

LIA Guide for the Selection of Laser Eye Protection

Table of Contents

I.	Introduction.....	1
II.	Laser Bioeffects	3
III.	General Policy.....	6
IV.	Factors to Consider	7
V.	Selection of Eye Protection	8
VI.	Limitations of Eye Protection	13
VII.	Minimum Technical Requirements for Laser Eye Protection ...	16
VIII.	Hazard Analysis and Eye Protection	19
IX.	Laser Goggle Testing	20
X.	To Use or Not Use Laser Eye Protection	20
XI.	Checklist for Choosing Laser Eye Protection.....	21
XII.	Optical Density Tables for Commercially Available Eye Protection.....	22
XIII.	Laser Eye Protection Vendors in Survey.....	64
XIV.	List of Other Laser Eye Protection Vendors.....	65
XV.	References	66
XVI.	List of Tables and Figures	68

I. Introduction

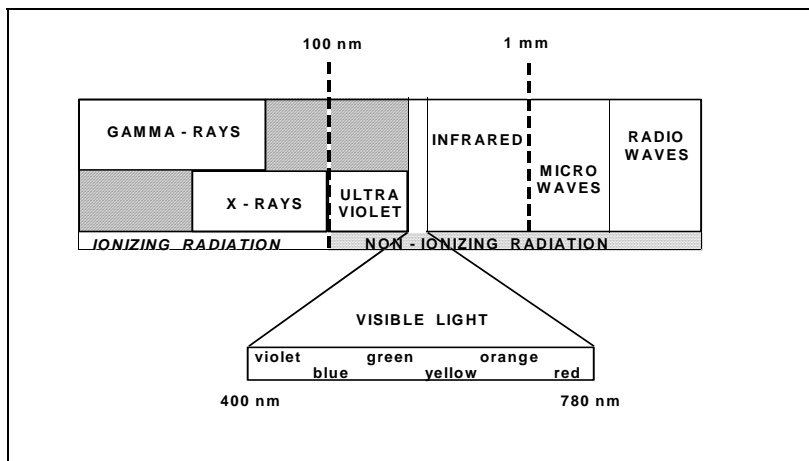
The enormous expansion of laser use in medicine, industry, and research has generated an increased demand for laser eye protection. Various laboratories and manufacturers have developed a large variety of laser protective eyewear. Commercially available eye protection is available for most wavelengths and in a variety of different designs. According to ANSI Z136.1, eyewear is required for Class 3B and Class 4 lasers or laser systems when engineering and administrative controls are inadequate to eliminate the potential exposure in excess of the applicable maximum permissible exposure (MPE) level (i.e. within the nominal hazard zone) . Figure 1 illustrates the more recent designs in laser eyewear.



Figure 1 - Different types and styles of commercially available laser eye protection.

The first types of eye protection can be traced back to 1962 when Dr. H.W. Straub of the U.S. Army's Harry Diamond Laboratory first recommended Schott BG-18 filter glass as an ideal absorbing glass filter to be used as protection against the ruby laser wavelength (694.3 nm). At this point, it had already been realized that visible and near infrared laser wavelengths presented a unique hazard to the retina. Within the retinal hazard region (400-1400nm), the retina is of the order of 100,000 times more vulnerable to injury than the skin. Because of the human eye's ability to focus this region of light onto the retina, eye protection with enormous attenuation factors are necessary to adequately protect the eye from lasers.

Figure 2 below illustrates the various regions of the electro-magnetic (optical) spectrum. Note that the visible region (approx. 400-750 nm) is what the eye can recognize, whereas the retinal hazard zone (400-1400 nm) represents what the eye can transmit and focus on the retina.



- UVC: 100 nm to 280 nm (Actinic UV)**
- UVB: 280 nm to 315 nm (Actinic UV)**
- UVA: 315 nm to 400 nm (Near UV)**
- Visible Light: 400 nm to 780 nm**
- IRA: 780 nm to 1400 nm (Near IR)**
- IRB: 1400 to 3000 nm (Mid IR)**
- IRC: 3000 nm to 1 mm (Far IR)**

Figure 2 - Electromagnetic Spectrum

Since 1962, many types of laser eye protection have been developed. Eye protection for Ultraviolet (UV, approx. 180-400 nm) and for Infrared (IR, approx. 780 nm-1mm) lasers appeared several years after the first types of laser safety eyewear. In spectral regions outside the retinal hazard region, namely the ultraviolet, middle, and far infrared regions, the skin and eye are equally vulnerable to injury. Hence, the emphasis for protection of the eye shifts to a requirement to consider protection for both eye and skin. However, some additional protection for the eye is still desirable because of more lasting and more severely incapacitating effects created by laser injury to the eye as opposed to a skin burn. While a skin burn will generally heal, a severe burn of the cornea may produce permanent scarring with partial loss of vision.

However, there may be instances where eye protection should not be relied upon, such as with very high power laser systems where direct exposure is possible. In these cases, engineering controls, which preclude direct exposure to such systems may be the only option.

II. Laser Bioeffects

The laser produces an intense, highly directional beam of light. If directed, reflected, or focused upon an object, laser light will be partially absorbed, raising the temperature of the surface and/or the interior of the object, potentially causing an alteration or deformation of the material. These properties which have been applied to laser surgery and materials processing can also cause tissue damage. In addition to these obvious thermal effects upon tissue, there can also be photochemical effects when the wavelength of the laser radiation is sufficiently short, i.e., in the ultraviolet or blue region of the spectrum.

The human body is vulnerable to the output of certain lasers, and, under certain circumstances, exposure can result in damage to the eye and skin. Research relating to injury thresholds of the eye and skin has been carried out in order to understand the biological hazards of laser radiation. It is now widely accepted that the human eye is almost always more vulnerable to injury than human skin. The cornea (the environment clear, outer front surface of the eye's optics), unlike the skin, does not have an external layer of dead cells to protect it from the environment. Figure 3 shows the various structures of the human eye. In the far-ultraviolet and far-infrared regions of the