Volume 3
Issue 3

# Laser Lessons News Letter

This issue:



*"With all of its complexities it will be quite some time, if ever, before we can hope to duplicate the wonders of the human eye. Think before you work, you only have two eyes." BE SAFE!*

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## Introduction

The human eye is an incredible organ. It stands unequaled by even the latest in optics and computer advancements. When people are asked which sense they cherish the most, the sense of sight easily ranks as number one. Ten to fifteen years ago, when people still talked to each other whether on the phone or face-to-face, hearing may have given sight a run for the money.

In today's world of tweets, texts, and blogs, the sense of sight has never been more important or more valued. We took a look at the eye and biological effects in volume 1, issue 1. This issue will delve a little deeper into how the varying wavelengths affect the structures contained within.

## The Eye Revisited

When discussing the eye, in terms of injuries from laser

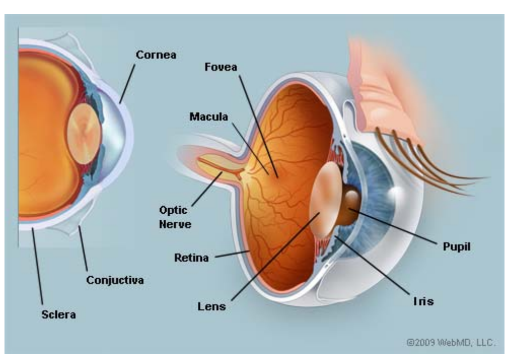



Figure 1. Diagram of Human Eye (courtesy of WebMD)

radiation, we typically point out the cornea, lens, and retina (Figure 1). These structures are "critical" to clear and acute vision, and damage to them depends on the wavelength of the incident laser beam.

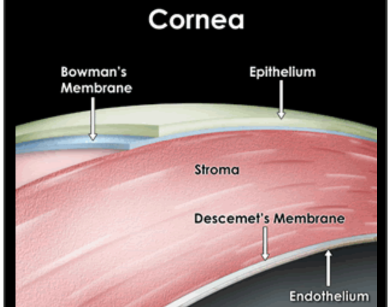
When discussing the sense of sight, we are typically talking about the wavelengths in the region of ~380nm to ~780nm. This is considered the "visible" portion of the electromagnetic spectrum and is the world that we "see" in (for simplicity, the visible band is typically stated as 400-700nm). Light is transmitted through the cornea where a majority of the refraction takes place, through the fine tuning of the lens, and onto the retina where the object is imaged.

*Refresher: The cornea provides ~70% refractive power of the eye with the lens providing ~30%. The pupil range is typically from 2mm-8mm with 7mm used for laser hazard analysis.*

When the environment is very bright, our pupil, or aperture, gets smaller. When darker, it opens up to allow in more light. If you accidently look directly at the sun or a Class 2 laser beam, your aversion response would cause you to blink and look away within 0.25 seconds. Prior to lasers, the only advice one needed to heed was not to look into a solar eclipse. A mistake many individuals still make and pay for with blindness or severely degraded vision. With high power lasers, your aversion response provides no protection whatso-

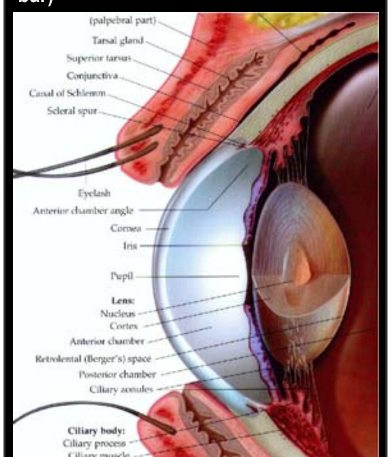
# Parts of the Eye:

**The cornea consists of several different layers of tissue. Epithelial cells are sloughed off, rejuvenating the cornea every 24-48 hours. Should the cornea be damaged into the stroma layer, a corneal transplant would be needed. (See opposite sidebar)**



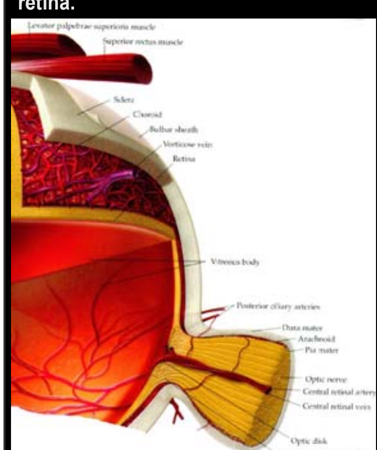

(Photo courtesy advancedivisionsurgery.com)

**The lens is a transparent crystalline structure located behind the cornea. As we age, additional layers of lenticular cells are formed around the outside of the capsular structure. This causes the lens to be squeezed tighter, forcing water out of the lens. A damaged lens can be replaced with a synthetic one. (See opposite sidebar)**




(Photo courtesy eyedesignbook.com)

**The retina lines the inside of the eyeball. Its shape is maintained by the pressure of the vitreous humor, which fills the eye. The retina is made up of rods (peripheral and night vision) and cones (acute and color vision). There is no repair mechanism for laser exposure to the retina.**



(Photo courtesy eyedesignbook.com)

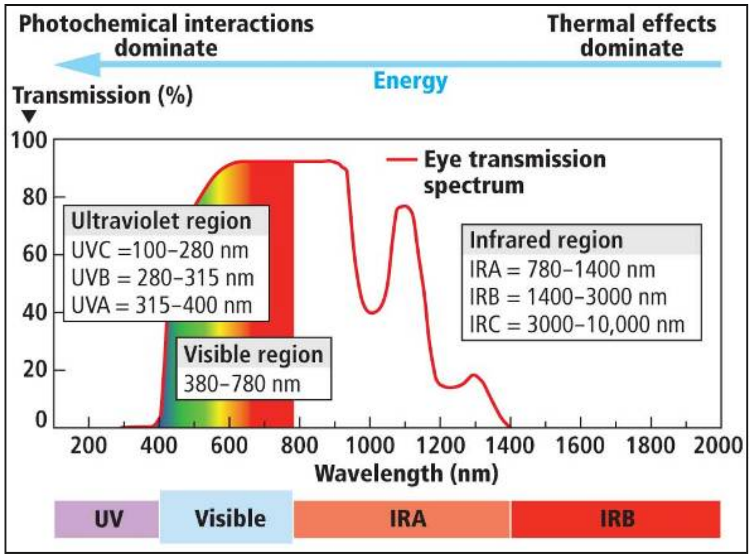



Figure 2. Transmission of wavelengths into the eye. (Courtesy of LEDs Magazine)

ever.

An interesting fact, although we can only "see" in the visible portion of the spectrum, we actually transmit infrared wavelengths onto the retina out beyond 1000nm (Figure 2). As shown, peak transmission to the retina extends out to about 900nm then drops and peaks again around 1100nm where it drops to zero at about 1400nm.

*Reminder: Lasers sold with wavelengths longer than 1500nm are generally listed as "eye-safe". The actual term that should be used is "retina-safe" as a high power laser in this region will considerably damage the lens and cornea, which ARE parts of the eye.*

There have been many reported incidents of cataracts in glass blowers and metal workers from the thermal effects of these wavelengths onto the crystalline structures of the cornea. This is different than senile cataracts typically found in many individuals as they age, which is cause by the shorter ultraviolet wavelengths through a photochemical effect. We will discuss those later.

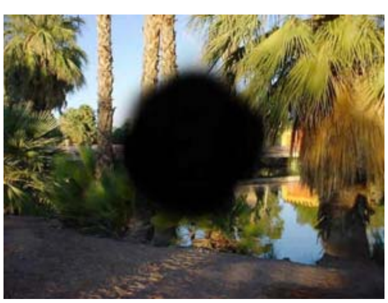


Figure 3. Blind spot at center of vision. (Courtesy ACBVI.org)

For now we will stick with the shorter visible to longer infrared wavelengths. In this region, the biological damage is caused by a thermal effect. A majority of our lasers operate around 800nm to just over 1000nm. If an injury were to occur, the retina is where the damage would take place. Unfortunately, the retina has no repair mechanism and damage inflicted is permanent (scarring). The result is loss of the use of the rods and cones in the affected area.

An individual with a minor injury may never realize that they have been struck by a laser beam. This depends on where the damage occurs. If the area is small and out on the periphery of vision, your brain may fill in the blank spots, much like it does for the optic nerve head (optic disc) of each eye.

If the strike occurs to the cones contained in the macula or foveal pit, blind spots are what you will see. This is PERMANENT! (See Figure 3)

With increased study on the effects of laser wavelength to the eye, new Maximum Permissible Exposure (MPE) Limits were released for the near to mid infrared wavelengths in the latest ANSI Z136.1 (2014) *Safe Use of Lasers.* In some situations, the MPEs have actually increased significantly (~factor of 1000). This will result in much lower Optical Density (OD) requirements for laser eyewear.

Why such a decrease in required protection? This is because there are now better studies on the effects of transmission and imaging of these wavelengths onto the retina. Time plays a factor in this also. For shorter picosecond pulse widths, the retina was the area of concern, but for the longer pulse widths, it was the cornea.

As you move to the longer wavelengths of the far infrared regions, the cornea becomes the area of interest where the MPE is the same as the skin.

Now let's look at the other end of the spectrum. We will start with the very short visible (blue light) and move to the much shorter ultraviolet (UV) wavelengths.

"Blue Light" is not very friendly to the retina as it degrades vision. That being said, we do have natural protections against this. The cornea filters some of this light out. The effect here though is that it will yellow over time. The yellowing allows for even more filtering of the blue light. Lastly, the retina contains a yellow pigment which further filters out this blue light.

On the longer wavelengths of the visible and IR, the effect is acute and is thermal.

Exposure time equates to an immediate effect. For the shorter wavelengths of the UV, we are looking at both an acute and chronic effect. The biological damage is via a photochemical effect rather than thermal. Usually the effect takes a few hours to present. For the shorter UV wavelengths, the target structure is the cornea and the result is photo-kerato -conjunctivitis or a sunburn on the eye. This is very painful (like sand or grit in the eye) but, because of the high rejuvenation rate of the cornea, it will general heal in 24-48 hours. This is done through a constant sloughing off process of the outer corneal cells.

If a high power short UV laser beam were to strike the cornea and damage it beyond repair, one could get a corneal transplant. This is a very simple procedure where a donor cornea is attached to the eye. Because of the low blood flow in the cornea, the body's rejection of the donor cornea is rare.

On the other hand, these wavelength lasers can be used to correct hereditary vision problems. Speaking as a sufferer of extreme myopia for over half of my life, LASIK is a godsend which has removed the disability of needing prescriptive eyewear to do even the basic every day tasks.

The longer UV-A wavelengths target the lens of the eye. The cells of the lens do not slough off, but rather form layer over layer (like an onion). Over time, the exposure, normally from unprotected sunlight, will present as a cataract (clouding of the eye). The cataract takes years to form and usually does not show up until later in life, thus the name senile cataracts (See figure 4). Remember that this is caused through a photochemical effect.

This clouding makes it very difficult to see, but one can get an artificial lens transplant. The positive here is that a fairly short outpatient procedure will allow the patient to see clearly again, The negative is that you no longer will

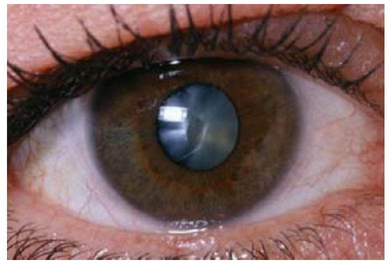


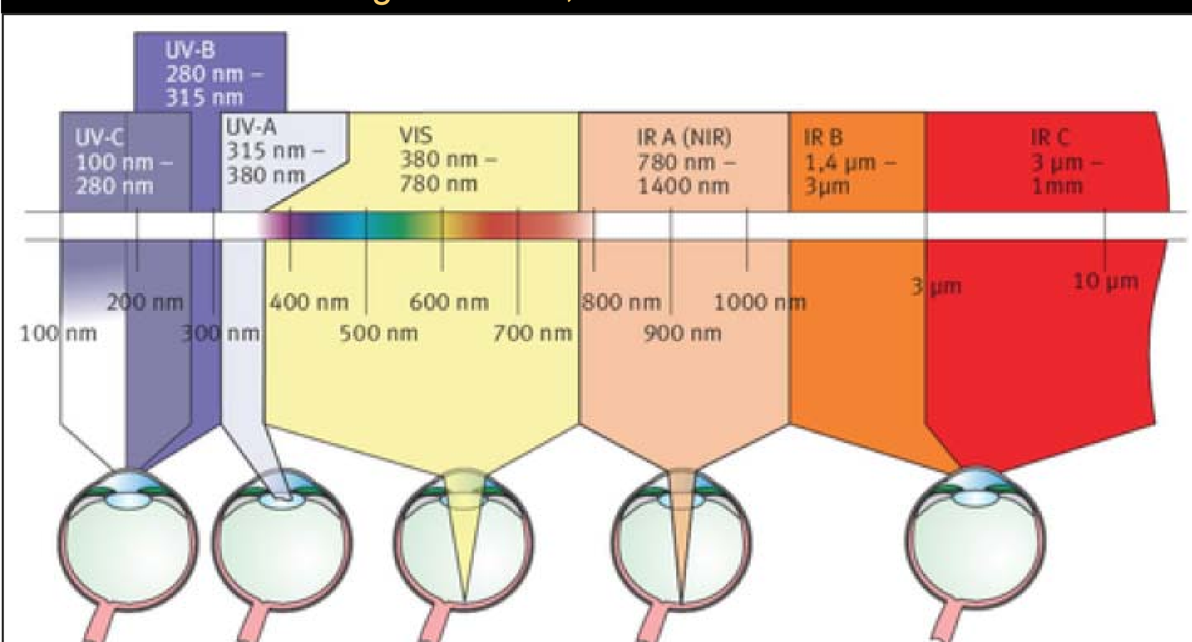
Figure 4. Cataract (courtesy WebMD.com)

have the blue light blocking capabilities that the biological lens provides. There are lenses available that are tinted to block the blue light, but the tradeoff is diminished night vision.

Like we mentioned earlier, there is currently no repair mechanism or surgery to fix a damaged retina. Studies are being performed using an artificial retina developed by LLNL, but detailed and clear vision is considerably lacking at this time.

With all of its complexities it will be quite some time, if ever, before we can hope to duplicate the wonders of the human eye. Think before you work, you only have two eyes. **BE SAFE!**

## Different wavelength bands, different effects:



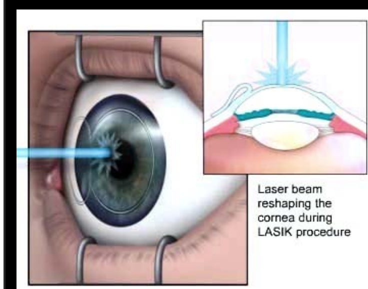

(Photo courtesy laser2000.co.uk)

# The wonders of science:

## Corneal Transplant

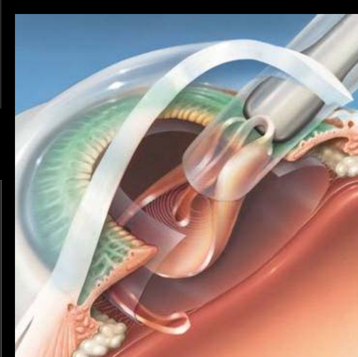
(Photo courtesy huroneye.com)

## LASIK Surgery



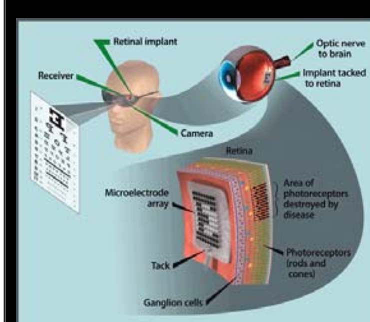

(Photo courtesy improve-vision-naturally.com)

## Artificial Lens Replacement



(Photo courtesy stahlvision.com)

## Artificial Retina




(Photo courtesy llnl.gov)

# Barriers (commercial or custom)

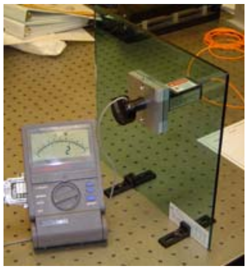
With a quick thought on the previous section regarding your eyesight, remember this...**Laser Protective Eyewear is your LAST LINE OF DEFENSE!**

In order to protect you and your coworkers from the hazards of the laser, you will want to contain the laser beam and its reflections as close to the source as possible. This ensures that the eyewear is truly the last line of defense. In order to do this you will be using barriers. Laser barriers can be anything from curtains, flat panels, beam tubes, table enclosures, or even room walls. They can be made of a variety of materials, depending on the output characteristics of the laser beam. When choosing barriers you have a decision to make, should I purchase a commercially available product or custom-make my own?

When available, you should choose commercially available barriers. This is especially true when selecting non-opaque materials. Why is this? These materials are usually glass, polycarbonate, or acrylic and are tested and rated per ANSI Z136.7 *for Testing and Labeling of Laser Protective Equipment.* You can be assured when purchasing these items, from a reputable vendor, that your workers will be safe. It also saves you from expending the time, money, and liability of testing and rating these materials yourself.

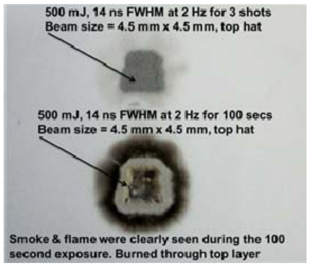
In choosing most opaque materials, good judgment should be used to ensure that your barrier will hold up to the task. This is true for what we have previously thought of as typical Class 3B and Class 4 lasers. As a Class 3B laser typically cannot start a fire, you could choose something of a less robust material. Cardboard or opaque plastics may work. Moving up to the typical Class 4, you could use Alumalite™ or other flat or sandwiched metals. Remember that a barrier is meant to block stray, scattered, or misdirected laser beams. What happens when you are using 10s to 100s of kilowatts of average power? Those working in this regime, especially R&D work, will find that there are no commercially available items rated for the extreme high average outputs. You may also find that, because of the size of the barrier needed, either the item is not commercially available or the cost is extremely prohibitive in getting the work done. When faced with this dilemma, you may choose to custom-make your own.

I would not recommend that one gets into the business of making their own barriers. That being said, if you are faced with that as your only path to move the project forward and you have the equipment needed to do the testing, one may successfully test and rate their own barriers in a way that is cost effective and rewarding. The following are several examples of self-tested and rated barriers.



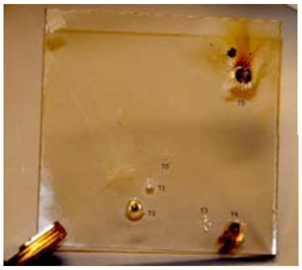
Problem: While under construction, a request was made to install "observation windows" in a gallery overlooking Laser Bay #1 of the National Ignition Facility (NIF). These windows needed to be safe to protect against a high-energy laser shot and stand up to years of abuse (touching) by visitors to the facility.

Solution: Determination was to use glass. This size material was not commercially available. Architectural skyscraper glass was chosen for excellent IR blocking capabilities (NIF primary beam is 1053nm). Window material was tested and determined that 5 sheets of glass were needed to meet laser safety requirements.




Problem: A request was made to install curtains around the compressor vessels of the Advanced Radiographic Capability (ARC) in the NIF. The cleanliness requirements were too high for any commercially available laser curtain material to meet. Only one type of non-opaque curtain could meet these requirements. The curtains must also serve as a laser barrier.

Solution: A sample of the curtain material was tested to a level of burn through. The curtains were then installed and rated at a level below the tested levels. The curtain also met fire safety requirements for personnel occupancy.



Problem: In designing laser operating stations, where workers might be located for up to 8-hours, an "open-feel" was requested. This required the use of 4'x8' sheets of non-opaque material. The material must both serve as a room enclosure and laser barrier for $CO_2$ laser.

Solution: Determination was to use polycarbonate sheets. Commercially available material was prohibitively costly. Only one type of polycarbonate met the fire safety requirements for a room enclosure. Window material was tested for burn-through times. A primary barrier, using same material, was installed as table edge guards with large panels serving as secondary barrier.

Problem: A Failure Modes Effects Analysis (FMEA) was requested for a room containing a very high average power laser system (burn-through 1" steel in 10 seconds). It was found that a single point of failure could cause redirection of the primary laser beam at a room wall constructed of gypsum board.

Solution: A sample piece of gypsum board was taken and inserted into the laser's beam for a period of 10 seconds (maximum "on-time" of the laser). It was discovered that the top layer of the paper on the gypsum board burned off and the gypsum material held up with minimal damage.

**BE SAFE!**