



LIONS LASER SKIN CENTRE

Vancouver Hospital & Health Sciences Centre

Laser Safety and the Eye: Hidden Hazards and Practical Pearls

Osama Bader, MD, and [Harvey Lui](#), MD, FRCPC

From the [Lions Laser Skin Centre](#), [Division of Dermatology](#),
Vancouver Hospital & Health Sciences Centre,
and University of British Columbia, Vancouver, B.C.

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Abstract

THE UNPROTECTED HUMAN EYE is extremely sensitive to laser radiation and can be permanently damaged from direct or reflected beams. The site of ocular damage for any given laser depends upon its output wavelength. Laser light in the visible and near infrared spectrum 400 - 1400 nm (the majority of lasers used in dermatology) contributes to the so-called "**retinal hazard region**" and can cause damage to the retina, while wavelengths outside this region (i.e., ultraviolet and far infrared spectrum) are absorbed by the anterior segment of the eye causing damage to the cornea and/or to the lens. The extent of ocular damage is determined by the laser irradiance, exposure duration, and beam size. As laser retinal burns may be painless and the damaging beam sometimes invisible, maximal care should be taken to provide protection for all persons in the laser suite including the patient, laser operator, assistants, and observers.

Protective eyewear in the form of goggles, glasses, and shields provides the principal means to ensure against ocular injury, and must be worn at all times during laser operation. **Laser safety eyewear** (LSE) is designed to reduce the amount of incident light of specific wavelength(s) to safe levels, while transmitting sufficient light for good vision. In accordance with the **ANSI Z136.3 (1988) guidelines**, each laser requires a specific type of protective eyewear, and factors that must be considered when selecting LSE include: laser wavelength and peak irradiance, optical density (OD), visual transmittance, field of view, effects on color vision, absence of irreversible bleaching of the filter, comfort, and impact resistance. Ignorance of any of these factors may result in serious eye injury. As LSE often look alike in style and color, it is important to specifically check both the wavelength and OD imprinted on all LSE prior to laser use, especially



in multi-wavelength facilities where more than one laser may be located in the same room. Color coding of laser handpieces and LSE may help to minimize confusion. LSE should not move between laser rooms, nor should they be carried in lab coat pockets between use. The integrity of LSE must be inspected regularly since small cracks or loose fitting filters may transmit laser light directly to the eye. With the enormous

expansion of laser use in medicine, industry and research, every facility must formulate and adhere to specific safety policies that appropriately address eye protection.

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What are the effects of laser energy on the eye?

The site of damage depends on the wavelength of the incident or reflected laser beam:

- Laser light in the visible to near infrared spectrum (i.e., 400 - 1400 nm) can cause damage to the retina resulting in scotoma (blind spot in the fovea). This wave band is also known as the "retinal hazard region".
- Laser light in the ultraviolet (290 - 400 nm) or far infrared (1400 - 10,600 nm) spectrum can cause damage to the cornea and/or to the lens.

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Are there any specific symptoms of laser eye injuries?

- Exposure to the invisible *carbon dioxide laser* beam (10,600 nm) can be detected by a burning pain at the site of exposure on the cornea or sclera.
- Exposure to a visible laser beam can be detected by a bright color flash of the emitted wavelength and an after-image of its complementary color (e.g., a green 532 nm laser light would produce a green flash followed by a red after-image).
- When the retina is affected, there may be difficulty in detecting blue or green colors secondary to cone damage, and pigmentation of the retina may be detected.
- Exposure to the *Q-switched Nd:YAG laser* beam (1064 nm) is especially hazardous and may initially go undetected because the beam is invisible and the retina lacks pain sensory nerves. Photoacoustic retinal damage may be associated with an audible "pop" at the time of exposure. Visual disorientation due to retinal damage may not be apparent to the operator until considerable thermal damage has occurred.

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What types of laser safety eyewear are available?

Goggles:

- fit tightly on the face
- typically worn over vision-correcting prescription eye glasses
- usually constructed with frame vents to minimize lens fogging
- larger, heavier than spectacles or wraps



Spectacles:

- a frame that usually has two separate lenses with side shields
- can be made with vision-correcting prescription eye glasses



Wraps:

- a frame with a single lens that covers both eyes
- usually lighter than spectacles/goggles



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What are the technical considerations for eye safety?

There are two important concepts:

1. Maximum permissible exposure (MPE), is the level of laser radiation to which a person may be exposed without hazardous effects or biological changes in the eye. MPE levels are determined as a function of laser wavelength, exposure time and pulse repetition. The MPE is usually expressed either in terms of radiant exposure in J/cm^2 or as irradiance in W/cm^2 for a given wavelength and exposure duration.

- Exposure to laser energy above the MPE can result in tissue damage.
- The ANSI 136.1 standard defines MPE levels for specific laser wavelengths and exposure durations. Generally, the longer the wavelength, the higher the MPE; the longer the exposure time, the lower the MPE.

2. The Nominal Hazard Zone (NHZ) is the physical space in which direct, reflected or scattered laser radiation exceeds the MPE. LSE must be worn within the NHZ.

- In practical terms, when using dermatologic lasers the entire laser procedure room should be considered to be within the NHZ because the laser fiber or handpiece can be directed anywhere in the room.

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What factors should be considered when selecting specific eyewear?

1. Laser *wavelength* at which protection is afforded.
2. *Optical density (OD)* of the LSE for the wavelength being used. OD refers to the ability of a material to reduce laser energy of a specific wavelength to a safe level below the MPE. It can be expressed by the following formula:

$$OD = \log_{10}(E_i/E_t)$$

E_i = incident beam irradiance (W/cm²) for a "worse case exposure"

E_t = transmitted beam irradiance (MPE limit in W/cm²)

Example: OD of 4.0 allows 1/10,000 of the laser light energy to be transmitted.

The required OD for any given laser can be determined by:

- (a) calculation,
- (b) consulting nomograms or tables (e.g., ANSI 136.1 guidelines), or
- (c) consulting the laser manufacturer.

The OD of the LSE will decrease if the LSE is damaged. The *damage threshold* refers to the maximum protection that the LSE will provide for at least 5 - 10 seconds following noticeable melting or flame.

1. *Comfort* of the design to enhance compliance.
2. *Field of view* provided by the design of the eyewear.
3. *Absence of irreversible bleaching* when the LSE filter is exposed to high peak irradiance.
4. *Effect on color vision*: the colored filter material may reduce color vision and contrast, creating additional hazards. For example, certain LSE may interfere with visualizing monitoring equipment or detecting cyanosis during general anesthesia.
5. *Impact resistance*. LSE must be resistant to dust, heat, etc., so that they will not lose their effectiveness.

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Practical Pearls in Laser Eye Safety

1. *Laser warning signs* must be placed at the entrance to laser operating rooms.

2. Access to the laser operating room should only be granted to those individuals who have been appropriately ***educated in laser safety***. Each laser facility must develop its own Safety Procedures to be enforced by an appropriately trained ***Laser Safety Officer*** for the facility. Safety procedures should be in accordance with ANSI and OSHA guidelines (and others, where appropriate).
3. As LSE often looks alike in style and color, it is mandatory to ***check the wavelength and optical density*** imprinted on each pair of LSE prior to its use.
4. ***Color coding*** of the laser handpiece and LSE may help to minimize confusion especially in facilities where multiple laser wavelengths are available.
5. ***LSE should not move between laser rooms***, nor should they be carried in lab coat pockets between use.



LSE can be very expensive, so proper care and handling is mandatory. The integrity of the LSE must be ***inspected regularly*** since small cracks or loose fitting filters may permit the laser beam to reach the eye directly.

7. The ***patient's eyes must always be protected*** from laser energy. If the patient is awake, appropriate opaque "mini"

goggles must be worn. Great care must be taken to avoid accidentally exposing the straps of the patient goggles to laser light, since this can ignite them.

8. Whenever laser energy is used in the immediate vicinity of the eye (e.g. treating eyelids) a



stainless steel or lead eye shield should be positioned on the surface of the orbit after the application of a topical ophthalmic local anesthetic.

Plastic patient eye shields cannot be expected to withstand the thermal and mechanical effects of



pulsed lasers, and should never be used.

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