Many reported laser eye accidents have occurred as a result of not wearing or having the incorrect eyewear.

Laser eyewear should be readily available and worn whenever a hazardous condition exists.

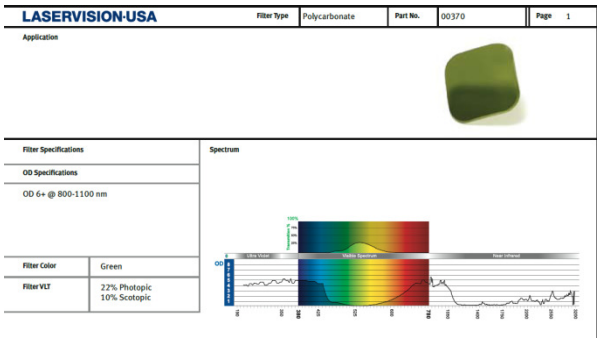
Laser eye protection should be selected on the basis of affording the protection required to protect the eye against the maximum exposure anticipated while still permitting the greatest amount of light to enter the eye for the purpose of seeing. The following factors must be taken into account in any selection of specific types of eye protection:

- Laser wavelength or spectral range at which protection is afforded.
- Pulsed or Continuous wave operation.
- Power (watts for continuous and Joules for pulse operation).
- Pulse duration and pulse repetition rate.
- Optical density at that spectral wavelength.
- Threshold Damage Factor - Maximum beam power (W) to which the eyewear provides the protection for at least 5 seconds, preferably, 10 seconds, following noticeable melting or flame.
- Curvature of the lens surface and the field of view provided by the design of the eyewear.
- Ventilation ports to prevent fogging on full-face fitted protection.
- Effect upon color vision.
- Environment to be used.
- Impact resistance.
- Visible Light Transmission
- Prescription eyewear

Not all laser eye protection is the same. The kind of lens you use should be based on the wavelength and power (Damage Threshold) of the laser you're working with.

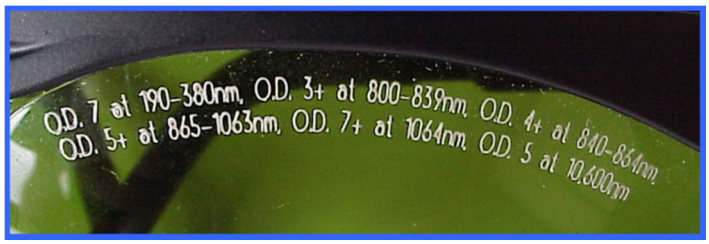
Most eyewear is either polycarbonate or glass and employs filters or coatings.

Neutral density
absorbs and reflects
Bandpass
transmits weaker light
Cut-off
blocks light at one end
Dielectric Coatings
Scatters and reflects



THE BASIC REQUIREMENTS UNDER ANSI Z136.1

- **Protective eyewear shall be worn whenever operational conditions may result in potential eye hazard**.



- All laser protective eyewear shall be **clearly labeled** with the **optical density** value and **wavelength** for which protection is afforded.

- Protective eyewear should be **comfortable**, provide **adequate visibility** (luminous transmission) and prevent hazardous peripheral radiation.

- **Periodic frequent inspection** shall be made of protective eye wear to insure the maintenance of satisfactory filtration ability especially following exposure to hazardous Class 4 laser radiation. See "Care and Maintenance" section below.

CARE AND MAINTENANCE

The proper care and maintenance is essential to ensure that the equipment remains in good condition and is serviceable. Eyewear can represent a significant investment. It will last longer and give better service if it is kept clean and properly stored. Poorly maintained eyewear will not only need to be replaced more often but can be a liability to the wearer.

Storage: Eyewear should be stored in clean and sanitary "ready for use" condition in an area away from dust and dirt and other contaminants. The eyewear should also be kept in an area away from exposure to chemicals and vapors, which could degrade or affect the material over time. This may be especially true in some of the plastic lenses in that the organic dyes used as absorbers are more readily affected by heat and/or ultraviolet radiation, which cause the filter to significantly darken. In addition to affecting the eyewear, contaminants in the work area may also be introduced into or around the eye when the contaminated eyewear is worn.

Cleaning: If the eyewear needs to be cleaned, follow the recommendations of the manufacturer. Generally, a mild soap solution is fine for polycarbonate eyewear. Special care may need to be taken for coated or laminated eyewear.

Inspection: This shall include inspection of the filter material **for pitting, crazing, cracking,** and inspection of the goggle frame for mechanical integrity and light leaks. Straps should be inspected as well and replaced if they have been stretched or are frayed.

Eyewear Inspection

- **Match Eyewear to Laser (OD and Wavelength)**
  - Markings must be legible and meet the OD and wavelength requirements of the laser(s) in use.
  - Inspect the Lens

- **Inspect the Lens**

	Peripheral	Central	Rim
White Marks	None	None	None
Blemishes	< 0.5 mm	None	Acceptable
Swirls	None	None	Acceptable
Pits, Digs	< 4 mm	None	< 6mm
Surface Scratches (mm)	< 0.011 (w) x 3 (l) mm	None	< 0.11(w) x 6(l) mm
Coating Tack (Thumb Test)	None	None	None

Central (C) = 28mm Optical Center or apex of the lens, Peripheral (P) = Remaining area outside optical center, Rim (R) = 3mm Perimeter of the lens

- **Inspect the Frame**

The mechanicals must be intact and all features operational. Uniformity of the frame surface is paramount to performance and protection. Discoloration or worn areas can indicate chemistry change and possible frame brittleness.

  - Is the frame broken?
  - Is the frame cracked?
  - Do the temples adjust as the frame design allows?
  - Do the ratchets function and do they hold the weight of the lens?
  - Are the retainer straps or goggle straps functioning and not worn?

- **Evaluate the Fit**
  - Is the fit secure and stable to ensure eyewear stays in place?
  - Is it comfortable to ensure that eyewear is worn when needed?
  - Does the eyewear impede significant orbital and peripheral light?

Optical Density

O.D. - Optical Density - Approximately the order of magnitude of transmittance (**T**) at a given wavelength. More accurately the OD is equal to $\log_{10}(1/\mathbf{T})$

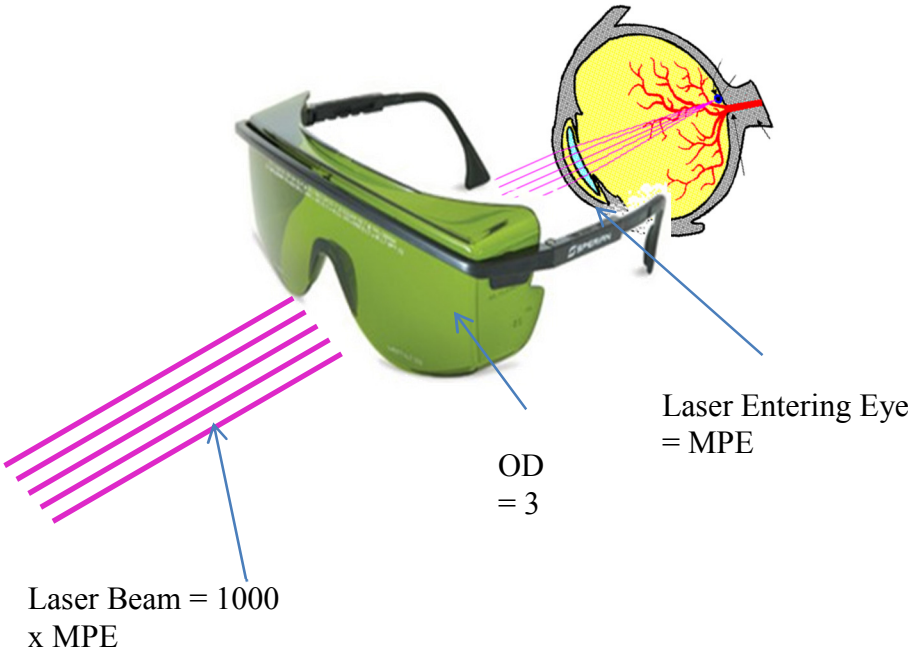
Mathematically,

$$OD = log_{10}\left[\frac{H_0}{MPE}\right]$$

Where: H_0 is the anticipated exposure or irradiance and MPE is the Maximum Permissible Exposure expressed in the same units as H_0

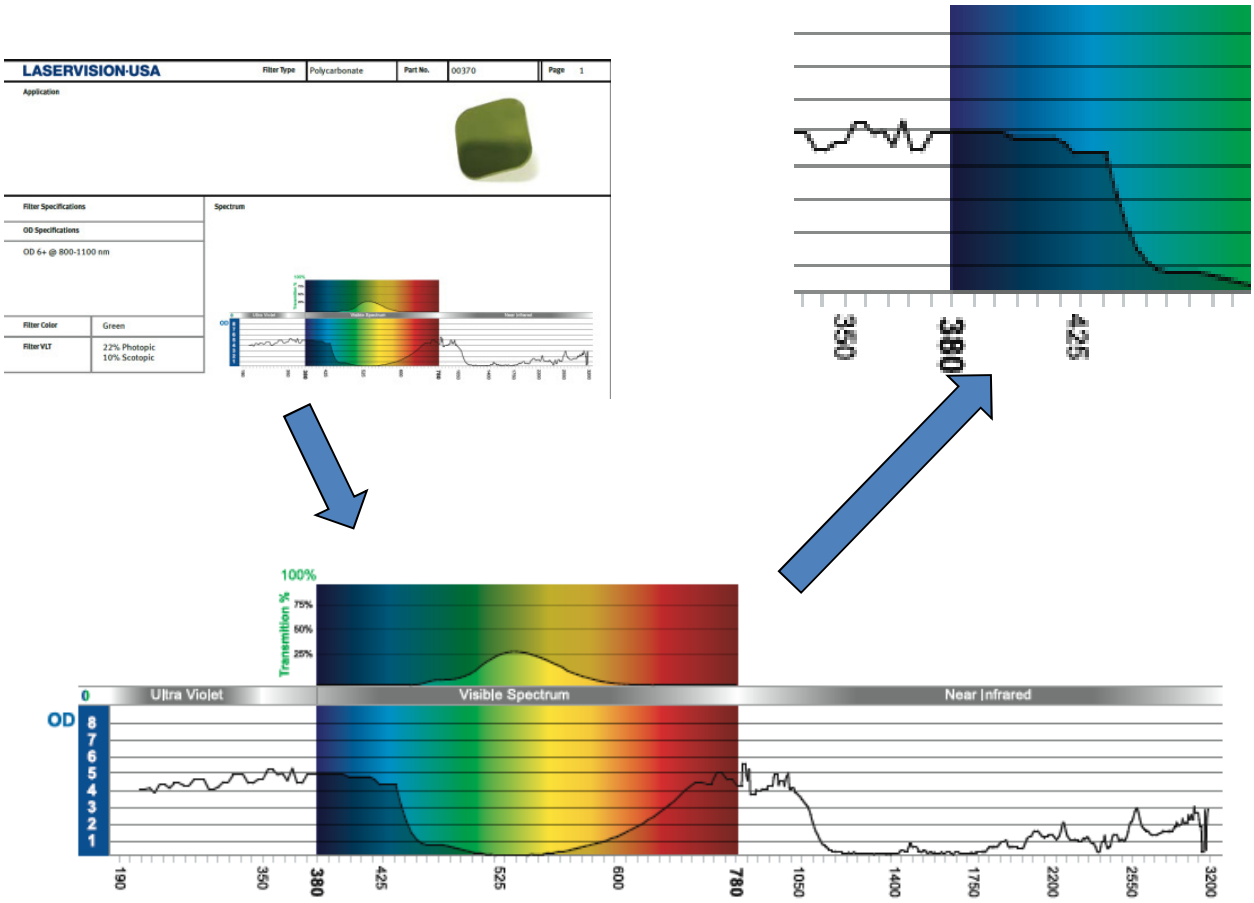
Rounded up for eyewear

OD 1 reduces transmission by 10
OD 2 reduces transmission by 100
OD 3 reduces transmission by 1,000
OD 4 reduces transmission by 10,000
OD 5 reduces transmission by 100,000
OD 6 reduces transmission by 1,000,000
OD 7 reduces transmission by 10,000,000



Close Doesn't Count

Consider an eyewear that is rated 4+ at 435 nm. At 445 this is reduced to 2+ and at 455 nm this is now less than 1. This is a drop of 4 orders of magnitude in protection. **Use only what is indicated in the labels provided by the eyewear manufacturer.**



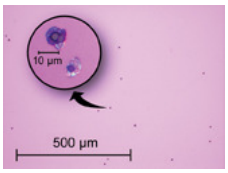
Limitations of Optical Density Specification and Damage Threshold

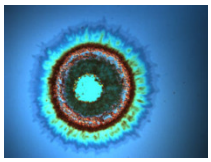
ANSI Z87.1 – 2007

- Optical Density alone does not take account of the damage threshold of the material which is used to protect us from the laser radiation - i.e. the power or energy density (W/m^2 or J/m^2) which the eyewear will withstand.

- Plastic materials have damage thresholds much lower than glass filters and glass (by itself) is lower than glass coated with a reflective dielectric coating.

- ANSI does not recommend the use of eyewear as a control procedure at levels exceeding 100 W or 200 W cm^{-2}. In other words, engineering controls and controlling the laser path must be implemented and adhered to since damage or destruction of the attenuating material used in the eyewear may result.



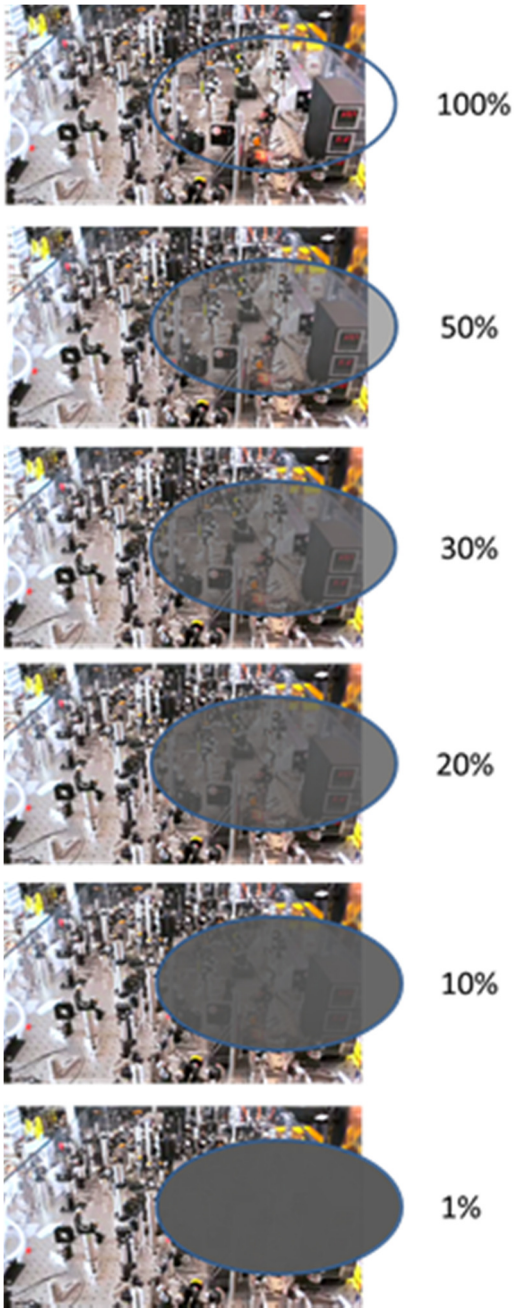


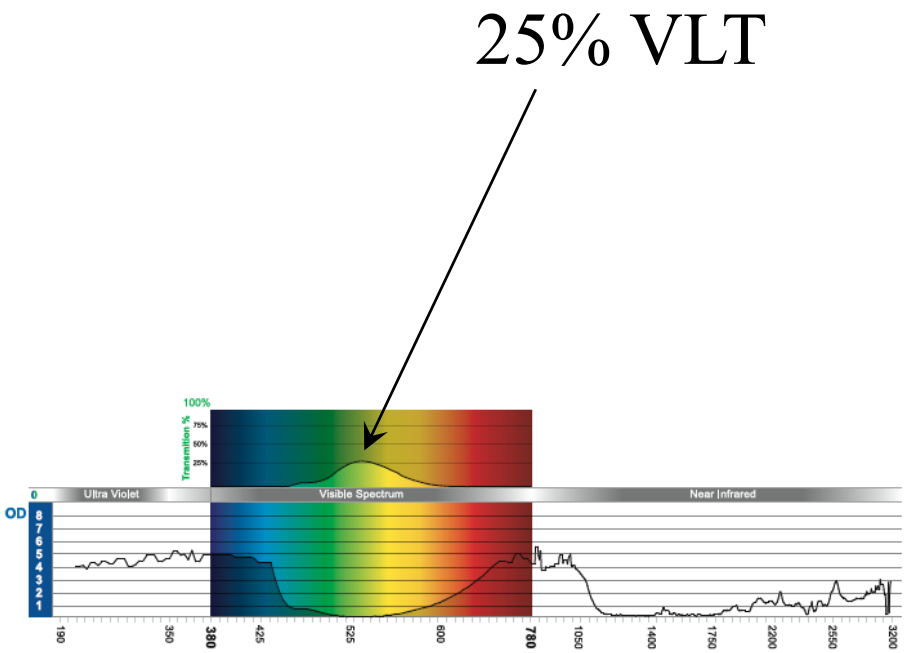
Material	Dielectric Coatings	Uncoated glass	Plastics
Damage (typ) Thresholds	500 and 1000 W·cm^{-2}	100 to 500 W·cm^{-2}	1 to 100 W·cm^{-2}

- **Degradation of absorbing media**: Plastic filter materials often offer greater impact resistance, lighter weight, and convenience of molding the eye protection into comfortable shapes. The disadvantages are that they are more readily scratched and the filters often "age" poorly in that the organic dyes used as absorbers are more readily affected by heat and/or ultraviolet radiation, which cause the filter to significantly darken. Plastic materials generally display a lower threshold for laser beam penetration. This may be offset somewhat by the fact that the absorbing media is contained throughout the matrix and is not subject to scratching or wearing off.

Visible Light Transmission (VLT)

Visible light (luminous) transmission requirements: This figure should be as high as practical. Laser protective eyewear with luminous transmissions of around 20% and less should be avoided.





Note that some color lost will occur. Beware of red and green instrument indicators.

Alignment

User awareness of eyewear limitations is critical

Often, eyewear designed for full protection often greatly reduces the possibility of seeing the beam. Thus a diffuse reflection cannot be seen during an alignment process. So-called "alignment" eyewear is designed to allow a safe level of laser light to be transmitted through the filter provided that special alignment procedures are followed. This requires viewing only diffuse (scattered light) reflections of the beam and never the direct beam.

Alignment eyewear is an option for use with visible beams and gives partial visibility for beam observation from diffuse or attenuated reflections, but not full protection from the direct beam. Use of alignment eyewear will be limited to situations where exposure to a direct beam is prevented, and thorough justification for the use of alignment eyewear must be provided by the laser user.

This must be specifically stated as part of a Laser Safety Procedure and approved by the LSO. Approval for the use of alignment eyewear should be reviewed periodically, based on an evaluation of the experimental conditions by the LSO.

The following criteria will be used as guidance in determining whether alignment eyewear is appropriate for particular circumstances and for selecting the appropriate eyewear OD*:

Alignment Eyewear should only be worn during reduced power operation. Laser eyewear used for alignment (at normal power operation) by definition will not protect one from a direct beam exposure it allows visualization of visible beams where full protection does not.

Prior to using alignment eyewear, consider the following;

- Can lowering or attenuating the beam output to a 3R level be possible?
- Can remote viewing aids, CCD, Web Cam that do not place the user over the beams be used?
- Can co-propagated (co-bore sighted) beams be used?

Pulsed lasers presents challenges, our recommendation is that the Alignment OD be no more than 1.4 OD less than that full protection.

Before using alignment eyewear, the user must review the set-up and follow the Alignment LSP.

Ensure the direct beam is provided with beam blocks and/or enclosures

Determination of the appropriate OD (and justification) must be made for specific circumstances by the laser user in consultation with the LSO.