University of Missouri - Columbia
Laser Safety Manual

October 2007

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1. Policy

The University of Missouri - Columbia (MU) policy is to protect personnel and property from harmful exposure to laser radiation. The Laser Safety Program described herein is primarily based on the American National Standards Institute "Guide for the Safe Use of Lasers" (ANSI Z136.1-2007). This guide is widely accepted and used within the fields of industry, education, research, and medicine. All lasers and laser systems must also be operated in accordance with federal guidelines (21 CFR J "Radiological Health" and 29 CFR 1910 "Environmental Health and Safety Standards").

2. Scope

Environmental Health and Safety regulates lasers on the MU campus. Laboratories with high-powered lasers (Class 3R, 3B, and 4) require special safety procedures.

3. Definitions

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

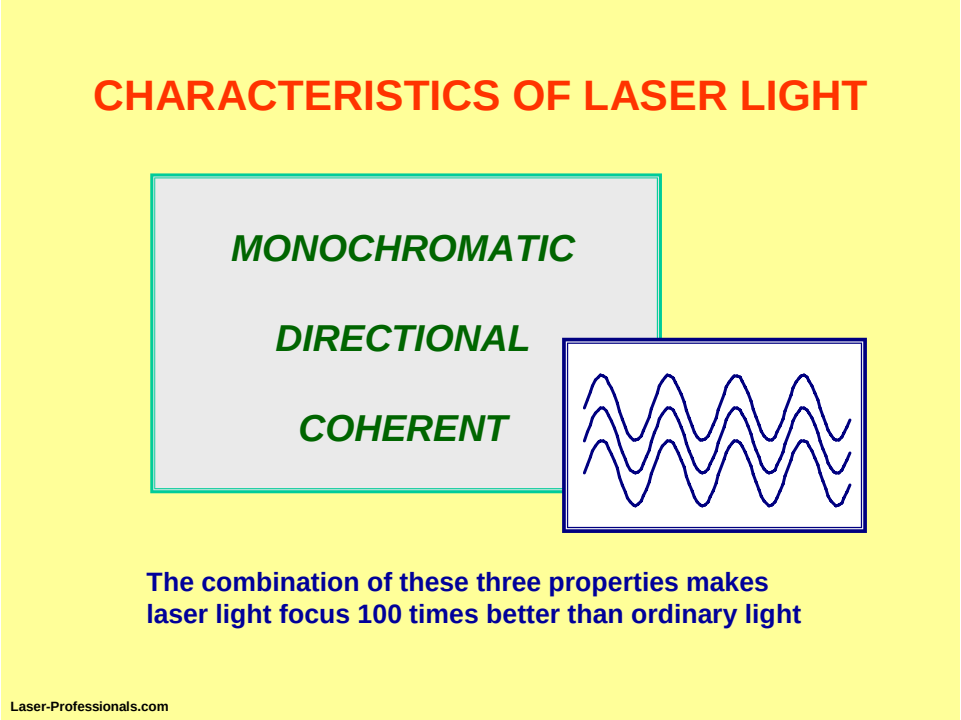
continuous wave (CW) – The output of a laser which is operated in a continuous rather than a pulsed mode. In this standard, a laser operating with a continuous output for a period ≥ 0.25 seconds is regarded as a CW laser.

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 hazards.

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

shall – The word "shall" is to be understood as mandatory.

should – The word "should" is understood as advisory.



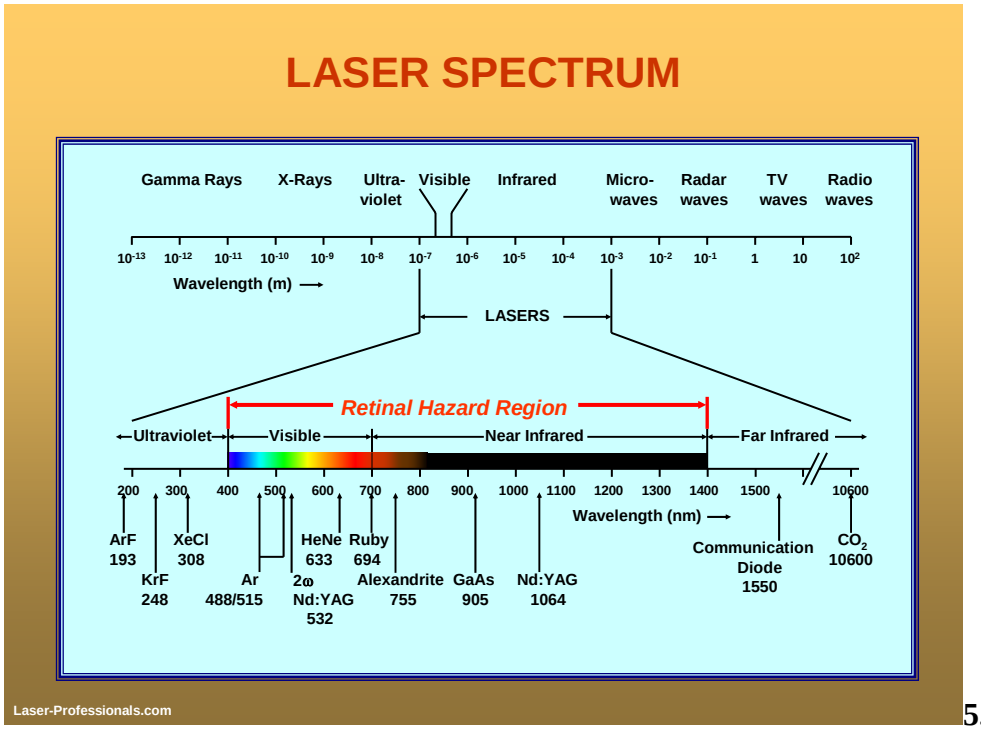
4. General

"Laser" is an acronym for Light Amplification by Stimulated Emission of Radiation. A laser produces an intense, coherent, directional beam of radiation in the ultraviolet, visible, or infrared regions of the electromagnetic spectrum. There is a high concentration of energy per unit area both at the laser end and at the far end of the beam.

Laser radiation transmits energy which, when a laser beam strikes matter, can be transmitted, absorbed, or reflected. A material that transmits a laser beam is transparent. If the beam is not transmitted, the material is opaque and the incident radiation is absorbed or reflected.

Absorbed laser energy appears in the target material as heat. (At certain, usually short, wavelengths photochemical reactions may also occur.) Absorption and transmission are functions of the chemical and physical characteristics of the target material and the wavelength of the incident radiation.

Reflection is primarily a function of the physical character of the target's surface material. A smooth polished surface is generally a good reflector. A rough uneven surface usually is a poor reflector, causing the reflected energy to be scattered in all directions thereby reducing the energy or power density, producing a "diffuse" reflection. A reflector such as a flat mirror changes the direction of an incident beam with little or no absorption. A curved mirror or surface will change the divergence angle of the impinging laser beam as well as its direction.



5. Hazards of Laser Radiation and Biological Effects

5.1 Radiation Hazards to the Eye and Skin

Biological effects from laser radiation depend on the radiant exposure, wavelength, source size, exposure time, environmental conditions, and individual susceptibility. The eye is the most important organ to protect. At visible wavelengths, laser radiation impinging on the eye is focused on the retina and, if sufficient energy is absorbed, can cause cell destruction. The focusing effect of the cornea and lens can concentrate energy on the order of 100,000 times on the retina. This can cause burning of the retina. At longer and shorter wavelengths, such as the far infrared and the ultraviolet, radiation striking the eye is absorbed in the cornea and the lens rather than being focused on the retina. Although these structures are less easily damaged than the retina, excessive energy absorption can cause cell damage and impairment of vision.

The skin and eyes are equally vulnerable in the ultraviolet and infrared regions of the spectrum. Low-powered and medium-powered lasers often do not cause skin injuries. High-powered Class 3B & 4 (See Sections 6.4, 6.5) lasers can cause injury to the skin as well as the eyes. A skin burn will normally heal, whereas an eye injury can cause scarring or permanent loss of vision.

There are usually no eye hazards from viewing laser beams reflected from a dull or rough surface. The energy from the laser beams are often dispersed and scattered in different directions. Lasers reflected from a flat shiny surface can be nearly as intense as the original laser beam. Protective eyewear (See Section 9.1) is often worn to protect the eyes.

5.2 Electrical Hazards

Most laser power supplies have the potential of causing electrical shock. Capacitors are used for pulsed lasers, and continuous-wave lasers use high voltage power supplies. Electrical maintenance of lasers must be performed by knowledgeable persons.

5.3 Chemical Associated Hazards

Explosive and highly toxic materials are sometimes used in laser research laboratories. A high-powered laser beam can vaporize an object and release hazardous airborne contaminants. Liquid nitrogen and other cryogenic fluids may be used as a coolant for certain laser systems. When these cryogenic fluids evaporate, they replace atmospheric oxygen. It is important to ensure that the laser laboratory is properly ventilated if toxic materials or cryogenic fluids are used with lasers.

5.4 Laser Generated Airborne Contaminants (LGAC)

LGAC may be aerosols, gases or vapors. When the laser comes in contact with tissue or blood generation of airborne infectious material or blood borne pathogens may occur along with a number of compounds like benzene, formaldehyde and hydrogen cyanide.

5.5 Miscellaneous Hazards

Fire hazards exist in and around some laser operations, but are usually limited to continuous-wave lasers with an output power above 0.5 watts. High-voltage laser power supplies may produce lower-energy x-rays, but sufficient shielding is normally installed in commercial lasers to prevent x-ray leakage. Trip hazards are real issue and can cause lab personnel to fall into the beam.

6. Laser Classification

Lasers are classified in terms of their potential to cause biological damage. The pertinent parameters are laser output energy or power, radiation wavelength, exposure duration, and cross sectional area of the laser beam at the point of interest. Most commercial lasers have an attached label specifying the classification of that laser. The hazard classification of a laser can be determined using ANSI Z136.1-2007 Section 3 and Appendix B. (The department of Environmental Health and Safety keeps a copy of this standard for reference)

6.1 Class 1 laser system

A Class 1 laser is considered to be incapable of producing damaging radiation levels, and is, therefore, exempt from most forms of surveillance. Example: laser printers

6.2 Class 1M laser system

Meets the Class 1 laser criteria except they may be a potential hazard when viewed with optical aids.

6.3 Class 2 laser system

Class 2 lasers and laser systems are visible (0.4 to 0.7 um) continuous wave (CW) and repetitive-pulse lasers and laser systems which can emit accessible radiant energy exceeding the appropriate Class 1 accessible emission limit (AEL) for the maximum duration inherent in the design or intended use of the laser or laser system, but not exceeding the Class 1 AEL for any applicable pulse (emission) duration < 0.25 seconds and not exceeding an average radiant power of 1mW.

A Class 2 laser is a low-powered laser in the visible range that may be viewed directly under carefully controlled exposure conditions. These lasers are considered safe because the natural reflex of the eye will prevent average exposure from causing damage. Example: laser pointers

6.3 Class 2M laser system

Meets the Class 2 laser criteria except they may be a potential hazard when viewed with optical aids

6.5 Class 3R laser system

Class 3R 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 0.4 μm or longer than 0.7 μm, or less than 5 times the Class 2 AEL for wavelengths between 0.4 and 0.7 μm.

Class 3R lasers will normally not produce injury if viewed only momentarily by the unaided eye. The Class 3R lasers may be a hazard if viewed using optics, e.g., telescopes, microscopes, or binoculars. Example: HeNe lasers above 1 milliwatt, but not exceeding 5 milliwatts; some laser pointers

6.6 Class 3B laser system

Class 3B lasers and laser systems include:

Ultraviolet (0.18 to 0.4 μm) and infrared (1.4 μm to 1 mm) lasers and laser systems which can emit during any emission duration within the maximum duration inherent in the design of the laser or laser system, but which (a) cannot emit an average radiant power in excess of 0.5 W for ≥ 0.25 seconds or (b) cannot produce a radiant energy greater than 0.125 Joules within an exposure time < 0.25 seconds.

Visible (0.4 to 0.7 μm) or near-infrared (0.7 to 1.4 μm) lasers or laser systems which emit in excess of the AEL of Class 3R but which (a) cannot emit an average radiant power in excess of 0.5 W for ≥ 0.25 seconds and (b) cannot produce a radiant energy greater than 0.03 Joules per pulse.

Class 3B lasers may cause severe eye injuries through direct or specular exposure. Examples: continuous lasers not exceeding 0.5 watts for any period greater than 0.25 seconds, pulsed visible lasers not emitting more than 0.03 joules per pulse, pulsed infrared or ultraviolet lasers not emitting more than 0.125 joules during any period less than 0.25 seconds.

6.7 Class 4

Class 4 lasers and laser systems are those that emit radiation that exceeds the Class 3B AEL.

Class 4 lasers are a hazard to the eye from the direct beam, specular reflections, and sometimes even from diffuse reflections. Class 4 lasers can also start fires and can damage skin. Example: lasers operating at power levels greater than 500 milliwatts for continuous wave lasers or greater than 0.03 Joules for a pulsed system.

7. General Laser Safety Requirements

A summary of the laser safety requirements for Class 3R, 3B, and 4 is in Appendix A.

7.1 Class 1

Exempt from any control measures, but looking into the direct beam should be discouraged as a matter of good practice. When using outdoors control measures apply.

7.2 Class 1M

Exempt from any control measures other than to prevent potentially hazardous optically aided viewing. Proper training and education should be received before use of laser. When using outdoors control measures may apply.

7.3 Class 2

Never allow a person to continuously stare into the laser source. Never direct the laser beam at a person's eye. Proper training and education should be received before use of laser. When using outdoors control measures may apply.

7.3 Class 2M (includes all class 2 requirements and the following)

Potentially hazardous optically aided viewing.

7.5 Class 3R (include all Class 2 & 2M requirements and the following)

A Laser Warning Sign should be posted in accordance with Section 8.1.
Appropriate warning labels shall be posted in accordance with Section 8.2.
The beam path should be enclosed as much as possible to prevent an individual from placing their head or reflecting objects into the beam path.
The laser system shall only be used under the supervision of a responsible person who is familiar with the potential hazards of the laser.

7.6 Class 3B and 4(include all Class 2, 2M and 3R requirements and the following)

Protective housing which encloses the laser shall be provided with an interlock system which is activated when the protective housing is opened or removed during operation and maintenance. Fail-safe interlocks shall be provided for any portion of the protective housing which, by design, can be removed or displaced during operation and maintenance.

Portions of the protective housing that are only intended to be removed from any laser or laser system by the service personnel, which then permits direct access to laser radiation shall either:

(1) be interlocked (fail-safe interlock not required) or
(2) require a tool for removal and shall have an appropriate warning label on the panel

If the interlock can be bypassed or defeated, a warning label with the appropriate indications shall be located on the protective housing near the interlock.

A Class 3B laser or laser system should be provided with a master switch. A Class 4 laser or laser system shall be provided with a master switch. This master switch shall effect beam termination and/or system shutoff and shall be operated by a key, or by a coded access.

The laser beam path shall be controlled. Section 4.3.6 of the ANSI Z136.1-2007 describes ways to control the beam path.

A Class 3B laser or laser system should be provided with a permanently attached beam stop or attenuator. A Class 4 laser or laser system shall be provided with a permanently attached beam stop or attenuator.

Class 3B lasers shall be operated in a controlled area, unless the beam path is completely enclosed. Class 4 lasers shall be operated in a controlled area, where all entryway safety controls shall be designed to allow both rapid egress by laser personal at all times and admittance to the laser controlled area under emergency conditions. If the laser is not fully enclosed, laser operation shall be in a light-tight room with interlocked entrances to assure that the laser will shut off when the door is opened.

Whenever appropriate and possible, Class 4 lasers or laser systems should be controlled and monitored at a position as distant as possible from the emission portal of the laser or laser system.

Standard operating procedures should be written for Class 3B lasers, and shall be written for Class 4 lasers.

For Class 3B lasers, a warning light or buzzer should indicate laser operation. This is especially important when the beam is not visible, i.e. Class 3B ultraviolet or infrared lasers. For Class 4 lasers, a warning light or buzzer shall indicate laser operation.

8. Warning Signs and Labeling Requirements

8.1 Warning Signs

A CAUTION sign should be used for Class 2 and 2M lasers (Figure 8.1-1).

Figure 8.1-1 Caution Sign

A DANGER sign **should** be used for Class 3R lasers and **shall** be used for class 3B and 4 lasers (Figure 8.1-2).

Figure 8.2-2 Danger Sign

The laser hazard symbol (a sunburst pattern consisting of two sets of radial spokes of different lengths and one long spoke, radiating from a common center) is on both the Caution Warning Sign and the Danger Warning Sign.

Sign information and warnings shall conform to the following specifications:

(1) Above the tail of the sunburst, special precautionary instructions or protective action may be applicable, for example:

Laser Protective Eyewear Required
Invisible Laser Radiation
Knock Before Entering
Do Not Enter When Light is On
Restricted Area

(2) Below the tail of the sunburst, the type of laser (i.e. Nd:YAG, Helium-Neon, etc.), or the emitted wavelength, pulse duration (if appropriate), and maximum output shall be written or printed.

(3) In the bottom right-hand corner of the Caution and Danger Warning Signs, the class of the laser or laser system shall be written or printed.

8.2 Labeling

Class 2 lasers or laser systems should have appropriate warning labels with the sunburst logotype symbol (located in both Figures 8.1-1 and 8.1-2) and an appropriate cautionary statement. Class 3a, 3b, and 4 lasers or laser systems shall have appropriate warning labels with the sunburst logotype symbol (located in both Figures 8.1-1 and 8.1-2) and an appropriate cautionary statement. The label shall be affixed to a conspicuous place on the laser housing or control panel.

9. Protective Equipment

9.1 Protective Eyewear

Eye protection devices which are specifically designed for protection against radiation from Class 3B lasers or laser systems should be administratively required and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable maximum permissible exposure (MPE).

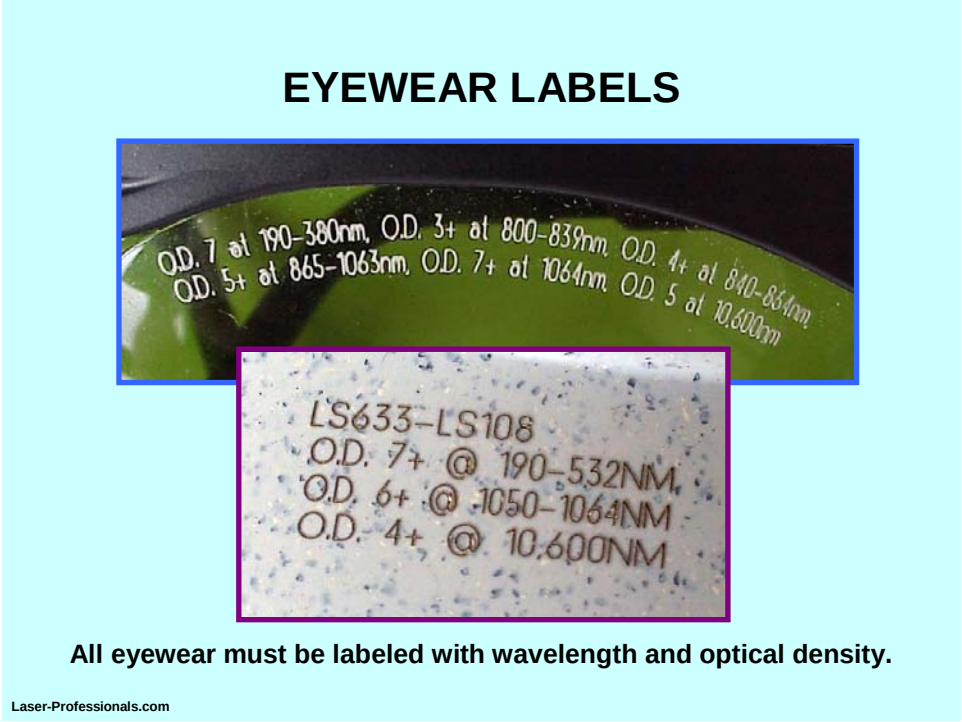
Eye protection devices which are specifically designed for protection against radiation from Class 4 lasers or laser systems shall be required and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE.

Laser protective eyewear is usually not required for Class 2, 2M and 3R lasers or laser systems except in conditions where intentional long-term (>0.25 seconds) direct viewing is required.

Laser protective eyewear may include goggles, face shields, spectacles, or prescription eyewear using special filter materials or reflective coatings (or a combination of both) to reduce the potential ocular exposure below the applicable MPE level.

Eyewear shall have the following requirements:

(1) Protective eyewear shall be used only at the wavelength and energy/power for which it is intended.
(2) Label the protective eyewear with the laser type and/or light wavelength that the eyewear is designed for.
(3) Keep protective eyewear in good condition. Replace damaged or defective eyewear.



ANSI Z136.1-2007 Section 4.6.2 can be used to select appropriate eyewear.

9.2 Other Protective Equipment

Protective eyewear should not be considered the primary means to protect against laser radiation. Protective equipment such as beam stops, shields, safety interlocks, and warning lights and horns shall be maintained in proper operating condition and shall be utilized whenever indicated to prevent harmful exposure to laser radiation.

10. Roles and Responsibilities

10.1 Laser Safety Officer

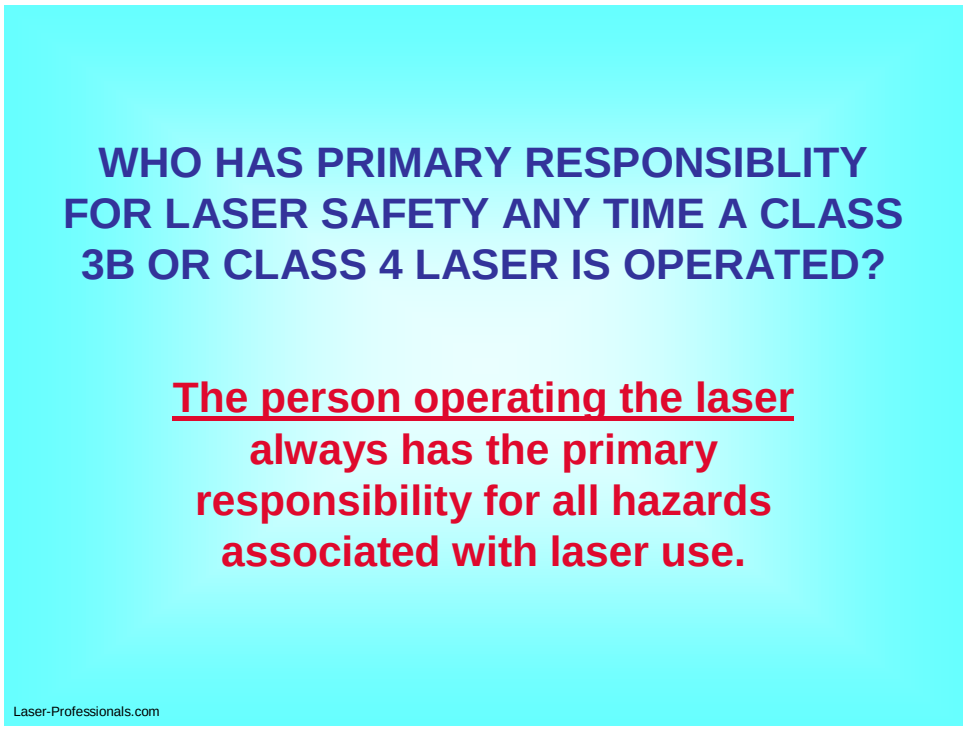
A laser safety officer (LSO) shall have the responsibility and authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards. The Radiation Safety Officer will designate a LSO. The LSO responsibilities include the following:

(1) Maintain records of all Class 3b and 4 lasers and laser operators
(2) Perform a periodic inspection of laser equipment
(3) Provide appropriate warning signs for posting
(4) Provide guidance on proper protective eyewear
(5) Assist Laser User with the controlled laser area and laser protection enclosures
(6) Participate in accident investigations involving lasers
(7) Periodically audit the departmental Laser Safety Program
(8) Maintain the laser safety training program

10.2 Laser User

A Laser User is the person responsible for the use and maintenance of a laser. Laser Users are responsible for the following:

(1) Comply with the requirements of the Laser Safety Manual and the LSO
(2) Notify the LSO of any new Class 3B and Class 4 lasers on the MU campus, or any major changes to a current Class 3B or 4 laser.
(3) Notify the LSO of any suspected overexposures to the laser beam
(4) Responsible for training persons who work with the laser



10.3 Laser Operator

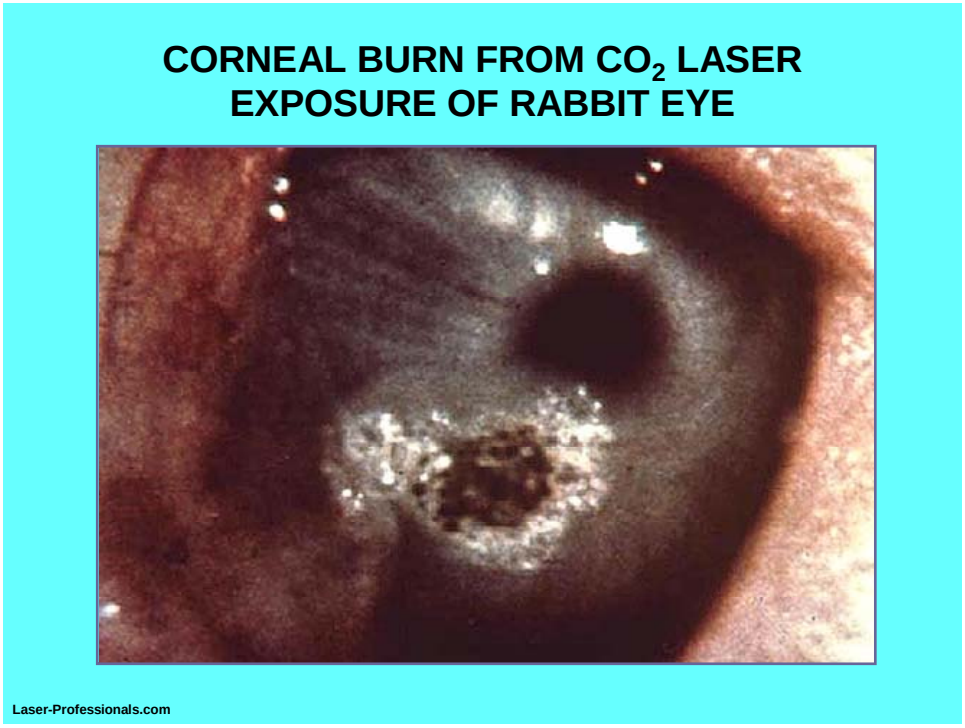
Laser Operators include persons who use the laser equipment. Laser operators shall use the laser equipment in accordance with the Laser Safety Manual.

11. Training

Laser safety training program shall be required for Class 3B and 4 lasers and laser systems. Laser safety training program should be required for Class 2, 2M and 3R lasers and laser systems. The LSO will provide assistance, if needed, for creating and implementing a laser safety training program. The laser safety training program should include the information in ANSI Z136.1-2007 Section 5.

12. Laser Accidents and Incidents

Persons receiving or suspected of having received a harmful laser light exposure must report such a fact or suspicion immediately to the named responsible person and the LSO. The LSO can be reached during business hours at 882-7018. For all emergencies, contact the MU Police at 882-7201.



13. References

American National Standard for Safety Use of Lasers; ANSI Z136.1-2007.

Laser Radiation Safety Manual; University of Missouri-Columbia Environmental Health and Safety; 1986.

UNC-CH Laser Safety Manual; University of North Carolina at Chapel Hill Environmental Health and Safety; http://ehs.unc.edu/radiation/laser/index.htm.

21 CFR Subchapter J "Radiological Health".

29 CFR Part 1910, Occupational Safety and Health Administration.

Appendix A
Class 3R, 3B, and 4 Requirements Summary

Table A-1 Requirements Summary

Requirement	**Laser Class**		
	3R	**3B**	**4**
Warning Signs	**X**	**X**	**X**
Warning Labels	**X**	**X**	**X**
Enclosed Beam Path	--	--	--
Supervision and/or use by knowledgeable person	**X**	**X**	**X**
Interlocks on Removable Protective Housing		**X**	**X**
Service Access Panel Locks		**X**	**X**
Key Control (master switch)		--	**X**
Beam Path Control		**X**	**X**
Beam Stop or Attenuator		--	**X**
Laser Controlled Area		**X**	**X**
Controlled Operation (distant operation)			--
Standard Operating Procedures		--	**X**
Warning Light or Buzzer		--	**X**
Protective Eyewear		--	**X**
Training	--	**X**	**X**
-- Recommended **X Required**			