Laser Smart Technologies

FIRST QUESTIONS

When you are shopping for protective eyewear, we hear questions regarding laser safety technologies that suggest even the most sophisticated laser people often do not understand the basics. Consider, for example, these typical queries:

- Can I get a plastic version of this glass eyewear?
- Is polycarbonate eyewear as safe as filter glass eyewear?
- Where does the laser radiation go if it hits my eyewear?
- Can I choose the color of my filters?

Because these questions often muddy the eyewear buying process, we hope this article will help cultivate a more expert group of customers. Our premise is that smart customers will ask smart questions and will be more satisfied with the products they select.

TECHNOLOGIES FOR EYEWEAR

Let's review briefly what a laser filter is designed to do. Recognize first that a laser emits radiation at a specific wavelength which may or may not be within the normal visible spectrum. Some lasers, particularly tunable lasers, may emit radiation at several wavelengths simultaneously. So, a laser filter must protect the eyes from a particular set of wavelengths, but at the same time allow at least some "normal" light to pass through to the eyes. This means that one filter alone can not block all wavelengths and still allow the user to see his work. Although the laser filters as described by this article are primarily related to eyewear, similar science applies to filter glass windows, other laser work area viewing products, and optics.

There are two basic types of laser protection filter technologies: absorption and reflection. In absorption, the energy of the laser is captured by the protective medium and transformed into heat, which must then be dissipated by the surrounding materials. Absorbers can be formulated for selective wavelength attenuation and for broad band or multiple wavelength attenuation. Reflection means that laser radiation directed at the filter bounces off in a different direction, often in a broad, scattering pattern. Reflective filters can also be designed for one or several wavelengths.

Absorption – Filter Glass The traditional material to effect absorption of laser radiation for eye safety is filter glass. The products are sometimes referred to by the colors of the final glass product – for example blue glass, green glass, and orange glass. Each filter contains an element or mix of elements that is known to absorb laser energy at particular wavelengths. Two common approaches are to introduce into the glass ions of heavy metals or rare earth elements and to introduce colloidal colorants.

Absorption – Polymers Polymers impregnated with dyes and other materials reproduce the absorptive behavior of mineral glass laser filters. The polymers used in laser safety are typically polycarbonates, but other materials, including nylons and acrylics, may be used. As is common in many industrial plastics processing technologies, dyes are mixed directly into the polymer during the molding process, extruded into concentrated pellets of the desired end product material and later "let down" (diluted) for product molding, or impregnated into the surface of the polymers. Although we will not discuss eyewear styles in detail, note that plastic laser safety compounds can be molded into a much wider variety of sizes and styles when compared to filter glass products.

Reflection Reflective laser safety coatings are known as thin film coatings, metallic film coatings, dielectric films, or dielectric interference coatings. Multiple layers of specially selected materials are applied to a substrate under vacuum conditions. A custom designed interference pattern is created that reflects only the desired wavelengths and allows remaining light to pass through. The laser energy is reflected not only at the surface, but at the layers built up near the surface of the substrate. The coatings used in laser safety are primarily applied to glass, but similar coatings on polymers are an eventuality.

Combination Technologies Some laser safety products are built with combinations of technologies, the most common of which include coatings on filter glass, laminations of multiple filter glass substrates, and laminations of filter glass and polymer substrates. Lamination of multiple protective layers often is the best way to build a product that protects against multiple wavelengths and unusual combinations of wavelengths.

Patient Eye Protection Completing our inventory of laser safety technologies is the growing family of opaque patient eyeshield products. These are technically "absorptive" products; they are also usually entirely opaque through the extended laser spectrum 380nm to 11000nm. Often these products are metallic or contain a metal layer. Increasingly, these products are available as disposable products for use in dermatological laser and Intense Pulsed Light applications.

TECHNOLOGY SELECTION

There are trade-offs involved with selecting any of the technologies available for laser safety eyewear. The nearby table summarizes our filter technology recommendation algorithm from the standpoint of performance needs. Filter glass will be heavier than polymer products, but usually provides better visible light transmission (VLT). Coated substrates are selected when multiple wavelength protection is required, but these products tend to be among the most expensive and require the most care. The physical properties of polycarbonate make those products suitable for all-day wearing and for molding single lens products with wide fields of view.

Before finalizing your selection of laser eyewear, ensure you consider the work environment, not just the laser system. High VLT products are best for low-light environments. Impact resistance is necessary in production environments and should be considered in all environments. UV protection or glare reduction may be needed for welding. Larger products and wrapping products provide additional splash protection for medical applications; many of these customers prefer lightweight polycarbonate eyewear. The technology you select will impact these performance characteristics.

FAILURE MODES AND TECHNOLOGY SELECTION

Because laser safety eyewear is a personal protective device, a review of the failure modes and failure characteristics of products made with the various technologies may further assist in technology selection.

Glass filters generally provide superior thermal stability when compared to plastic filters and polycarbonate in particular. Under high heat, however, glass will tend to splinter or shatter due to heat distortion. Glass filters should be treated or coated to hold the pieces together in the event of catastropic failure due to a direct hit by the laser. It's interesting to note that even a cracked glass filter provides some laser protection if the pieces remain intact.

Polymer lenses may carbonize if subject to a direct hit by a laser with high power density and then can be quickly penetrated. Also, dyes used in polymers may exhibit photochemical bleaching, a phenomenon in which the intensity of the laser radiation impinging on the dyes exceeds the ability of the material to absorb and dissipate the energy. The effect is to open a temporary window through the lens for the duration of the high intensity exposure.

A consideration for coated products is the "angle of incidence". The coating layers must protect against stray radiation that impinges the lens at an angle away from the perpendicular. Current standards require 30 degrees of protection and some products are available with protection up to 40 degrees.

QUESTIONS REDUX

Let's look again at our initial questions…

- Can I get a plastic version of this glass eyewear?
  Yes, but you may give up some VLT in exchange for lighter weight.
- Is polycarbonate eyewear as safe as filter glass eyewear?
  Yes. Similar optical density (OD) protection levels are achievable in polycarbonate, but you may give up some protection from any potential direct hits.
- Where does the laser radiation go if it hits my eyewear?
  Absorption technologies transfer laser energy to heat which is dissipated. Reflection technologies send the laser radiation elsewhere, often in a diffusing pattern.

- Can I choose the color of my filters?
  Yes, some of the time, but be aware of the tradeoffs including VLT and color recognition. Do not rely on color alone, however, when identifying eyewear that is suitable for your laser application.

To summarize, laser protective filter technology selection depends not only on the application, but also on the characteristics and relative tradeoffs of each technology. A careful review of your work environment and eyewear performance expectations against the criteria outlined herein will enable you to shop smartly and effectively for laser protection.

Credits

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Eyewear Materials Technology Selection

	Laser Protective Eyewear Technology			
Eyewear Performance Needs	**Filter Glass**	**Polymer**	**Coated Glass**	**Laminated**
Multiple Wavelength Coverage	Very good for standard wavelength combinations	A few good choices available	Best overall; Product selection currently limited	Often the only solution for unusual combinations
Prescription (R_x)	Good choice; R_x may be in laser lens	Usually requires an adaptor	Good choice; R_x may be in laser lens in newer products	Not typically used; thickness and layers impact the optics
Selective far IR wavelength coverage (e.g., 1540nm)	Best current choice	May not be possible depending on wavelength	Technologically feasible, requires custom design	Good choice if combining far IR with other wavelengths
Femtosecond (mode locked) coverage	Best current choice	Some new products emerging	Not available at present	Some new products emerging
Wide field of view	Larger lenses often too heavy	Molded single lens products are best choice	Larger lenses often too heavy	Larger lenses often too heavy
8-hour shift wear	Excellent VLT; request impact resistance from supplier	Lowest weight; impact-resistant products available	Excellent VLT; request impact resistance from supplier	Not typically used
High power protection	Best choice for direct laser impact	Excellent OD levels available; but not for direct hit	Excellent OD levels available; review each product for direct hit	Excellent OD levels available; review each product for direct hit