Introduction

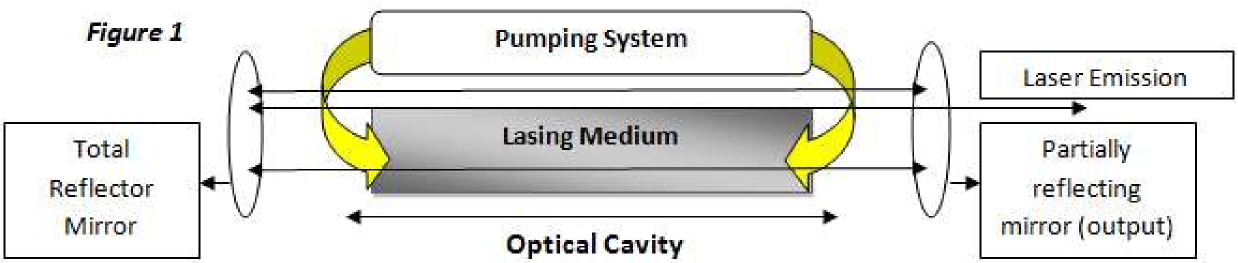
The Environmental Health & Safety (EH&S) Department continuously seeks to improve safety standards for all faculty, staff, students and visitors of Eastern Washington University (EWU). As stated in the Occupational Safety & Health Act (OSHA) Section 5(a)(1), often referred to as the General Duty Clause, employers are required to "furnish to each of his employee's employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees." Therefore, employers are required to "comply with occupational safety and health standards promulgated under this act." Specifically, Washington Administrative Code (WAC) 296-62-09005 requires a program which shall provide employees with adequate supervision, training, facilities, equipment, and supplies for the control of assessment of non-ionizing radiation hazards in our facility. Please read these regulations for further details.

The term LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. These devices generate a very intense light beam, which can be either visible or non-visible. Laser lights differ from the light we are accustomed to because of three primary characteristics. Laser lights are:

- **Monochromatic:** is of a single wavelength
- **Directional:** has very little beam divergence
- **Coherent:** with light waves moving in the same direction and "in phase"

A laser consists of an optical cavity, pumping system and an appropriate lasing medium (see figure 1).

Figure 1



- The **Optical Cavity** contains the media to be excited with mirrors to redirect the produced photons back along the same general path.
- The **Pumping System** uses photons from another electrical source such as lamps and lasers.
- The **Lasing Medium** designates the laser type. Different media can produce more than one wavelength. The lasing medium can be a solid, gas, dye (liquid), or semiconductor.
  1. **Solid** state lasers have lasing material distributed in a solid matrix. It is an optically clear material composed of crystal and an impurity dopant which will alter the optical/electrical properties of the semiconductor.
  2. **Gas** lasers (helium and helium-neon are the most common) have an electrical current which passes through the optical cavity, excites atoms and results in a primary output of visible red light.
  3. **Dye** (liquid) lasers use a complex organic dye and are usually pumped by a flash lamp or another laser. They are tunable over a broad range of wavelengths, but they tend to be complex systems and high maintenance.
  4. **Semiconductor** lasers are the most common lasers. They are not solid-state lasers and are generally very small in size do not use much energy. An example of a common use is they may be built into larger arrays, such as CD and CD/ROM players.

The wavelength output from a laser depends upon the medium being excited. The table below lists most of the laser types and their wavelength output as a result of the medium being excited.

Laser type	**Wavelength (µmeters)**	**Laser type**	*Wavelength (µmeters)*
Argon fluoride (Excimer-UV)	0.193	Helium neon (yellow)	0.594
Krypton chloride (Excimer-UV)	0.222	Helium neon (orange)	0.610
Krypton fluoride (Excimer-UV)	0.248	Gold vapor (red)	0.627
Xenon chloride (Excimer-UV)	0.308	Helium neon (red)	0.633
Xenon fluoride (Excimer-UV)	0.351	Krypton (red)	0.647
Helium cadmium (UV)	0.325	Rohodamine 6G dye (tunable)	0.570
Nitrogen (UV)	0.337	Ruby ($CrAlO_3$) (red)	0.650
Helium cadmium (violet)	0.441	Gallium arsenide (diode-NIR)	0.694
Krypton (blue)	0.476	Nd:YAG (NIR)	0.840
Argon (blue)	0.488	Helium neon (NIR)	1.064
Copper vapor (green)	0.510	Erbium (NIR)	1.15
Argon (green)	0.514	Helium neon (NIR)	1.504
Krypton (green)	0.528	Hydrogen fluoride (NIR)	3.39
Frequency doubled	0.532	Carbon dioxide (FIR)	2.70
Nd YAG (green)	0.543	Carbon dioxide (FIR)	9.6
Helium neon (green)	0.568		10.6
Krypton (yellow)	0.570		
Copper vapor (yellow)			

Key: UV = ultraviolet (0.200-0.400 µm)
VIS = visible (0.400-0.700 µm)
NIR = near infrared (0.700-1.400 µm)

** This table was taken from the OSHA LASER Technical Manual

General Safety Hazards of Lasers

There are various hazards associated with use of laser devices. The following topics should be considered while operating laser producing equipment.

- **Explosion Hazards:** High-pressure arc lamps and filament lamps or laser welding equipment shall be enclosed in housings which can withstand the maximum pressures produced by lamp explosion or disintegration. During laser operation, the laser target and elements of the optical training may shatter and should remain closed.
- **Optical Beam hazards:** Ultraviolet radiation emitted from laser discharge tubes, pumping lamps and laser welding plasmas should be suitably shielded to reduce exposure.
- **Radiofrequency (RF) Energy:** Radiation associated with the operation of a laser or laser system, radiofrequency energy associated with some plasma tubes, x-ray emission associated with the high voltage power supplies used with excimer lasers, shall be maintained below the applicable guidelines. Microwave energy and RF protection guides are given in the American National Standard "Safety levels with respect to human exposure to radio frequency electromagnetic fields, 300 kHz to 100 GHz" (ANSI C95.1). X-ray emission protection is found under Washington State Department of Health Radiation Safety office. If the laser in use is expected to generate significant levels of collateral radiation, they should be monitored on a regular basis.

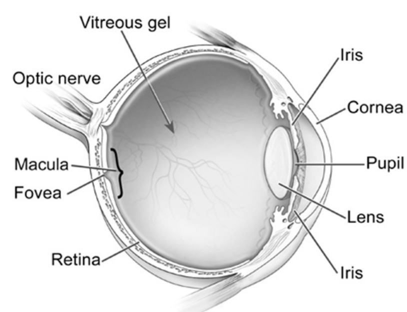
- **Electrical safety:** The method of electrical installation and power connection is determined by the intended application of laser use. Please follow standard Electrical Safety procedures. If you are in need of information on electrical safety, call EH&S at ext. 2788.
- **Flammability:** Enclosure of Class 4 laser beams and termination of some Class 3B lasers can result in potential fire hazards if the enclosure materials are exposed to irradiances exceeding watts per centimeter squared (W/cm^2). Plastic materials are not precluded as enclosure materials, but they are potentially flammable. Flame resistant materials and other various safety products should be considered!
- **Ergonomic:** Complexity of the workstation layout, operations and emotional stress also pose health risks. EH&S suggests you find the most comfortable position that does not compromise your overall safety. Call ext. 6697 for an ergonomic evaluation.

Biological Effects of Laser Beams

The primary concern when using laser(s) is the possibility of eye injury. Due to the intensity and concentration of the light, a laser beam of sufficient power can theoretically produce retinal intensities greater than conventional light sources and damage the retina; resulting in permanent blindness. The secondary concern is the potential damage to the skin. Biological effects depend on many factors including the wavelength of the light, power, intensity and whether it possesses a continuous wave nature or is pulsed. The risks associated with laser use are important and proper handling and caution should be used at all times.

The Eye

The most vulnerable areas of the eye that are susceptible to damage by visible and invisible laser beams are the cornea, lens and retina. Light enters through the layers of the cornea, and then focused by the lens and onto the retina to transform light into images as transmitted to the brain. The small area of the retina known as the fovea is responsible for acute color vision. If this area is damaged, a serious loss of sight can occur (see the diagram of the eye below).



This image is from the National Eye Institute

The Skin

Though damage to the skin is considered less dangerous, the chance for skin exposure from lasers is greater due to the skin's large surface area compared to the eye. Although it is possible to have a painful injury from a severe laser burn, most skin injuries heal and the damage is only temporary. Varying wavelength types penetrate the skin at different depths, the most penetrating being from 700-1,200 nm. Usually, the individual exposed to the laser will experience a heating sensation, thus noticing their risk and avoid injury.

Damage to the skin, also known as a thermal injury, is the most common cause of laser induced tissue damage as a result of increased temperature following absorption of laser energy. The principal thermal effects of laser exposure depend on the following factors:

- Absorption and scattering coefficients of the tissues at the laser wavelength

- Irradiance of radiant exposure of the laser beam
- Duration of the exposure and pulse repetition characteristics, where applicable
- Extend of the local vascular flow
- Size of the area which has been irradiated

The **Ultraviolet B** lasers can be the most injurious due to their ability to cause thermal damage, as well as increase potential for carcinogenesis**.** **Ultraviolet A** lasers can cause skin burns or discoloration of the skin. **Ultraviolet C** seems to have the least effect on the skin due to its short wavelength which is absorbed by the skin.

Laser Hazard Classification

A generalized method for determining the danger level of a particular laser is to provide labels and instruction with corresponding levels of accessible laser radiation. Lasers and laser systems are required by federal law, 21 CFR 1000, to be classified and appropriately labeled by the manufacturer. If the laser or laser system is modified at any time, the classification may change.

The larger the class number, the greater the potential hazard. There are four broad Classes (1-4) depending on the potential for causing biological damage. Class 3B and Class 4 are the most dangerous. The descriptions of each class are as follows:

- **Class 1 (Safe, Visible, or Non-visible):** cannot emit laser radiation at known hazard levels (typically a continuous wave). Safe under reasonably foreseeable conditions of operation; often consist of high power laser, but access to the beam is controlled by engineering means such as interlocks and protective enclosures.
- **Class 1A:** this is a special designation that is based on the idea that they are "not intended for viewing" such as a supermarket laser scanner. The emission from a Class 1A laser is defined such that the emission does not exceed the Class 1 limit for emission duration of 1000 seconds.
- **Class 2 (Low Hazard, Visible only):** low-power visible lasers that emit > Class 1 levels but at a radiant power less than 1 mW. The concept is that the human aversion reaction to bright light will protect an individual. Only limited controls are specified
- **Class 3A (Low and Medium Power):** intermediate power lasers. Risk of injury is greater that for the lower classes but not as high as for Class 3b.
- **Class 3B (Medium and high power, Visible and non-visible):** moderate power lasers. Direct viewing of these beams is always hazardous. Viewing diffuse reflections is normally safe as long as the eye is no closer than 13 cm from the diffusing surface and exposure is under 10 sec. Generally, does not pose a fire hazard, but specific controls for all potential hazards are recommended.
- **Class 4 (High Power, Visible and Non-visible):** These lasers are hazards to view under any condition (directly or diffusely scattered) and are a fire hazard, eye and skin hazards. Protective eyewear shall be worn for all operational conditions for maintenance which may result in exposures to laser radiation (WAC 296-62-09005 (4f)). Class 4 lasers require significant controls.

The classification of a laser or laser product is a detailed process, which can involve the determination of the Accessible Emission Limit, measurement of laser emission, pulse characteristics (if applicable), and evaluation of safety features as specified by the American National Standard (ANSI) for Safe use of Lasers 136.1 and 136.2 standards. The classification is required by the manufacturer and to be labeled on the lower left-hand corner of the warning logotype label. In addition to the specified classification, the laser type and power or energy output is specified. Class 1 lasers have no required labeling indicating their status.

Preventing Injury

Research staff and laser operators are obligated to follow all procedures and to wear protective equipment when required. Any accidents must be reported to EH&S as soon as possible and an Incident Report must be completed for review.

The ANSI has created four basic categories of useful controls in laser environments. They are engineering controls, personal protective equipment, administrative and procedural controls, and special controls. For example, Class 4 laser users shall initiate the following control measures according to the ANSI (please see Attachment A at the end of this document):

- Standard Operating Procedures
- Output Emission Limitations
- Education and Training
- Authorized Personnel
- Alignment Procedures
- Protective Eyewear
- Skin Protection
- Protective Barriers/Curtains
- Warning Signs/Labels
- Other Personal Protective Equipment

Personal Protective Equipment

The use of protective eyewear is particularly important during the operation of lasers. They are required if Class 3B or 4 lasers are being used and must be worn at all times when the machine is powered. Eyewear is strongly encouraged for all other Classes as well. When using Class 3B and 4 lasers, the eyewear must be labeled with the wavelength to be attenuated and the optical density (OD) for each wavelength. The equation for OD is as follows:

$$OD = \log_{10} H_0 * MPE$$

Where H_0 = Anticipated worst-case exposure (J/cm^2 or W/cm^2)

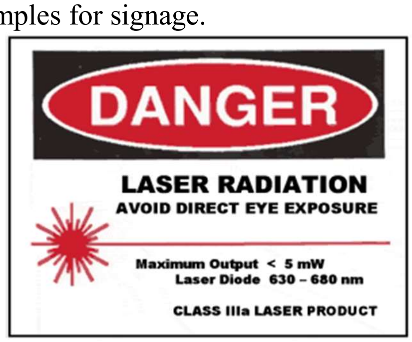
MPE = Maximum permissible exposure level, expressed in the same units as H_0

Users should routinely inspect protective eyewear for damage and degradation cause by age to ensure quality protection. Other factors to consider regarding your protective eyewear are:

- Laser wavelength or range
- Optical Density
- Damage Threshold
- Visual transmittance of eyewear
- Field of view and curvature of the lenses
- Ventilation
- Effect on color vision
- Impact resistance and cost

Administrative Controls

Administrative controls such as warning signs, standard operating procedures, and training are basic, yet effective, control initiatives that should be implemented for all laser users and locations. Products should have a warning label (example shown below) advising the user to avoid exposure to the laser radiation. At the end of this document, there are additional examples for signage.



www.fda.gov

When Class 3B and 4 lasers are in use, flashing red lights must be on outside the main entrance during operation. Window and door coverings are important to avoid reflected or scattered laser light from exiting through unblocked windows. All reflective objects should be removed from the beam path and the work area should be surrounded by a covering of some sort to ensure that laser light cannot reach other persons in the room. Please post one of the signs below on the exterior of the room door when laser is in use or being repaired.

The EH&S Department is expecting to see Standard Operating Procedures (SOP) for each laser that is operational. These procedures are important to be kept available near the laser area and in the EH&S office.

In Case of Emergency

In the event of an accident

- Immediately call 911 for medical assistance
- Turn off the laser system but leave the scene as it is
- Do not allow the injured person to drive themselves for medical attention
- Call EH&S at x6455, x6697, or x6497 as soon as possible
- Notify others in the work area, supervisor, and department chair
- Submit an Incident Report Form to EH&S as soon as possible: https://sites.ewu.edu/ehs/incident-reporting/incident-report/

The EH&S office asks all users to use engineering controls such as enclosures, interlocks and beam stops when possible, wear protective equipment, acknowledge and understand non-beam hazards, and follow alignment and operational procedures.

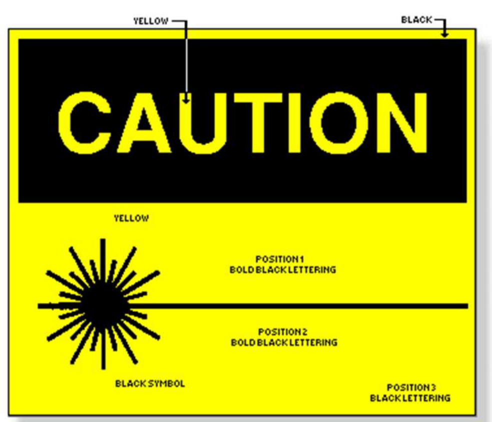
Attachment A. ENGINEERING CONTROL MEASURES FOR THE FOUR LASER CLASSES [ANSI Z 136.1 (1993)]

	------------------ Class ------------------					
Control measures	**I**	**IA**	**II**	**IIIA**	**IIIB**	**IV**
Protective housing	X	X	X	X	X	X
Without protective housing	-- LSO shall establish alternate controls --					
Interlocks on protective housing	a	a	a	X	X	X
Service access panel	b	b	b	b	b	X
Key switch master	_	_	_	_	·	X
Viewing portals	_	_	◊	◊	◊	◊
Collecting optics	_	_	◊	◊	◊	◊
Totally open beam path	_	_	_	_	X	X
Limited open beam path	_	_	_	_	X	X
Remote interlock connector	_	_	_	_	·	X
Beam stop or attenuator	_	_	_	·	·	X
Activation warning system	_	_	_	_	·	X
Emission delay	_	_	_	_	_	·
Class IIIB laser controlled area	_	_	_	_	X	_

Class IV laser controlled area	_	_	_	_	_	X
Laser outdoor controls	_	_	_	_	X	X
Temporary laser controlled area	b	b	b	b	_	_
Remote firing & monitoring	_	_	_	_	_	·
Labels	_	X	X	X	X	X
Area posting	_	_	·	·	X	X
Administrative & procedural controls	_	X	X	X	X	X
Standard operating procedures	_	_	_	_	·	X
Output emission limitations	_	_	_	--LSO determines--		
Education and training	_	_	_	X	X	X
Authorized personnel	_	_	_	_	X	X
Alignment procedures	_	_	X	X	X	X
Eye protection	_	_	_	_	·	X
Spectator control	_	_	_	_	·	X
Service personnel	b	b	b	b	X	X
Laser demonstration	_	_	X	X	X	X
Laser fiber optics	_	_	X	X	X	X

Key: X = Shall.
a. = Shall if embedded Class IIIA, Class IIIB, and Class IV.
b. = Shall if embedded Class IIIB or Class IV.
_ = No requirement.
· = Should.
◊ = Shall if MPE is exceeded

Administrative Control: Warning Signs



OSHA Technical Manual

"Caution" is for Class II and IIIa lasers and laser system use