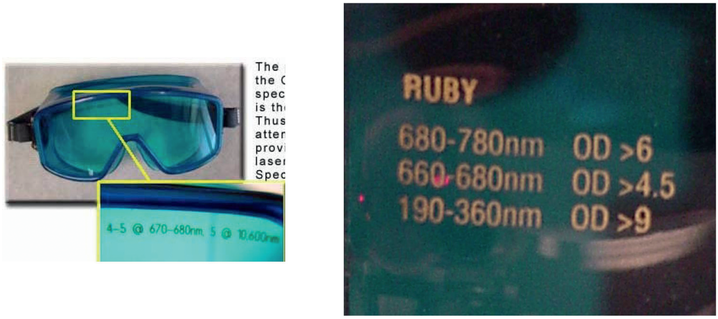


**Figure 7.2** Labeling on eyewear.

## 7.8 Identification of Eyewear

To be considered certified (i.e., legal) laser-protective eyewear, the eyewear must be labeled with its OD and wavelength or the wavelength range for which the eyewear is designed for. The laser manufacturer is only responsible for the wavelength marked on the eyewear (Fig. 7.2). Note: commercial laser-protective eyewear may have a duplicate labeling compliant with European Norm 207 or 208 testing conditions where:

D stands for continuous-wave laser,
I stands for pulsed laser,
R stands for Q-switched pulse,
M stands for mode-coupled pulsed laser (pulse length $<10^{-9}$ sec), and
L stands for a scale number that is nearly equivalent to OD.

## 7.9 Cleaning and Inspection

It is always an excellent idea to clean and inspect one's eyewear prior to use. Care should be taken when cleaning the lenses of protective eyewear to avoid damage to the absorbing and/or reflecting surfaces. Inspection needs to check for pitting, crazing, cracking, discoloration, etc. Remember to check the frame for mechanical integrity. Check for light leaks and coating damage. Most importantly, any eyewear in suspicious condition should be discarded.

## 7.10 Ultrafast Lasers

Testing by the Army branch at Brooks Air Force Base has shown a nonuniform bleaching effect on standard laser eyewear against ultrafast pulses. This relates back to the relaxation time of the absorption molecules. Not all eyewear for ultrafast pulses demonstrate this effect, but a significant enough number do to make it a real concern; therefore, ultrafast-laser users who wish for full protection will need to check with the manufacturer of the eyewear for their testing results to verify suitability of the eyewear for their use. Usually, the manufacturer can provide a sample piece of the lens for testing with a power meter in the actual application to verify the appropriateness of the lens in question. It is imperative to recognize that if one is using ultrafast lasers (particularly regeneratively amplified sources), there exists the potential that OD values may be compromised should femtosecond beam exposure to one's laser eyewear occur. Should temporary or permanent loss of OD (and commensurate exposure levels in excess of applicable MPE values) occur as a consequence of these conditions, obvious detrimental eye-safety effects become plausible. The core safety issue surrounding laser-protective eyewear and femtosecond lasers is as follows: in certain ultrafast (femtosecond) operating conditions, saturable absorption effects with calculable losses in purported OD values of the femtosecond-subjected laser eyewear have been observed. In addition, one needs to consider that the pulse produced by an ultrafast laser is not a single wavelength but a bandwidth of 20–50 nm.

## 7.11 Alignment Eyewear

One of the most common comments from users is that they take off their eyewear because they cannot see the beam. Alignment eyewear is one answer to that problem. For alignment of visible beams, conditions may arise that require the user to see the beam through their protective eyewear (cases where remote viewing is not possible). In these situations, the use of alignment eyewear can be approved by the LSO. Alignment eyewear is assigned an OD lower than that which will provide full protection from a direct accidental exposure. For continuous-wave lasers the alignment OD must reduce irradiance to a Class 2 or Class 3R level. For pulsed lasers the alignment OD must be no more than 1.4 less than the full-protection OD.

### 7.11.1 Factors in selecting alignment eyewear

By definition, alignment eyewear involves the use of visible laser light and requires the same attention and hazard analysis needed to adequately attenuate light from potential or accidental exposures to levels below MPEs by applying appropriate time-base criteria. Ultimately, the LSO must approve the selection, use, and appropriate OD values for all alignment tasks, with the ultimate goal of adequately attenuating light to levels safely below MPEs for all potential or accidental ocular exposures. Users must be aware that alignment eyewear will not provide full protection, but it should warn users that they are being exposed, thus allowing them to turn away prior to causing injury.

## 7.12 Eyewear Use with High-Power Lasers (High-Power, Multikilowatt Laser Beams)

Engineering control measures need to be the control of choice on these systems. Laser-protective eyewear is inadequate to protect the user from serious ocular exposure from high-power laser beams. If such beams miss one's eyewear, a significant injury (e.g., third-degree burn and/or laceration from facial motion during exposure) is possible.

Most of the radiant energy absorbed by the filter is transformed into heat. If the radiant flux is quite high, as it would be for multikilowatt beams, the heat may fracture a glass lens or melt polycarbonate. If the radiant energy is concentrated in a small diameter spot, then enhanced heat transfer may result in damage to the surrounding matrix material.

It is possible—even likely for powerful lasers—that the filter material, either glass or plastic, may be damaged in a time period that is shorter than the time base used to determine the MPE. This is particularly true as the radiant exposure increases. Guidance on typical laser-induced damage threshold (LIDT) levels may be found in ANSI Z136.7. For polycarbonate, these values are 10 J/cm$^2$ ($t < 10^{-3}$ s) and 300 $t^{0.5}$ J/cm$^2$ ($t \geq 10^{-3}$ s), where $t$ is the exposure duration. For glass, the values are 1 J/cm$^2$ ($t < 10^{-6}$ s) and 1000 $t^{0.5}$ J/cm$^2$ ($t \geq 10^{6}$ s). One should know the signs of damage, such as smoke, flame, incandescence, and luminescence.

## 7.13 Other Factors

**Saturable absorption.** Certain dyes used to absorb laser radiation may undergo saturable absorption (also called transient photobleaching), where the ability to absorb radiant energy decreases with increasing radiant exposure or peak irradiance. When this occurs, the OD may decrease. This has been reported for both glass and polycarbonate filters for certain pulsed lasers and is associated with high values of peak irradiance (e.g., ultrafast pulses).

**Angle of exposure.** Based on the composition of the laser-protective eyewear filter, the angle of exposure can affect the effectiveness of the eyewear filter. Dielectric coatings on laser-protective eyewear are designed to deliver the labeled OD within a set angle of acceptance. Laser radiation that is incident upon the eyewear outside that angle will yield a diminished OD. The obliqueness of the angle may or may not limit the laser radiation entering the pupil.

**UV laser protection.** Due to the potential for significant photochemical bioeffects and the high level of UV-radiation scattering by air molecules, particular care must be taken when using UV lasers or laser systems. In addition to other laser controls—which apply to all laser systems—exposure to UV radiation shall be minimized by using beam shields and clothing that attenuate the radiation to levels below the applicable MPE for the specific UV wavelengths. Special attention shall be given to the possibility of producing hazardous byproducts in the presence of UV radiation, e.g., formation of skin-sensitizing agents, ozone, laser-generated airborne contaminants (LGACs), etc. Personal protective equipment (PPE), must be used when working with open-beam Class 3B or Class 4 UV lasers. This must include both eyes and skin protection.

**Side shields.** Side shields can be transparent or opaque. Their application will depend mostly on the style of frame one picks out and the desire to have them. It is really a personal choice rather than a safety consideration.

**Impact resistance.** The ANSI Z136.1 standard does not require laser-protective eyewear to be ANSI Z87 compliant. ANSI Z87 is the standard for safety eyewear; the most common element is impact resistance. Therefore, in evaluating one's eyewear needs the question of impact resistance—is it needed or not—needs to be addressed. If not, no further action is needed; if the LSO hazard evaluation shows impact resistance is required, one has three choices:

1. Obtain a pair of laser eyewear that is compliant with ANSI Z87 (most polymer eyewear are compliant).
2. Wear safety glasses over the laser eyewear.
3. Have glass laser eyewear hardened to meet ANSI Z87.

Choice 2 can affect comfort or the ease of wearing the protective eyewear and general vision, while Choice 3 will affect the cost of the eyewear.

**Prescriptions.** There are several options for eyewear for users who require prescription glasses. These include eyewear with prescriptions ground into the glass laser lens (expensive and limited availability), eyewear that holds prescription inserts, and eyewear with flips that have polymer prescriptions in the base or the flip. The most common option is inserts, which for the laser user is better than glasses or goggles.