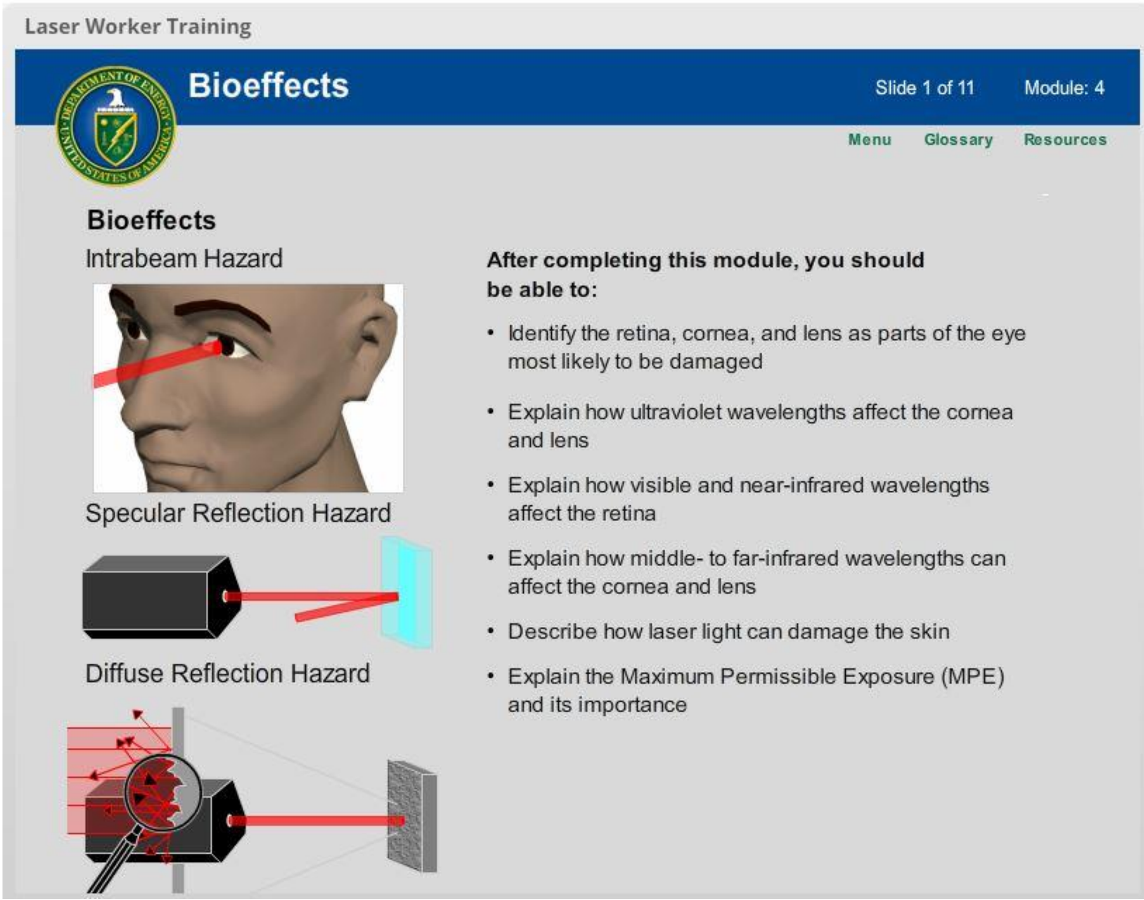
## *Slide 1 Bioeffects*

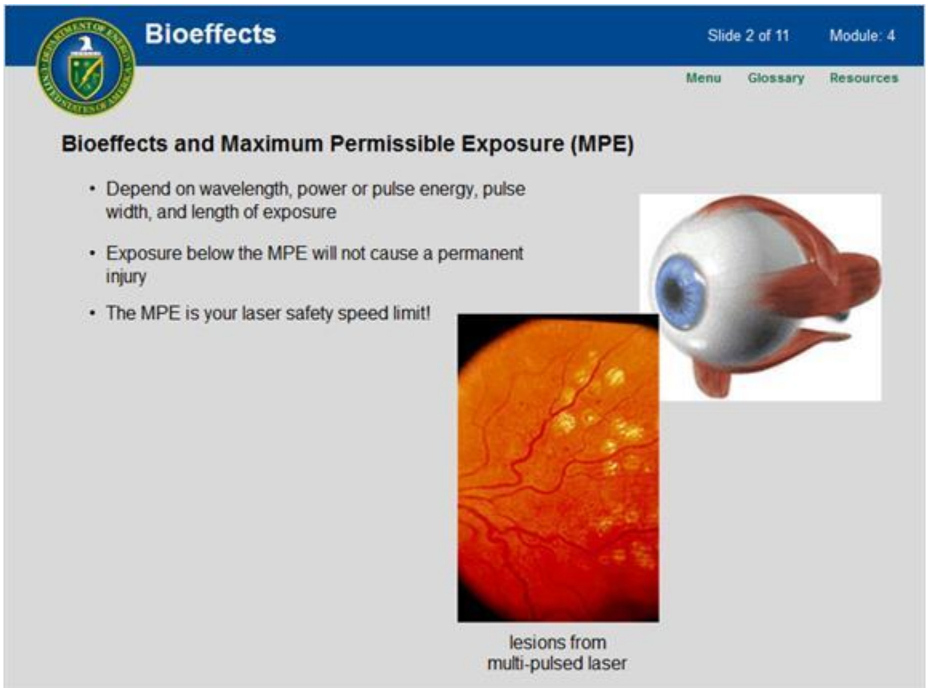



The three types of beam hazards — intrabeam, direct reflections, and diffuse reflections — can have negative effects on your body. In this module, we will explain these effects and examine some of the fundamentals for protecting yourself against these hazards.

After completing this module, you should be able to:

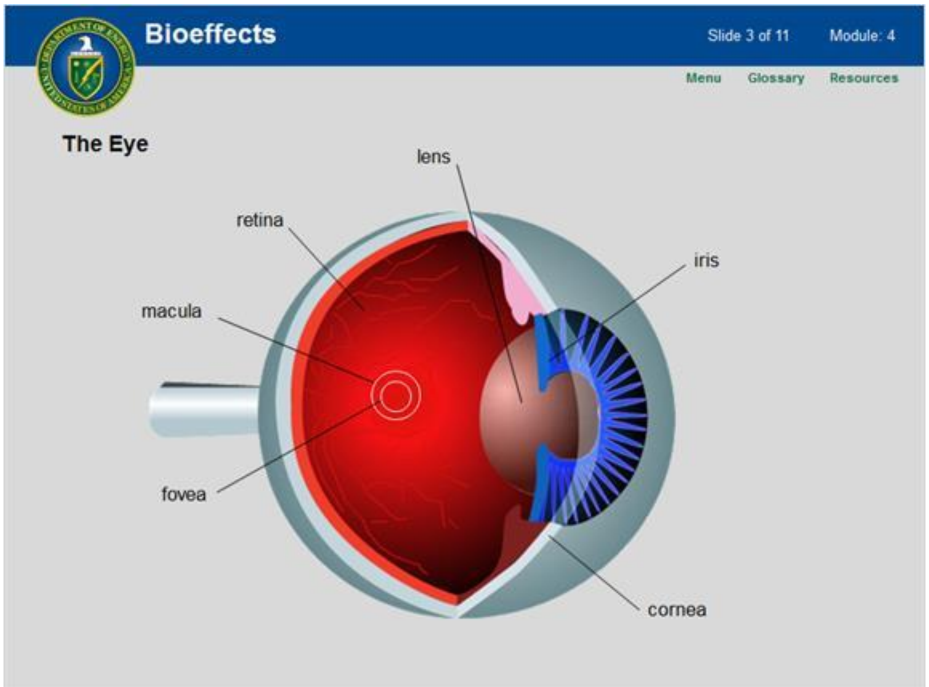
- Identify the retina, cornea, and lens as the parts of the eye most likely to be damaged
- Explain how ultraviolet wavelengths affect the cornea and lens
- Explain how visible and near-infrared wavelengths affect the retina
- Explain how middle- to far-infrared wavelengths can affect the cornea and lens
- Describe how laser light can damage the skin and
- Explain the Maximum Permissible Exposure (MPE) and its importance

## *Slide 2 Bioeffects*



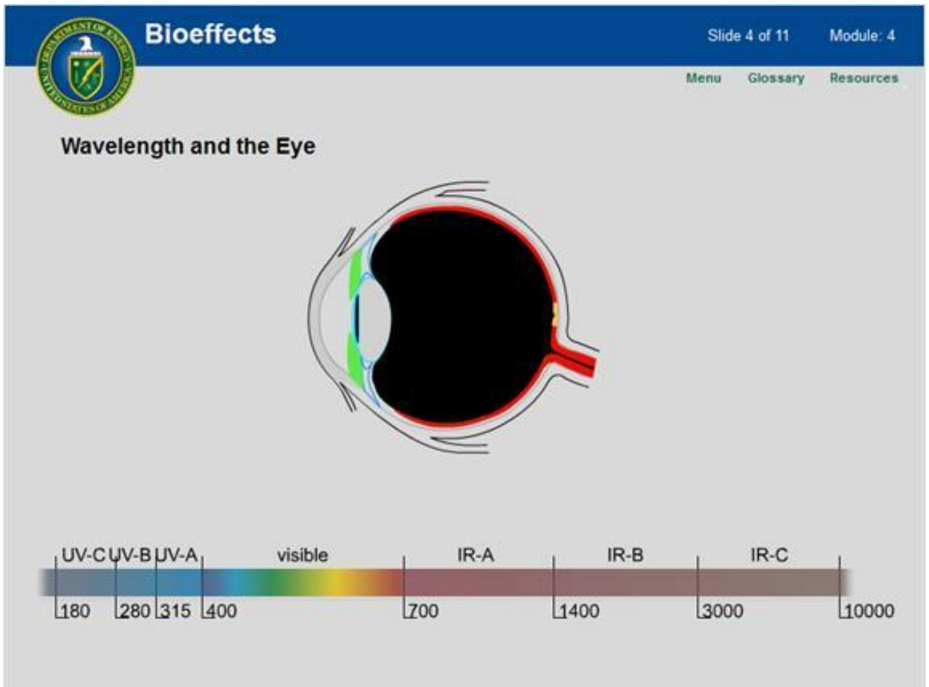

The greatest concern of those working with or around laser beams is eye injury. While laser eye injuries do occur, the data shows that such injuries generally are the outcome of not following safety protocols. Not every eye injury means complete or partial vision loss. The extent of damage depends on the part of the eye that is exposed and the exposure parameters, such as: wavelength, power or pulse energy, and the length of exposure. These factors are used to determine the Maximum Permissible Exposure, or MPE. The MPE is your biological limit for safety. It is the level of laser radiation to which a person may be exposed without adverse biological changes in the eye or skin. Think of the MPE as the speed limit. The higher you go above the limit, the greater your risk of having an accident and the greater the consequences of injury. MPEs determine the laser control measures and protective eyewear, which are discussed in other modules.

## *Slide 3 Bioeffects*



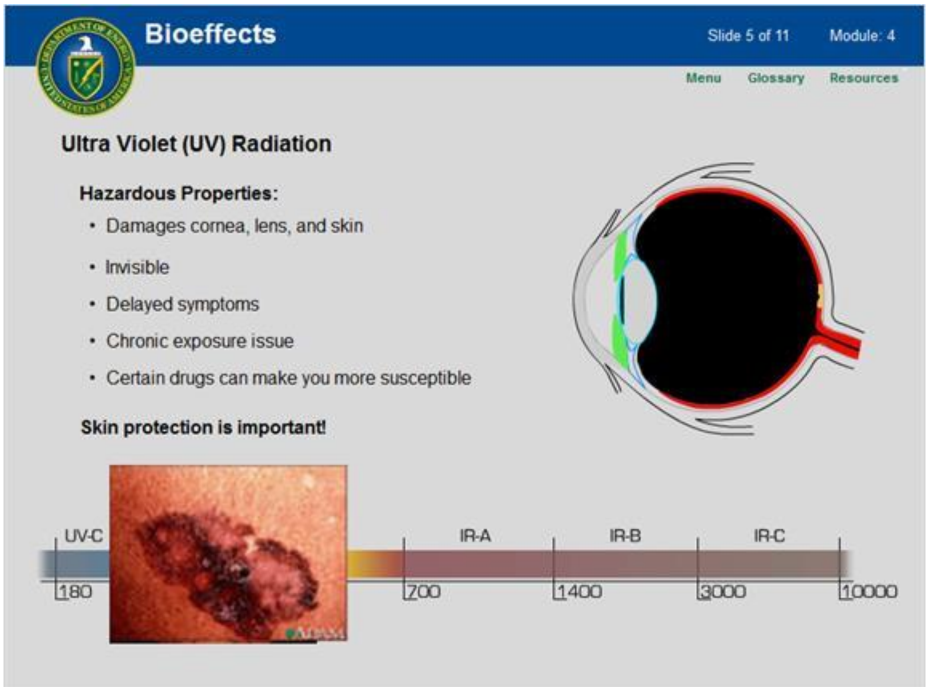

To understand the bioeffects of laser-induced eye injuries, let's start with an explanation of the functions of the major parts of the human eye. The cornea is the transparent layer of tissue covering the eye. Damage to the outer cornea may be uncomfortable (usually a gritty feeling) or painful, but it normally heals fairly quickly. Damage to the deeper layers can be permanent. Just beneath the cornea is the iris. The iris opens and closes to control the amount of light entering the eye through the pupil. A person's eye color is determined by pigmentation in the iris. Just behind the iris is the lens. The cornea and lens act together to focus incoming light onto the retina. A small area of the retina contains the macula and fovea. This area provides the most detailed and acute vision, as well as color perception. Damage to the fovea can have significant impact on your vision. The rest of the retina can perceive light and movement, and provides peripheral vision, but not very detailed images. Any damage to the retina will ultimately affect vision.

## *Slide 4 Bioeffects*



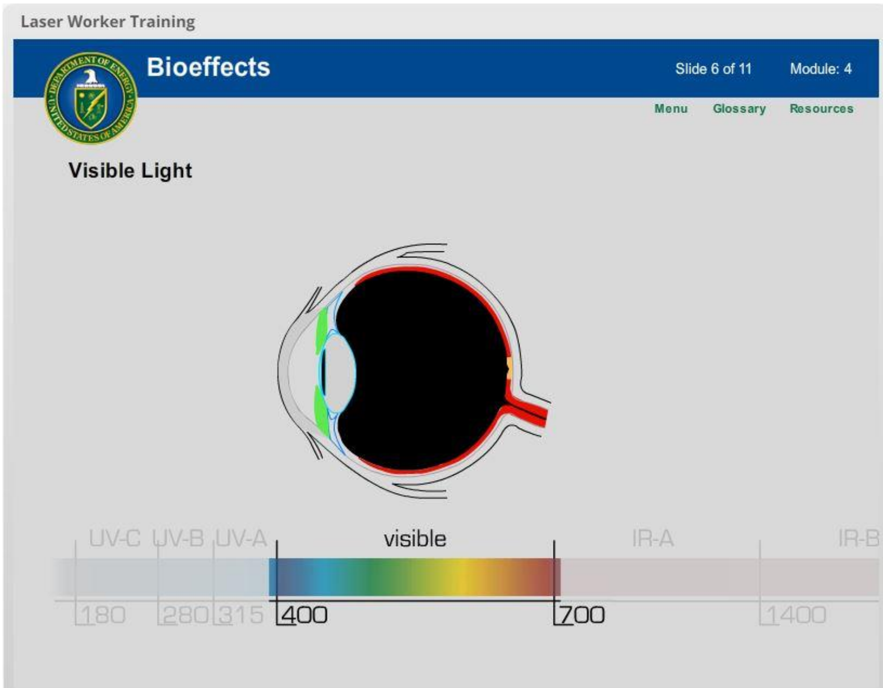

Laser light absorption and its effect on various parts of the eye are wavelength dependent. Here are some wavelength ranges and the parts of the eye each affects. Wavelengths in the ultraviolet range (180 to 400 nanometers) can cause damage to the cornea and lens but do not penetrate to the retina. Visible-light (400 to700 nanometers) is transmitted and focused by the cornea and lens onto the retina. Light in the near-infrared range (700 to 1400 nanometers) also reaches the retina with the potential to cause lesions. Finally, light in the mid- and far-infrared ranges (1400 nanometers to one million nanometers or 1 millimeter) is absorbed by the cornea and lens, and converted to heat; thus causing damage.

## *Slide 5 Bioeffects*




Ultraviolet, or UV, radiation extends from 180 to 400 nanometers and can cause injury to the cornea, lens and skin. Invisible to the eye, UV radiation can be a hidden danger. An injury can manifest itself some time (possibly hours) after the exposure occurs. As with a sunburn, you may not feel the pain from UV damage to your eye until well after the injury occurs. Long-term exposure can result in cataracts due to lens damage. Exposure in the UV-B range is most injurious to the skin. Chronic exposure can cause premature aging of tissue and skin cancer. Also be aware that sun block creams or spray do not provide protection for the entire UV spectrum and should not be relied upon as a protective barrier. Some drugs can make you more susceptible to injury from low levels of UV exposure by increasing your sensitivity to light. If you are taking a medication that warns of avoiding sunlight, and you are working around UV light, you should contact your occupational medical provider.

## *Slide 6 Bioeffects*

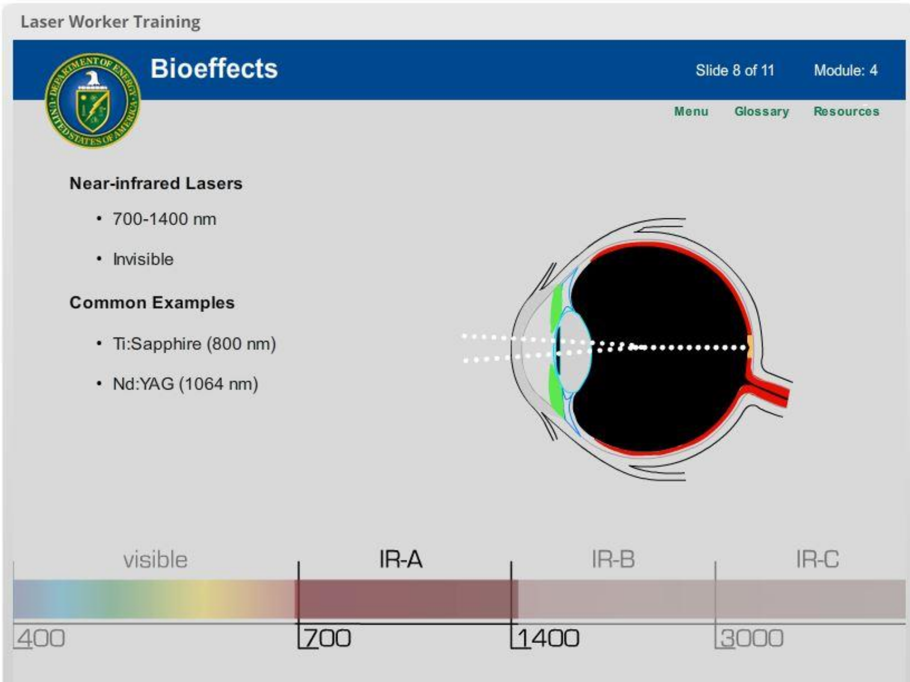



The properties of a laser make the visible laser the brightest light source to the human eye, and it is even brighter when focused by the lens. Incoherent light, like that from a light bulb, is focused by the lens of the eye to a 150 to 250 micrometer spot at the macula. Coherent light, like that from a laser, is focused to a 10 micrometer spot at the macula. In other words, the beam passing through the pupil is focused by the lens on a spot 100,000 times smaller at the macula. This is why a 1 milliwatt per centimeter squared laser beam entering the eye becomes 100 Watts per centimeter squared at the retina.

## *Slide 7 Bioeffects*

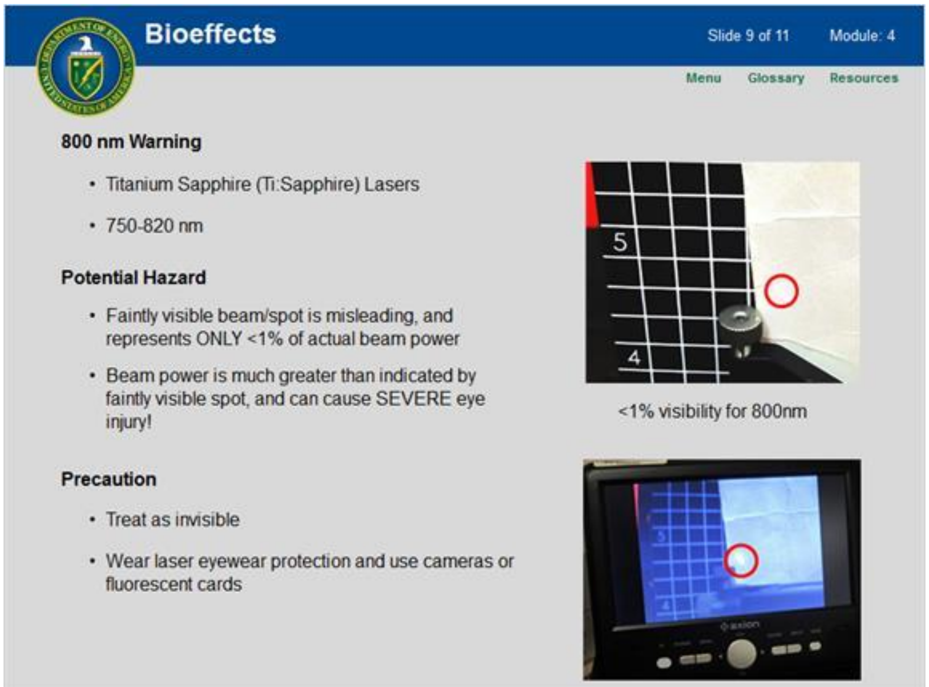

Visible light exposures can have a significant impact even if the exposure is below the MPE. While your blink or aversion response can help protect you from a Class 2 or Class 3R laser exposure, the bright light could startle you or cause temporary impaired vision. This is sometimes referred to as flash blindness and can include blurred vision, after images or glare responses. Being flashed by a low power visible laser may not cause a permanent eye injury, but if it startles you it could cause you to drop equipment, for example, or jerk your hand or body into a dangerous location in your work area.

## *Slide 8 Bioeffects*



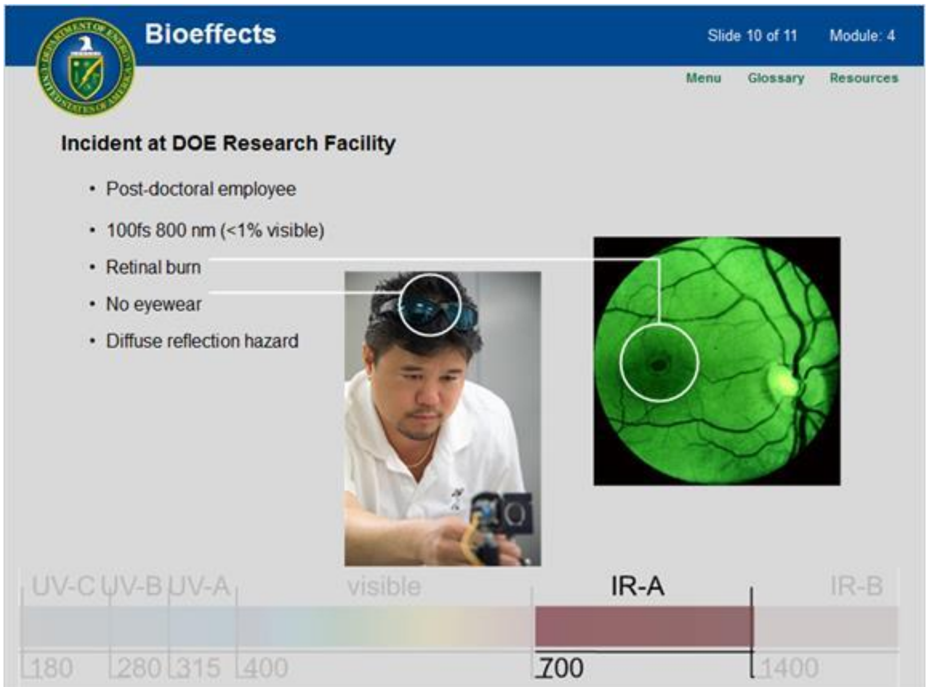

Near-infrared, or N-I-R., wavelengths extend from 700 to 1400 nanometers. Like visible light, near-infrared light is focused by the cornea and lens onto the retina, including the most critical vision area of the retina, the macula and fovea. Titanium Sapphire lasers at 800 nanometers and the common Neodymium YAG laser emitting at 1064 nanometers are major players in laser injuries. Almost all cases involve someone performing alignment without appropriate eyewear and being struck by a reflection off an optic, something else inserted into the beam path, or a full beam that is misaligned. Some people report seeing a flash and then hearing a pop from inside their eye when injured by this type of laser. Basically, a small part of the retina has vaporized

## *Slide 9 Bioeffects*




A large number of laser accidents have occurred using lasers operating in the 750 to 820 nanometer range, in particular, Titanium: Sapphire lasers. While the visible wavelength range is 400 to 700 nanometers, some texts indicate that the actual range is 380 to 780 nanometers and that a number of people can see out to 820 nanometers. 700 to 820-nanometer light is very deceptive, as individuals who can actually see the faintly visible spot can easily think that the beam power is much lower than it really is. The light from an 800-nanometer laser may appear faintly visible, but your perceived response to 800-nanometer light is much less than 1 percent of the actual beam intensity. This gives the false impression that the beam is of low power. The result of accidental exposure: severe eye injury.  Instead, wear laser eyewear protection and use a camera or fluorescent card to view 800nm beams! Let's look at an actual incident that took place at a DOE research facility.

## *Slide 10 Bioeffects*

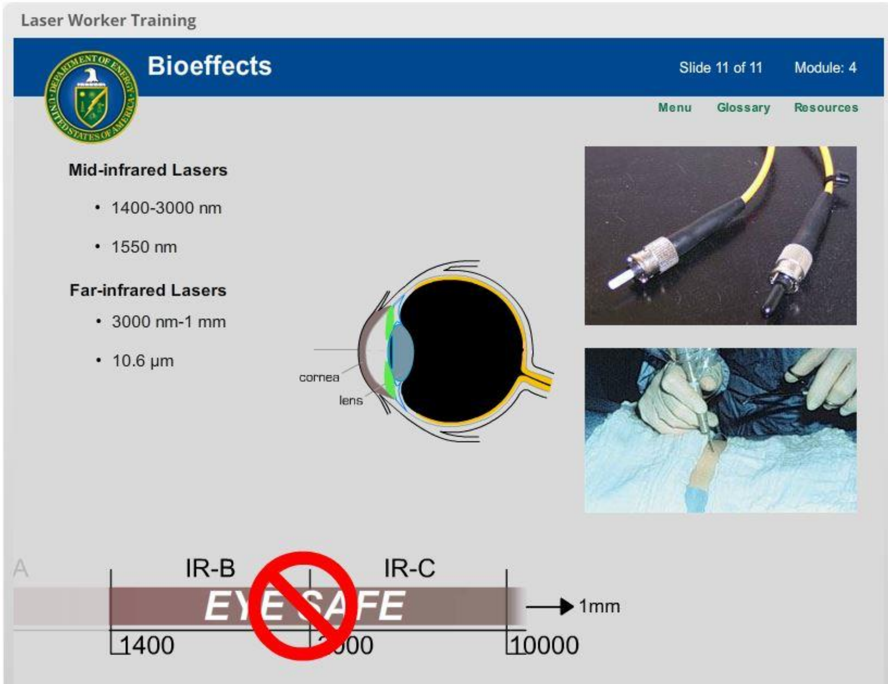



A postdoctoral employee received an eye injury from exposure to a diffuse reflection of a 100 femtosecond 800 nanometer Class 4 laser beam.

The extremely short pulse beam caused a 100 micrometer diameter burn to the employee's retina.

The accident occurred shortly after a mirror was removed from its mount and replaced with a corner cube. The researcher bent over to check the height of the corner cube without blocking the beam or wearing protective eyewear.  He received an eye injury from diffusely scattered light produced by the corner cube and its mount.

## *Slide 11 Bioeffects*




The mid- infrared range is fourteen-hundred nanometers to three thousand nanometers. Far-infrared wavelengths extend from three thousand nanometers to one million nanometers, or 1 millimeter. 1550 nanometer beams, for example, are commonly used for fiber optic communications. The Carbon Dioxide laser at 10.6 micrometers, is also found in this range. This laser is commonly used in medicine to cut tissue. Mid to Far-Infrared lasers operate outside the Retinal Hazard Region and have sometimes been mistakenly called "eye safe." This is incorrect as these wavelengths can still cause corneal damage and potential damage to the lens. There are no "eye safe" Class 3B or Class 4 lasers!