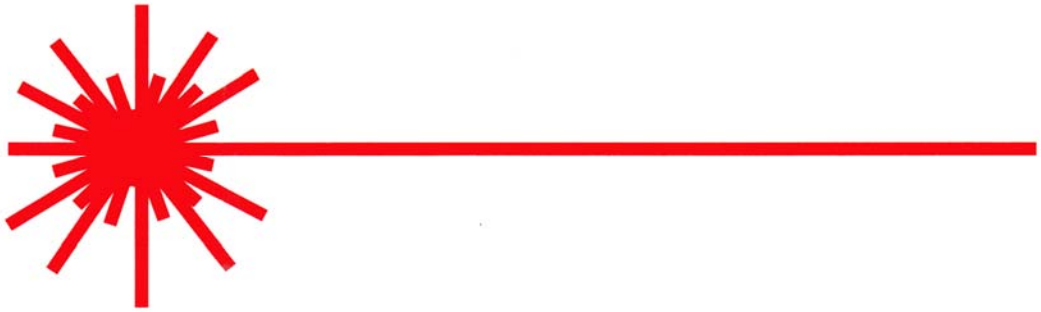
Yale University
Office of Environmental Health & Safety

Laser Safety Manual



Visible and/or Invisible Laser Radiation
Avoid Direct Exposure to Beam

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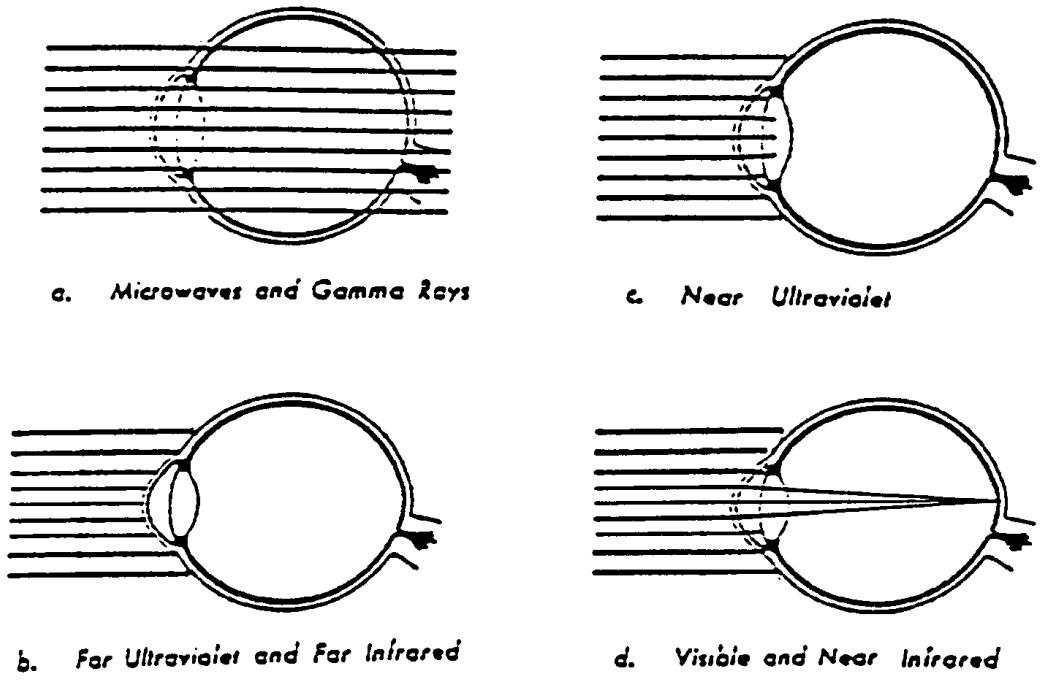
LASER SAFETY

The laser is a device which produces a very intense and very narrow (collimated) beam of electromagnetic radiation in the frequency range of 200 nm (nanometers,1 x 10^{-9} meters) to 1 mm. This radiation is generally in the form of intense visible light. Because laser light is not an ionizing type of radiation (i.e., not like gamma rays, x-rays, or beta particles), interaction with the body is generally at the surface. The eye and the skin are critical organs for laser radiation exposure, and the resultant effects vary depending on the type of laser (frequency or wavelength of the radiation) and beam energy output. Laser energy of the proper wavelength and energy may be focused by the lens of the eye onto the retina causing severe damage. If laser radiation is of high enough energy, skin burns may also result if extremities or other body parts are placed in the laser beam. The following table summarizes the various regions of the electromagnetic spectrum produced by laser and the organs of concern if exposure occurs.

LASER OUTPUT WAVELENGTHS AND ORGANS PRIMARILY EFFECTED

ELECTROMAGNETIC SPECTRUM REGION	WAVELENGTH RANGE	ORGAN EFFECTED
Ultraviolet	200 to 400 nm	Cornea, Lens, Skin
UV-C	200 to 280 nm	All absorbed in Cornea and Conjunctiva
UV-B	280 to 315 nm	Almost all absorbed in Cornea-Conjunctiva Cataract formation
UV-A	315 to 400nm	All absorbed in lens. Cataract formation.
VISIBLE LIGHT	400 to 780 nm	Retina
NEAR INFRARED (NIR)	780 nm to 1.4um	Retina, Lens, Skin
MID AND FAR IR		
IR-B	1.4 - 3.0 um	Cornea and Skin
IR-C	3.0 um to 1 mm	Cornea and Skin



Schematic diagram of the absorption of electromagnetic radiation in the eye.

Figure 1

The drawings shown in the **figure 1** indicate the absorption of electromagnetic energy by the eye at various frequencies. The most damaging frequency band is the "visible" as the lens has the ability to concentrate the laser energy incident in the cornea by 100,000 to 200,000 times producing a very intense spot on the retina (see d. in the figure).

In addition to the hazards described above, laser systems may involve high voltage hazards, toxic gas or vapors, fire hazards, and depending on experimental set up may involve microwave and/or x-radiation hazards. All of these hazards must be addressed for the overall safe operation of a laser installation.

I. Laser Classification Levels

The American National Standards Institute classifies laser systems into four classifications. These classifications are based on the potential for the direct beam or reflected beam to cause biological damage to the eyes and/or skin. Lasers are classed as:

CLASS I: Considered to be incapable of producing biological damage to eyes or skin.

CLASS II: "Low power systems", under certain conditions may be hazardous to eyes. Must have caution label affixed to laser.

CLASS IIIA: Intermediate power systems, require labeling and controls

CLASS IIIB: "Medium power systems", requires labeling and physical control measures to prevent viewing of direct and reflected beam.

CLASS IV: "High power systems", requires labeling and physical controls to prevent eye or skin contact with direct or reflected beam, and also with the diffusely reflected beam.

Embedded systems:

Class 2, 3 or 4 lasers or laser systems contained in a protective housing and operated in a lower classification mode may be classified at a lower classification. Specific control measures may be required to maintain the lower classification. For embedded systems that are non-commercial design and construction, the University LSO shall determine the classification.

For the purposes of laser safety, a direct laser beam which has been deflected from a mirror or polished surface is considered to be as intense as the direct beam. Laser beams which hit flat or non-mirror like surfaces are considered to be diffuse and the diffusely reflected beam is not as intense or as well defined as the direct beam.

II. Safety Guidance For Laser Operation

The guidelines which follow may or may not be applicable for each type of laser installation. Because the laser hazard is related to the wavelength, intensity, and intended use of the laser, the guidelines may be relaxed accordingly. For example, a class IV laser placed into a properly constructed enclosed beam path system may be reclassified as class I or II. The required safety measures would then be reduced.

For all lasers, use the minimum amount of laser radiation possible to ascomplish the experimental objective. Adjust beam height so that it is at a level OTHER THAN that of a seated or standing person.

DIRECT EXPOSURE OF THE EYE BY A LASER BEAM SHOULD ALWAYS BE AVOIDED WITH ANY LASER, NO MATTER HOW LOW THE POWER.

A. CLASS I LASER CONTROL MEASURES

1. Control measures or warning labels are not required, although needless direct exposure of the eyes should be avoided.

B. CLASS II LASER CONTROL MEASURES

1. An appropriate warning label must be placed on the housing.

2. Do not stare into the beam or allow other persons to do so.

C. CLASS III A or B LASER CONTROL MEASURES

1. The laser must have a protective housing such that laser light emerges from the aperture only.

2. A Key switch interlock system should be used to prevent unauthorized use of the laser.

3. The direct or mirror-reflected beam should not be viewed with the naked eye or with optical instruments such as telescopes.

4. Do not align the beam with the naked eye.

5. A beam stop must be provided to adequately stop the beam with the absence of scattered light emission.

6. Laser goggles may be necessary. Be certain that the goggle in use is appropriate both in the attenuation factor provided by the goggle and that the goggle is for the proper wavelength. LASER GOGGLES MUST BE MATCHED TO THE WAVELENGTH(S) OF THE LASER SYSTEM(S) BEING USED! Be aware of the dangers that reflected lasers can pose. In addition to mirrors, many smooth surfaces can reflect lasers.

7. Spectators must be limited.

8. The laser system should be installed in a sole use laboratory and the door kept closed during operation. The door should be labeled.

9. Be certain that scattered laser radiation is not escaping through a window to the outside.

10. Label high voltage areas and investigate for other associated hazards.

11. Eye examinations may be required prior to the use of such laser systems.

D. CLASS IV LASER CONTROL MEASURES

Call the Radiation Safety Section at 785-3550 for additional requirements.

1. All of the measures outlined in 3. above should be followed in addition to the measures below.

2. Goggles are required when such systems are in operation.

3. Spectators are prohibited.

4. The entrance to such areas must be interlocked such that entry shuts the beam down.

5. Such systems must be in sole use areas.

6. Access to such lasers shall be controlled by keyed access to both the room and the power panel to the laser. Such key will be kept in the possession of the Principal Investigator and access will be the Principal Investigator's responsibility.

7. Eye examinations are required prior to the use of such laser systems.

8. The Radiation Safety Section may institute additional control measures as deemed necessary for the safe operation of the laser.

Responsibilities of the Principal Investigator

1. To read and comply with University Laser Safety procedures.

2. To be familiar with content of LIA Laser Safety Guide [Class 3B , 4] and ANSI Standard [Class 4].

3. To train all users about specific safe use of laser.

4. To provide adequate supervision of all laser users.

5. Notify OEHS of all laser users names [Class 3B and 4].

6. To comply with medical surveillance program.

7. To have written standard operating procedures for use of Class 3B and Class 4 lasers.

8. To submit a copy of SOPs to OEHS. Notify OEHS of any changes in COP in writing.

9. To notify OEHS of any changes to enclosed laser systems.

10. To post appropriate signage.

11. To report accidents/injuries to University Health Services and OEHS within 24 hours.

Responsibilities of Individual Users

1. To read and comply with University Laser Safety procedures.

2. To be familiar with the content of LIA Laser Safety Guide [Class 3B,4] and ANSI standard [Class 4].

3. To participate in medical surveillance program.

4. To comply with written SOP established by Principal Investigator.

5. To NOT permit entry by ancillary services personnel into a room or area where a Class 3B or 4 laser system is operating.

6. To report all accidents or injuries to PI, University Health Services and OEHS within 24 hours.

7. To avoid working alone with high voltage or energy storage [capacitor banks] systems.

8. To see PI for any specific laser training, questions , supervision and before modifying the system.

The laser safety program is a part of the University Radiation Safety program. As such, laser use is under the general direction and authority of the Radiation Safety Section and the Radiation Safety Committee.