4.3.9.4)	N	N	N	S	R
Emission delay (4.3.9.1)	N	N	N	N	R
Indoor laser controlled area (4.3.10)	N	N	N	R, NHZ	R, NHZ
Class 3b laser controlled area (4.3.10.1)	N	N	N	R	N
Class 4 laser controlled area (4.3.10.2)	N	N	N	N	R
Laser outdoor controls (4.3.11)	N	N	N	R, NHZ	R, NHZ
Laser in navigable airspace (4.3.11.2)	N	N	S	S	S
Temporary laser controlled area (4.3.12)	∇, MPE	∇, MPE	∇, MPE	N	N
Remote firing and monitoring (4.3.13)	N	N	N	N	S
Labels (4.3.14 and 4.7)	R	R	R	R	R
Area posting (4.3.9)	N	N	S	R, NHZ	R, NHZ

Legend:
- R - Required
- S - Should
- N - No requirement

∇	-	Shall if embedded Class 3b or Class 4
MPE	-	Shall if MPE is exceeded
NHZ	-	Nominal hazard zone analysis required
LSO	-	LSO determination
*	-	Section from ANSI Z136.1 - 2000

VIII. Summary of Administrative and Procedural Control Measures for Lasers

From ANSI Z136.1 – 2000, Table 10

Feature*	Classification				
	1	2	3a	3b	4
Standard operating procedures (4.4.1)	N	N	N	S	R
Output emission limitations (4.4.2)	N	N	LSO	LSO	LSO
Education and training (4.4.3)	N	S	S	R	R
Authorized personnel (4.4.4)	N	N	N	R	R
Alignment procedures (4.4.5)	N	R	R	R	R
Protective equipment (4.4.6)	N	N	N	S	R
Spectator (4.4.6)	N	N	N	S	R
Service personnel (4.4.7)	∇, MPE	∇, MPE	∇, MPE	R	R
Demonstration with general public (4.5.1)	MPE**	R	R	R	R
Laser fiber optics systems (4.5.2)	MPE	MPE	MPE	R	R
Laser robotic installations (4.5.3)	N	N	N	R, NHZ	R, NHZ
Eye protection (4.6.2)	N	N	N	S, MPE	R, MPE
Protective windows (4.6.3)	N	N	N	R, NHZ	R, NHZ
Protective barriers and curtains (4.6.4)	N	N	N	S	S
Skin protection (4.6.6)	N	N	N	R, MPE	R, MPE
Other protective equipment (4.6.7)	LSO	LSO	LSO	LSO	LSO
Warning signs and labels (4.7)	N	S	S	R, NHZ	R, NHZ
Service and repairs (4.4.7)	LSO	LSO	LSO	LSO	LSO
Modification of laser systems (4.1.2)	LSO	LSO	LSO	LSO	LSO

Legend:
- R - Required
- S - Should
- N - No requirement
- ∇ - Shall if embedded Class 3b or Class 4
- MPE - Shall if MPE is exceeded
- NHZ - Nominal hazard zone analysis required
- LSO - LSO determination
- * - Numbers in parenthesis are sections from ANSI Z136.1 - 2000
- ** - Applicable only to UV and IR Lasers (4.5.1.2)

IX. Guidelines for Preparing Standard Operating Procedures (SOP)

A. Basic Guidance

1. The written SOP must discuss beam alignment and normal operation for each laser system. It is advisable to include non-beam hazard management and servicing in the SOP.
2. The SOPs should be concise and accurate to ensure they are read and used.
3. The primary intent of the SOP is to institutionalize good safety practices.
4. The Radiation Safety Manual, Part II, Requirements for Lasers has information that may be useful when developing SOPs.
5. If requested, EH&S Radiation Safety will review and comment on draft SOPs. Contact the Laser Safety Officer (LSO) for assistance.

B. Beam Alignment

1. Security – Secure the lab, and to avoid distractions, mark the door with the following sign: "NOTICE – Laser alignment in Progress – DO NOT ENTER – EYE PROTECTION REQUIRED".
2. Preparation – Locate all equipment and materials needed to perform the alignment prior to beginning the procedure.
3. Beam Characteristics – Is the beam visible or invisible? Is special equipment needed to view the beam? If the beam is pulsed, can you fire single pulses to limit the exposure hazard.
4. Beam Viewing – Intrabeam viewing is prohibited on campus and a remote viewing camera should be used if intrabeam viewing is required to align the beam. Only diffuse reflections should be viewed directly. Use a low power alignment laser (Class 2 or 3a) or if none is available, always use the lowest beam power, which will allow viewing of an image with protective eyewear.
5. Personal Protective Equipment – Use laser protective eyewear with a low enough OD to allow viewing of the diffuse reflection (contact the LSO if you need information on alignment eyewear). Use skin covers (lab coats, gloves, and UV face shield) to protect users from UV laser beam scatter.
6. Personnel – Whenever possible, the "buddy" system should be used during alignments. If another person is not available to be in the room, let someone else know where you are and check in with them on a regular basis.
7. Exposure Precautions – Keep the optical table clear of objects that may cause unwanted specular reflections. Always close the laser shutter while adjusting optics or when entering the beam path. After making adjustments, assure the optics are secured prior to use.

C. Servicing a Laser

1. Only PI approved and properly trained personnel can service laser systems. Vendor service staff is required to follow the vendor's laser safety policy. If UCR staff assists the

service staff, UCR staff must follow campus laser safety policy (eye protection).

2. If UCR staff performs the service, a written service procedure with safety practice information must be available for reference (the manufacturer will often supply this information). All enclosures, interlocks, and safety devices (shutters) must be replaced and verified operational prior to returning the laser to service.
3. Safety interlocks must not be permanently disabled without the consent of the Radiation Safety Committee.

X. Requirements for Lasers Built/ Modified At UCR

All lasers and laser systems constructed/ modified on the UCR campus must meet certain safety standards (see below). The campus Laser Safety Officer (LSO) must be contacted prior to operation of such lasers so that they can be properly classified by the ANSI Z136.1-2000 standard. The LSO will inspect the laser system, make power output measurements (if needed), classify the laser, and inform researchers of any deficiencies that need to be corrected prior to use. All lasers classed as 3b or 4 will need to be operated under a Laser Use Authorization (LUA).

A. Safety Standards for Lasers Assembled on Campus

1. There must be an appropriate fixed enclosure to prevent casual contact with exposed electrical contacts, radiation from excitation sources, and hazardous materials (laser dyes, excimer gasses). The enclosure must be marked on the outside with appropriate warnings of enclosed hazards (see the LSO for assistance), and should not be removed without the use of tools.
2. The laser system must meet reasonable standards for electrical safety. These must include: components rated for appropriate amperages and voltages, proper grounding of housings, the use of properly wired 3 prong (grounded) plugs, enclosure of all live contacts/ wires with appropriate insulators, and proper marking of electrical hazards. Note: Cal-OSHA requirements allow only properly trained and qualified individuals to construct or maintain electrical systems and components.
3. Lasers must be designed to prevent accidental activation/ operation. At a minimum, a properly marked and lighted on/ off switch must be required. It is preferable to use a key interlock switch, so that the laser cannot be operated when the key is removed from the switch.
4. The physical components used in the laser must be made of appropriate materials to assure safety both during normal operation and failure modes (implosion of flash lamps). Some examples: cardboard is not an appropriate material for the laser enclosure (sheet aluminum is acceptable), and tubing used for piping halogen gasses should be stainless steel, monel, or copper, rather than aluminum.
5. Although it is not required, the Radiation Safety Committee recommends that researchers involve the LSO during the design process.

Tables

Table I

Accessible Emission Limits for Continuous-Wave Small-Source Lasers and Laser Systems[a]

From ANSI Z136.1 – 2000, Table 1

Wavelength Classification	Wavelength Range (μm)	Emission Duration (s)	Class 1[b] (W)	Class 2 (W)	Class 3[c] (W)	Class 4 (W)
Ultraviolet	0.18 – 0.302	3×10^4	$\leq 9.6\times10^{-9}$		> Class 1 but ≤ 0.5	> 0.5
"	0.302 – 0.4	3×10^4	$\leq 3.2\times10^{-6}$[d]			> 0.5
Visible	0.4 – 0.7	10^b	$\leq 0.4\times10^{-3}$[d]	> Class 1 but $\leq 1\times10^{-3}$	> Class 1 but ≤ 0.5	> 0.5
Near Infrared	0.7 – 1.05	≥ 10	$\leq 0.4\times10^{-3}$ to $\leq 1.9\times10^{-3}$		> Class 1 but ≤ 0.5	> 0.5
"	1.05 – 1.15	≥ 10	$\leq 1.9\times10^{-3}$		> Class 1 but ≤ 0.5	> 0.5
"	1.15 – 1.2	≥ 10	$\leq 1.9\times10^{-3}$ to 1.5×10^{-2}			
"	1.2 – 1.4	≥ 10	$\leq 1.5\times10^{-2}$			
Far Infrared	1.4 – 100	≥ 10	$\leq 9.6\times10^{-3}$		> Class 1 but ≤ 0.5	> 0.5
Sub-millimeter	10^2 - 10^3	≥ 10	$\leq 9.5\times10^{-2}$		> Class 1 but ≤ 0.5	> 0.5

a) Emission duration ≥ 0.25 s.

b) When the design or intended use of the laser or laser system ensures personnel exposures of less than 104 s in any 24 hour period, the limiting exposure duration may establish a higher exempt power level, as discussed in ANSI Z136.1 – 2000 section 3.2.3. The Class 1 AEL's calculated with this standard, under certain circumstances, may not be equivalent to those calculated with FLPPS or the IEC Standard.

c) For 1 – 5 mW CW laser systems (Class 3a) see ANSI Z136.1 – 2000 sections 3.3.3.1 and 3.3.3.2.

d) Depending on wavelength (see ANSI Z136.1 – 2000, Table 5)

Note: The wavelength range λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$, e.g., 0.18 to 0.4 μm means $0.18 \leq \lambda < 0.4$ μm.

Table I, cont.

Accessible Emission Levels (Radiant Energy) for Single-Pulse Laser and Laser System Classification[a]
From ANSI Z136.1 – 2000, Table 2

Wavelength Classification	Wavelength Range (μm)	Emission Duration[b] (s)	Class 1 (J)	Class 3b (J)	Class 4 (J)
Ultraviolet	0.18 – 0.302[c]	10^{-9} – 0.25	$\leq 2.4x10^{-5}$	> Class 1 but $\leq$ 0.125	> 0.125
"	0.302 – 0.4	10^{-9} to	$\leq 2.4x10^{-5}$	> Class 1 but $\leq$ 0.125	> 0.125
"	"	0.25	$\leq 3.1x10^{-3}$	> Class 1 but $\leq$ 0.125	> 0.125
Visible	0.4 – 0.7	10^{-9} to	$\leq 0.2x10^{-6}$	> Class 1 but $\leq$ 0.03	> 0.03
"	"	0.25	$\leq 0.25x10^{-3}$	> Class 1 but $\leq$ 0.03	> 0.03
Near Infrared	0.7 – 1.05	10^{-9} – 0.25	$\leq 1.9x10^{-7}$ to $\leq 1.2x10^{-3}$	> Class 1 but $\leq$ 0.03 C_A	> 0.03 C_A
"	1.05 – 1.4	10^{-9} – 0.25	$\leq 1.9x10^{-6}$ to $\leq 9.8x10^{-3}$	> Class 1 but $\leq$ 0.125	> 0.125
Far Infrared	1.4 – 100	10^{-9} – 0.25	$\leq 79x10^{-6}$ to $\leq 7.9x10^{-3}$	> Class 1 but $\leq$ 0.125	> 0.125
Sub-millimeter	10^2 - 10^3	10^{-9} to $5x10^{-6}$	$\leq$ 0.01 – 0.025	> Class 1 but $\leq$ 0.125	> 0.125
"	"	$5x10^{-6}$ to 0.25	$\leq$ 0.025 – $\leq$ 0.38	> Class 1 but $\leq$ 5 x Class 1	> 5 x Class 1

a) There are no Class 2 single-pulse lasers.

b) See note in ANSI Z136.1 – 2000, section 8 for pulse widths less than 1 ns.

c) Wavelength dependent, see ANSI Z136.1 – 2000, Table 5.

d) Not to exceed 0.125 J.

Note: The wavelength range λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$, e.g., 0.18 to 0.4 μm means $0.18 \leq \lambda < 0.4$ μm.

Table II

Time Factor Recommendations for CW and Repetitive-Pulse Laser Optical Density Calculations[a]

From ANSI Z136.1 – 2000, Table 4a

Wavelength Designation	Wavelength Range	Diffuse (seconds)	Intrabeam (seconds)
UV	0.200 – 0.400 µm	30,000	30,000
Visible	0.400 – 0.700 µm	600	0.25[b]
NIR	0.700 – 1.400 µm	600	10
FIR	1.400 µm – 1 mm	10	10

a) For single pulse lasers (PRF < 1 Hz), use actual laser pulse time.

b) For unintended or accidental viewing only. For other conditions, use the time of intended viewing.

Table III

Simplified Method for Selecting Laser Eye Protection for Small-Source Viewing

(Wavelength Between 0.400 and 1.400 μm)[a]
From ANSI Z136.1 – 2000, Table 4b

Q-Switched Laser (10^{-9} – 10^{-2}s)		Non-Q-Switched Laser ($0.4x10^{-3}$ – 10^{-2}s)		Continuous-Wave Lasers Momentary (0.25 – 10 s)		Continuous-Wave Lasers, Long-Term Staring (< 1 hr)		Attenuation	
Maximum Output Energy (J)	Max Beam Radiant Exposure (J•cm^{-2})	Max Laser Output Energy (J)	Max Beam Radiant Exposure (J•cm^{-2})	Maximum Power Output (W)	Maximum Beam Irradiance (W•cm^{-2})	Maximum Power Output (W)	Maximum Beam Irradiance (W•cm^{-2})	Attenuation Factor	OD
10	20	100	200	10^{5}[b]	$2x10^{5}$[b]	100[b]	200[b]	10^{8}	8
1	2	10	20	10^{5}[b]	$2x10^{5}$[b]	10[b]	20[b]	10^{7}	7
10^{-1}	$2x10^{-1}$	1	2	10^{5}[b]	$2x10^{5}$[b]	1	2	10^{6}	6
10^{-2}	$2x10^{-2}$	10^{-1}	$2x10^{-1}$	10^{5}[b]	200[b]	10^{-1}	$2x10^{-1}$	10^{5}	5
10^{-3}	$2x10^{-3}$	10^{-2}	$2x10^{-2}$	10	20	10^{-2}	$2x10^{-2}$	10^{4}	4
10^{-4}	$2x10^{-4}$	10^{-3}	$2x10^{-3}$	1	2	10^{-3}	$2x10^{-3}$	10^{3}	3
10^{-5}	$2x10^{-5}$	10^{-4}	$2x10^{-4}$	10^{-1}	$2x10^{-1}$	10^{-4}	$2x10^{-4}$	10^{2}	2
10^{-6}	$2x10^{-6}$	10^{-5}	$2x10^{-5}$	10^{-2}	$2x10^{-2}$	10^{-5}	$2x10^{-5}$	10	1

a) Use of this table may result in optical densities (OD) greater than necessary. See section 4.6.2 in ANSI Z136.1 for other wavelengths.

b) Not recommended as a control procedure at these levels. These levels of power could damage or destroy the attenuating material used in the eye protection. Skin also needs protection at these levels.

Table IV

Summary of Area Warning Signs
From ANSI Z136.1 – 2000, Table 11a

Clause	Title	Class 2	Class 3a	Class 3b	Class 4	Required Statement or Comment
3.5.1	Personnel	X	X	X	X	Some individuals may be unable to read or understand signs
4.3.9.1	Laser Warning Sign Purpose		X	X	X	States 4 purposes of warning signs
4.3.9.2	Warning Sign Postings		X	X	X	Specifies which sign required: Caution, Danger, Notice
4.3.9.3	Warning Sign Non-Beam Hazard	X	X	X	X	Must follow requirements of other appropriate documents
4.3.9.4.1	Audible Warning Devices			X	X	Audible warning must be required for class 4 and should be for 3b
4.3.9.4.2	Visual Warning Devices			X	X	Visual warning must be required for Class 4 and should be for 3b
4.7.1	Sign Design		X	X	X	Per ANSI Z535 requirements
4.7.2.1.1	Laser Symbol		X	X	X	Laser sun burst required on all signs per ANSI
4.7.2.1.2	International Laser Symbol					International symbol as specified in IEC 60825-1
4.7.2.1	Safety Alert Symbol		X	X	X	The alert symbol is required on all Caution and Danger signs
4.7.3.1	Signal Word “Danger”		X	X	X	Specifies when to use “Danger” word and format
4.7.3.2	Signal Word “Caution”		X			Specifies when to use “Caution” word and format
4.7.3.3	Signal Word “Notice”		X	X	X	Specifies when to use “Notice” word and format
4.7.4	Pertinent Information		X	X	X	Specifies the location of words on signs
4.7.4.3	Location of Signs		X	X	X	Specifies location of signs

Note: Signs and labels prepared in accordance with previous revisions of this standard area considered to fulfill the requirement.

Table V

Summary of Labeling Requirements
From ANSI Z136.1 – 2000, Table 11b

Clause	Title	Class 1	Class 2	Class 3a	Class 3b	Class 4	Required Statement or Comment
3.5.1	Personnel	X	X	X	X	X	Some individuals may be unable to read or understand signs
4.3.14.1	Warning Label and Words Required		X	X	X	X	Class label with symbols and specific words
`	Protective Housing	X	X	X	X	X	Specifies word depending on internal laser, see 4.7.5 for suggested words
4.3.14.3	Conduit Label		X	X	X	X	
4.3.3	Service Access Panel	X	X	X	X	X	Label required in removal permit access to laser
4.5.2	Optical Fiber Transmission			X	X	X	Words required if not disconnected in a laser controlled area
4.7.5	Equipment Labeling Information	X	X	X	X	X	Specifies wording by class

Note:
1) Labeling of laser equipment in accordance with the Federal Laser Product Performance Standard (FLPPS) may be used to satisfy the equipment labeling requirements in this standard.
2) Signs and labels prepared in accordance with previous revisions of this standard area considered to fulfill the requirement.

Table VI

Summary of Protective Equipment Labeling
From ANSI Z136.1 – 2000, Table 11c

Clause	Title	Summary
4.6.5.1	Protective Eyewear	OD and wavelength marking required
4.6.5.2	Protective Windows	OD, wavelength, threshold limit and exposure time marking required
4.6.5.4	Protective Barriers	Threshold limit and exposure time marking required

Note: Signs and labels prepared in accordance with previous revisions of this standard area are considered to fulfill the requirement.

References

The following references may be useful. Some references are available on the web or on the EH&S web site. Contact EH&S Radiation Safety for more choices.

1. Title 8, California Code of Regulations (CCR), Sections 1516, 1801, 8416, and 8617.
2. Safe Use of Lasers, ANSI Z136.1-2000
3. Safe Use of Optical Fiber Communications Systems Utilizing Laser Diode and LED Sources, ANSI Z136.2-1988
4. Safe Use of Lasers in Health Care Facilities, ANSI Z136.3-1988
5. Guide to the Selection of Laser Eye Protection, Laser Institute of America
6. Laser Safety Guide, ninth edition, 1993, Laser Institute of America
7. ACGIH TLVs – Physical Agents - Lasers

Glossary

A

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

Absorption: Transformation of radiant energy to a different form of energy by the interaction with matter. A process in which a substance retains some incident electromagnetic radiant energy, not transmitted or reflected.

Attenuation: The decrease in radiant energy as it passes through an absorbing or scattering medium.

Aversion Response: Movement of the eye, eyelid or head to avoid an exposure to a noxious stimulant or bright light. It can occur within 0.25 s, including the blink reflex time.

C

Continuous Wave (CW): The output of a laser that is operated in a continuous rather than a pulsed mode. In the ANSI standard, a laser with a continuous output for a period ≥ 0.25 s is defined 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 hazards.

D

Diffuse Reflection: Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or medium.

E

Energy (Q): The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is expressed in joules (J).

I

Ionizing Radiation: Electromagnetic radiation having sufficiently large photon energy to directly ionize atomic or molecular systems with a single quantum event.

Irradiance (E): The time-averaged radiant power incident on an element of a surface divided by the area of that element, expressed in watts per square centimeter (W/cm^2). The unit applied to CW laser sources.

M

Maintenance: The performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser product which are to be performed by the user for the purpose of assuring the intended performance of the product. It does not include operation or service.

Maximum Permissible Exposure (MPE): The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in eyes or skin.

N

Nominal Hazard Zone (NHZ): The space within which the level of the, direct reflected or scattered radiation during normal operation exceeds the applicable MPE.

Nominal Ocular Hazard Distance (NOHD): The distance along the axis of the unobstructed beam from the laser to the human eye beyond which the irradiance or radiant exposure during normal operation is not expected to exceed the appropriate MPE.

P

Power (P or ϕ): The rate at which energy is emitted, transferred, or received (Joules/sec), expressed as watts.

Protective Housing: Portions of a laser product designed to prevent human access to laser or collateral radiation in excess of the prescribed accessible emission limits.

Pulsed Laser: A laser that delivers its energy in the form of a single pulse or train of pulses. In the ANSI standard, the duration of a pulse < 0.25 s.

Q

Q-switch: A device for producing very short (5-250 ns), intense laser pulses by enhancing the storage and dumping of energy in and out of the lasing medium.

Q-switched laser: A laser that emits short (5-250 ns), high-power pulses by means of a Q-switch.

R

Radiant Exposure (H): The radiant energy incident on an element of a surface divided by the area of the element, expressed in joules per square centimeter (J/cm^2). Unit applied to pulsed lasers.

Repetitively Pulsed Laser: A laser with multiple pulses of radiant energy occurring in sequence with a pulse repetition frequency $\geq$ 1Hz.

S

Service: The performance of the procedures or adjustments described in the manufacturer's service instructions, by qualified personnel, which may affect any aspect of the product's performance. It does not include maintenance or operation.

Specular Reflection: A mirror like reflection.

W

Watt (W): The unit of power or radiant flux. One Watt equals one Joule per second.