Understanding laser protective eyewear requirements

Meeting user and regulatory needs for a safe work environment

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Laser-protective eyewear formulations should match the laser requirements

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Regardless of the type of laser, all can produce biological effects on the human body if protective eyewear is not used. Many lasers produce a beam of light in the UV or infrared spectrum that our eyes are not able to detect. To qualify as laser-protective eyewear, independent laboratory tests validate and certify the protective capabilities and optical density (OD) against the standard, using the actual laser, including performing destructive testing. This certification is required to meet standards like European norm CE EN207 and American National Standard for Safe Use of Lasers ANSI Z136.

Lasers are a tool used in a wide range of applications, such as medical, military, industrial, entertainment, education, farming, and research. Monochromatic light is emitted at a single wavelength while white light is a combination of many different wavelengths. Laser light is monochromatic, directional, and coherent.

Depending on the wavelength of laser emission, it is either visible or invisible. Laser light is emitted as a relatively narrow beam that follows a single direction and creates a high power density when it falls on a material. It is also coherent, which means the photons of the laser light are in the same phase and frequency.

Lasers can be combined into a system that produces multiple wavelengths of light designed for a specific application. Many of these systems are combined with incoherent light sources like UV, or broad-spectrum flash systems such as intense pulsed light for targeted medical or welding applications. Without proper protection, radiation from laser systems can lead to serious biological effects on the eye and skin. The intensity and types of light used within a given application must be considered when designing laser eye protection to meet user needs while conforming to regulations, which are key to creating a safe work environment.

Types of lasers

There are five main types of lasers found on the market today. They are grouped by the gain medium or material within

Expanding use of novel laser systems continues to drive reformulation of protective eyewear design

the laser that is used to produce excitation and lasing. The five types are:

- gas
- liquid
- semiconductor
- solid-state
- fiber

Gas lasers use a glass or ceramic tube that is filled with a gas or gas mixture. Gas lasers tend to have very narrow bandwidths and defined wavelengths. There are lasers that cover the spectrum from UV through visible and into the near infrared. Although gas lasers have been superseded by newer technologies, some, like CO_2 lasers, are still very popular for cutting and welding operations.

Company

Epolin

Since 1983, Epolin has produced the highest quality materials to meet laser protective eyewear manufacturer needs, with Epolight dyes and Luminate thermoplastic pellets. Epolin develops and manufactures near-infrared absorbing dyes and thermoplastic compounds. Our materials provide premium performance for laser and welding eyewear, light filters, touchscreens, night vision products, sensors, lidar, and security inks. Epolin is a subsidiary of the Chroma Color Corporation, and manufactures and ships products from our headquarters in Newark, New Jersey, USA. Epolin regional distributors include AAKO BV (Europe), SN Consultant (Japan), and Sun & Bright Industrial Ltd (China).

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Liquid lasers use a range of organic dyes dissolved into solvents that are excited with either a flashlamp or other lasers. The dyes will absorb and then radiate energy that can be tuned and focused to produce the desired lasing effect. Due to their extensive maintenance requirements, these lasers have been largely replaced by newer technologies.

Semiconductor lasers are often referred to as diode lasers because they operate in the same fashion as a light-emitting diode, an LED. Power is driven through the diode junction, which in turn achieves lasing. Most common semicon lasers operate in the near infrared (NIR) region of the spectrum, which enables their use in a wide range of modern applications.

Solid-state lasers are based on glass or crystal mediums that are doped with rare earth elements. One of the most common types is the neodymium-doped yttrium aluminum garnet (Nd:YAG) laser. These lasers achieve some of the highest power and energy levels possible today. The wide range of possible wavelengths, power outputs, and flexibility offered by solid-state lasers has enabled their use in everything from material processing and measurement to weapon systems and autonomous vehicles.

Fiber lasers are built from doped optical fibers with an integrated resonator. As a flexible medium, it is easy to position these optical fibers and focus the laser light. The fibers can be bent or coiled over a substantial length, creating high optical gain while at the same time providing a substantial cooling surface. Fiber lasers tend to be very efficient and long lasting, even at the high-power levels used in cutting or welding. These systems excel in pulsed laser applications.

Laser modes of operation

Within these laser types, there are various modes of operation, such as continuous wave, pulsed, or mode-locked.

Continuous wave (cw) produces a constant wave of energy with a consistent power output. Because many of the laser systems are excited by pulsed energy, continuous wave lasers are defined as having a pulsed length of greater than 0.25 seconds, given a 'D' designation.

Pulsed lasers have a single short burst of energy or a repetitive periodic emission. These lasers will have a short pulse length of 1 microsecond to 0.25 seconds. They have been further divided into pulsed lasers and giant pulsed lasers which are designated with an 'I' or an 'R' respectively.

Mode-locked lasers generate ultrashort pulses from the laser. These systems will have a component that will only allow the pulse of energy to be released when it achieves certain parameters. This can be done either through active or passive means. Because these lasers are selectively releasing an incredibly short pulse they are often referred to as femto or picosecond lasers. Mode-locked lasers will have an 'M' designator.

Biological effects

Regardless of the type of laser, they are all capable of producing biological effects on the human body if protection is not used. It is important to note that many lasers produce a beam of light in the UV or infrared spectrum that our eyes are not able to detect. Some lasers are powerful enough that the even reflected light is sufficient to damage the eye. Pulsed lasers are also of particular concern because calculations will show a lower average energy level than the peak pulse is actually achieving.

The lens in our eye will pass light in the 400 – 1,400 nm range and can focus the radiated energy, concentrating it onto a small area of our retina. Concentrated light will quickly heat the area and destroy those cells. This typically happens faster than our blink reflex can shield our eyes. With an infrared laser system, the hazards are even more severe because our eyes will not react to the invisible light. The retinal area of the human eye lacks pain receptors and so there are no initial indications of damage until vision is lost.

Laser hazard classification

To help with identification, a laser hazard classification was established with International Standard IEC 60825-1 and then adopted by the American National Standard for Safe Use of Lasers as ANSI Z136. A system of four classes identifies the hazard level and laser exposure limit. A laser user needs to answer two important questions prior to using the device:

- Is laser eye protection required?
- Are there alternate sources of light that I should take into consideration (like welding or IPL, intense pulsed light).

Class	Safety
Class 1	Safe under normal use
Class 1M	Safe for all conditions except when passed through telescopic optics
Class 2	Safe due to the human blink reflex
Class 2M	Safe due to the human blink reflex when not viewed through telescopic optics
Class 3R	Careful handing is required with restricted beam viewing
Class 3B	Hazardous if the eye is exposed directly, but safe when viewing as a diffuse reflection on a surface
Class 4	Devastating and permanent eye damage through direct or indirect viewing of the beam. Powerful enough to burn skin

Table Laser safety classes and potential hazards

More formally, these questions are answered and monitored by an appointed laser safety officer (LSO). In the US, all Class 3B and 4 laser environments are required to have an LSO. Depending on the application, LSOs may also be required for Class 1M and 2M lasers.

A laser safety officer typically constructs and reviews a standard operating procedure to ensure a safe environment for the user and to comply with applicable regulations. They consider maximum permissible exposure (MPE) and nominal hazard zone (NHZ) calculations to prevent excess radiation exposure. There are software tools on the market that can calculate MPE and NHZ values and limits by considering the characteristics and properties of the laser. Laser-protective eyewear should be considered when the user would be outside the MPE and NHZ requirements or is exposed to other light systems within their work environment.

Eye protection standards and certification

Standards such as ANSI Z136.7, CE 60825-4, and CE 12254 also govern the manufacture of laser safety equipment. Laser-protective eyewear should never be considered the first line of defense, so the use of engineering control measures, standard operating procedures, and adequate user training are key to ensuring a safe environment. Eye protection must also to allow wearers to safely perform essential job functions, providing high visible light transmittance during the day along and high scotopic visible light transmittance for the early evening.

Optical density (OD) is a logarithmic ratio of the energy of light entering the lens divided by the energy of the light leaving the lens. An optical density of zero allows 100 % transmission of the energy through the lens. Stepping up to an OD of 1.0 would only allow 10 % of the energy through and an OD of 2.0 would only allow 1 %. Optical density is achieved using absorbing dyes that are specific to the wavelength and energy produced by the laser. These are chemical structures that absorb photons of light and dissipate their energy through emission or heat. In addition to the MPE and NHZ values, there are several other design considerations to take into account when designing a laser-protective lens. In most cases, computer modelling of the dye formulation can help to build target specifications prior to the costly expense of certification testing.

Formulation of laser-protective lenses

Design considerations for lenses or filters include

- What is the wearer trying to see?
- Laser requirements – optical density (OD)
- Laser requirements – frequency (nm)
- Lens or filter thickness
- UV requirements
- Visible light transmission (VLT) requirements
- Scotopic light transmission (SLT) requirements

During the development process, dyes are modelled, synthesized and mixed to absorb specific wavelengths of laser radiation. They can be added to a thermoplastic polymer, typically polycarbonate, via a compound extrusion process to create a ready-to-mold pellet built for a specified thickness and optical density ready for injection molding. Lenses are then analyzed on a spectrophotometer, which reads the optical density, absorbance, attenuation, and transmission from 200 to 3,300 nm, from ultraviolet through visible light and into the near infrared.

Although laser eye protection seems complex, there is an established industry that has grown to support the ever-expanding market, and industry experts who can guide you through the regulations and safety concerns. If you are a manufacturer of laser protective eyewear and you are looking for dyes or polycarbonate pellets for your applications, Epolin's technical team can discuss your specific laser-absorbing requirements.

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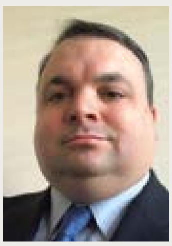

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