LASER PROTECTIVE EYEWEAR
SafetyNet #73

Laser protective eyewear is presently available from several commercial sources and in many varieties. Several factors should be considered in determining whether eyewear is necessary and, if so, selecting the proper eyewear for a specific situation. At least two output parameters of the laser or laser system must be known and knowledge of environmental factors such as ambient lighting and the nature of the laser operation is also required. Laser eye protection generally consists of a filter plate or stack of filter plates or two filter lenses that selectively attenuate specific laser wavelengths but transmit as much visible radiation as possible. Eyewear is available in several designs including spectacles, coverall types with opaque side-shields, and coverall types with somewhat transparent side-shields.

Factors to Consider in Selecting Protective Eyewear

- Do you need to see the beam spot for alignment?
  (Continuous wave, visible wavelengths only) Yes o No o
- Wave length in Nanometers ______________________________(list all applicable wavelengths and ranges)
- Circle all lasers that you use:
  Eximer, Argon, Argon Alignment, ND: YAG, Yag & Harmonics, Holmium, Erbium, CO2, Alexandrite, Ruby, HeNe, Dye (tunable), Diode, Ti:Sapphire, OPO, MOPO. Add any others that are not here __________________
- Power in Watts (continuous wave lasers)____
- Power in Joules (pulsed lasers)____
- Pulsed duration in seconds (pulsed lasers)____
- Pulse repetition frequency in Hertz (pulsed laser) ____
- Beam diameter at exit aperture in millimeters__________________(if you want eyewear to wear internationally)
- Do you need to cover prescription eyewear?
  (goggle or DVO-OGT type) Yes o No o
- Do you prefer prescription laser eyewear?
  (Rx insert eyewear also available in some frame styles) Yes No o

Requirements

- **Outdoor Applications**: The most desirable hazard control procedure for class 3b and 4 lasers is to make sure you have no reflective surfaces (thus no chance of specular or diffuse reflections) in the beam path.
- **Laboratory Applications**: Eye protection is required when using all class 3b and 4 lasers or laser systems. Most accidents occur during alignment of the laser.

- **Curved Lenses**: Potentially hazardous specular reflections can exist when using flat lens surfaces (filters). Curved filters are safer than flat lens filters for other staff that may be in the operational area.

Parameters

- **Wavelength**: Protective eyewear should be specific to prevent the particular wavelength(s) of the laser from reaching the individual's eye.   Each wavelength must be considered when selecting protective eyewear. Many lasers radiate at more than one wavelength, thus, eyewear designed to have adequate attenuation for a particular wavelength could be completely inadequate at another wavelength. This may become particularly serious with lasers that are tunable over broad wavelength bands. In these cases, alternative methods, such as indirect viewing may be appropriate.

- **Optical Density**: The optical density is a parameter for specifying the attenuation afforded by a given thickness of any transmitting medium. Optical density is a logarithmic notation and is described by the following mathematical expression:

  $$\text{O.D.} = \log_{10}(H_0/\text{MPE})$$

  Where H_0 is the anticipated worst-case exposure (expressed usually in units of W/cm^2 for continuous wave sources of J/cm^2 for pulsed sources). The MPE (maximum permissible exposure) is expressed in units identical to those of H_0 .

- **Laser Beam Irradiance**: The maximum laser beam radiant exposure in joules/cm^2 for pulsed lasers or maximum laser beam irradiance in watts/cm^2 for continuous wave lasers cannot always be readily determined. If the beam is never focused and is larger than the diameter of the pupil of the eye, the output energy per unit area or power per unit area should be the guiding value. If the beam is focused or if the beam cannot be observed at the output, the maximum total beam energy or power output must be used.

- **Visible Transmittance of Eyewear**: The purpose of protective eyewear is to filter out the laser wavelength(s) while allowing as much of the visible light as possible to pass through. A low visible transmittance creates problems of eye fatigue and may require an increase in ambient lighting in the laboratory. However, adequate optical density at the laser wavelength(s) should not be sacrificed for improved visible transmittance.

- **Laser Filter Damage Threshold**: At very high beam intensities, filter materials that absorb the laser radiation are damaged. Thus, it becomes necessary to consider a damage threshold for the filter. Typical damage thresholds from q-switched pulsed laser radiation fall between 10 and 100 joules/cm^2 for absorbing glass and 1 to 100 joules/cm^2 for plastics and dielectric coatings. Continuous wave power higher than 10W can fracture glass filters and burn through plastics. If you smell smoke and see a dark spot on your laser safety eyewear getting larger, you may want to move as you are in the beam path and will soon sustain eye damage.

Selecting Appropriate Eyewear

- Determine wavelength(s) of laser output.

- Determine required optical density. Attachment 1 provides the required optical densities for various laser beam irradiances that could be inadvertently directed upon the protective eyewear. To determine the maximum incident beam irradiance, consider the following:

  - If the emergent beam is not focused down to a smaller spot and is greater than 7 mm in diameter, the emergent beam radiant exposure/irradiance may be considered the maximum intensity that could reach the unprotected human eye.
  - If the emergent beam is focused after emerging from the laser system or if the emergent beam diameter is less than 7 mm in diameter, assume that all of the beam energy/power could enter the eye. In this case, use the columns labeled "Maximum Laser Output Power/Energy" in attachment 1.

- If the observer is in a fixed position and cannot receive the maximum output radiant exposure/irradiance, then a measured value may be used (e.g., downrange from the laser beam).

Testing Laser Eye Protection

Eye protection should be checked periodically for integrity. The measurement of eye protection filter optical densities in excess of 3 or 4 without destruction of the filter is very difficult. Because of this problem, requirements originally proposed by many laser hazard control guidelines stated that the optical density of protective eyewear be periodically checked have been deleted. The greatest concern has been with goggles having specified optical densities at or only slightly above the density required for protection.

Identification of Eyewear

All laser protective eyewear must be clearly labeled with the optical density value and wavelength to indicate the level of protection provided. Color-coding or other distinctive identification of protective eyewear is recommended for multi-laser systems.

Comfort and Fit

Protective eyewear should be comfortable and prevent hazardous peripheral radiation. For additional information, contact your EH&S Safety Advisor, EH&S at 530-752-1493 or ehsdesk@ucdavis.edu.

Rev 9/08
RS

Attachment 1

Selecting Laser Eye Protection for Intrabeam Viewing for Wavelengths Between 400 and 1400 nm

Q-Switched (1 ns to 0.1 ms)		Non-Q-Switched (0.4 ms to 10 ms)		Continuous Wave Momentary (0.25 s to 10 s)		Continuous Wave Long-term Staring (greater than 3 hrs)		Attenuation	
Max. Output Energy (J)	Max. Beam Radiant Exposure (J cm^{-2})	Max. Laser Output Energy (J)	Max. Beam Radiant Exposure (J cm^{-2})	Max. Power Output (W)	Max. Beam Irradiance (W cm^{-2})	Max. Power Output (W)	Max. Beam Irradiance (W cm^{-2})	Attenuation Factor	Optical Density (O.D.)
10	20	100	200					100,000,000	8
1.0	2	10	20					10,000,000	7
$10E^{-1}$	2 x $10E^{-1}$	1	2			1	2	1,000,000	6
$10E^{-2}$	2 x $10E^{-2}$	$10E^{-1}$	2 x $10E^{-1}$			$10E^{-1}$	2 x $10E^{-1}$	100,000	5
$10E^{-3}$	2 x $10E^{-3}$	$10E^{-2}$	2 x $10E^{-2}$	10	20	$10E^{-2}$	2 x $10E^{-2}$	10,000	4
$10E^{-4}$	2 x $10E^{-4}$	$10E^{-3}$	2 x $10E^{-3}$	1	2	$10E^{-3}$	2 x $10E^{-3}$	1,000	3
$10E^{-5}$	2 x $10E^{-5}$	$10E^{-4}$	2 x $10E^{-4}$	$10E^{-1}$	2 x $10E^{-1}$	$10E^{-4}$	2 x $10E^{-4}$	100	2
$10E^{-6}$	2 x $10E^{-6}$	$10E^{-5}$	2 x $10E^{-5}$	$10E^{-2}$	2 x $10E^{-2}$	$10E^{-5}$	2 x $10E^{-5}$	10	1