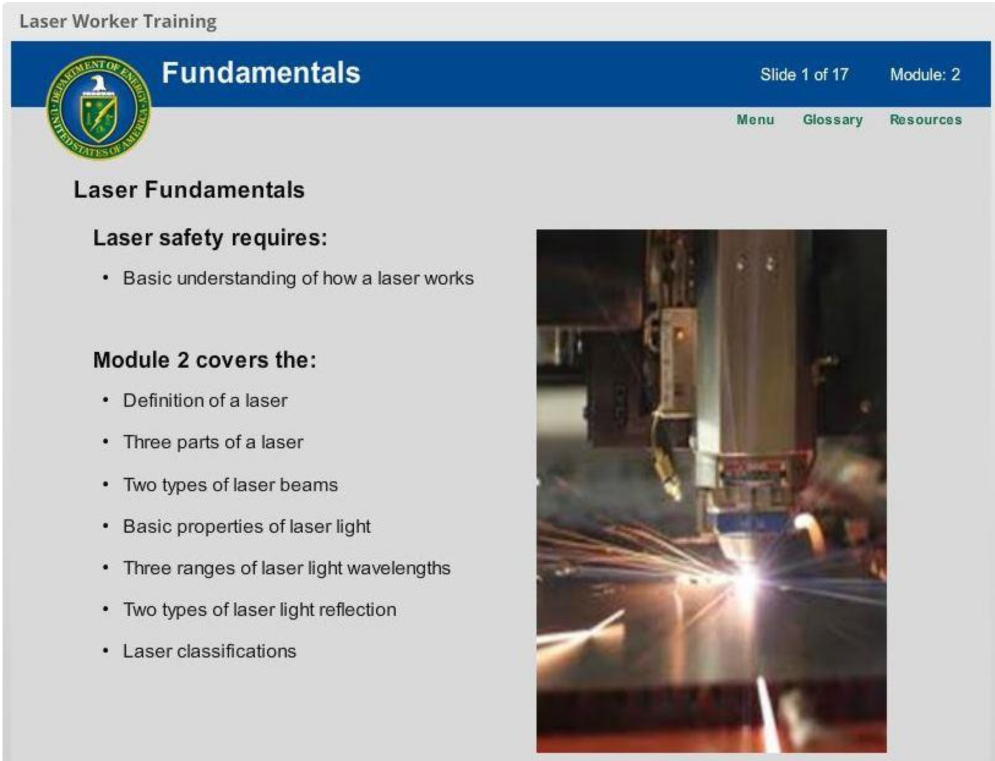
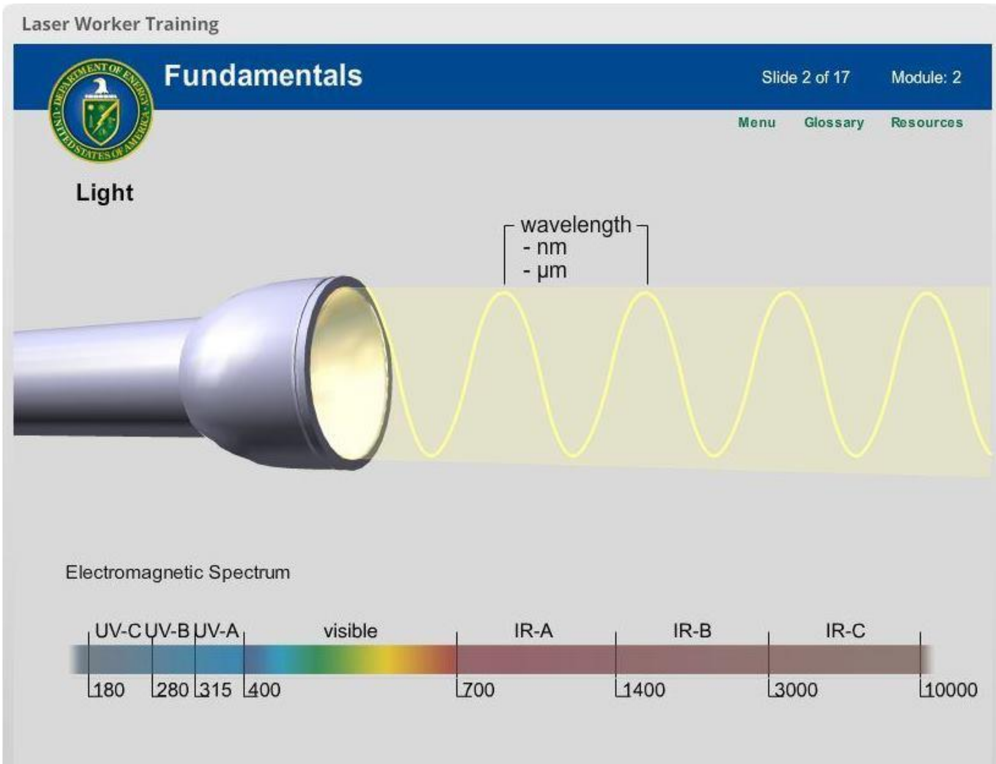
Slide 1 Fundamentals



Lasers are used in a wide variety of areas from research and medicine to a wide range of military, entertainment, and industrial applications. Lasers range from high power facilities to very low-power systems used in some CD players. They are used to cut materials, measure with great accuracy, print pictures and many other applications. And partly because they are so prevalent in the DOE complex, lasers present some very real safety concerns.

Any discussion of laser safety requires a basic understanding of how a laser works, which is the goal of this module. This section will cover the definition of a laser, the three parts of a laser, the two types of laser beams, the basic properties of laser light, the three ranges of laser light wavelengths, the two types of laser light reflection, and the laser classifications.

Slide 2 Fundamentals



Light is energy in the form of waves, electromagnetic waves to be exact.

Light waves can be of many colors. Actually, white light, as shown here, is made up of all the colors of the rainbow.

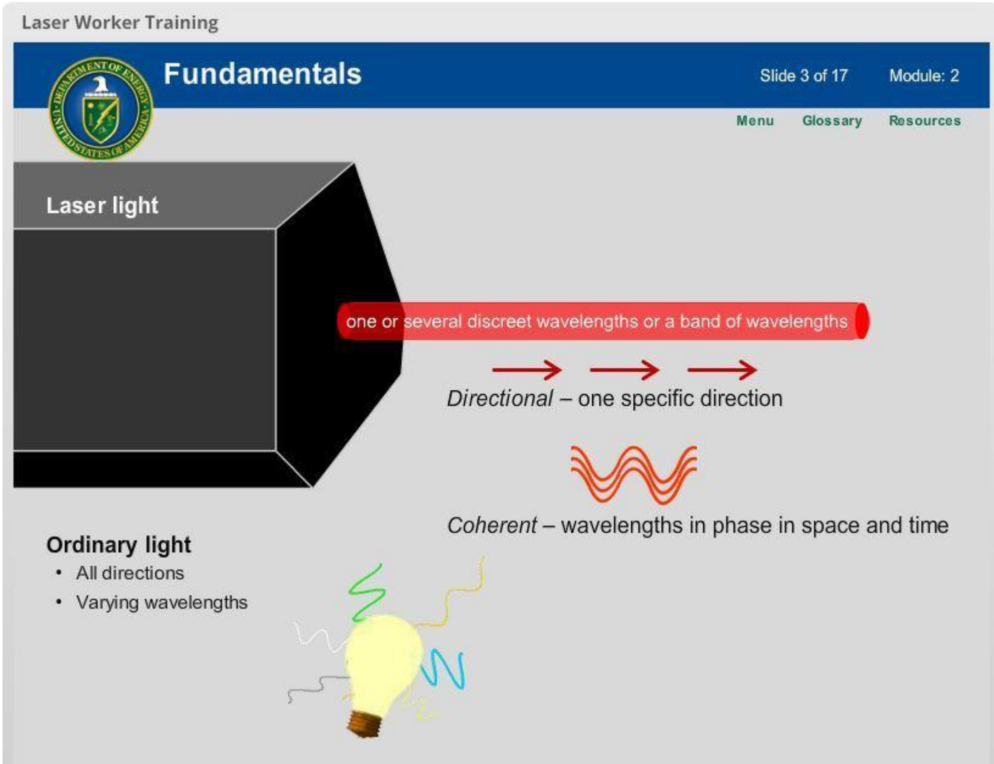
A light's color is defined by the wavelength. Wavelength is the distance between peaks, from crest to crest, of a light wave.

Wavelength is usually measured in nanometers or micrometers.

Today's laser light covers three ranges of the electromagnetic spectrum:

- ultraviolet, UV, (180-400 nm)
- visible (400-700 nm) and
- infrared, or IR, (700 nm - 1,000,000 nm or 1 mm)

Slide 3 Fundamentals

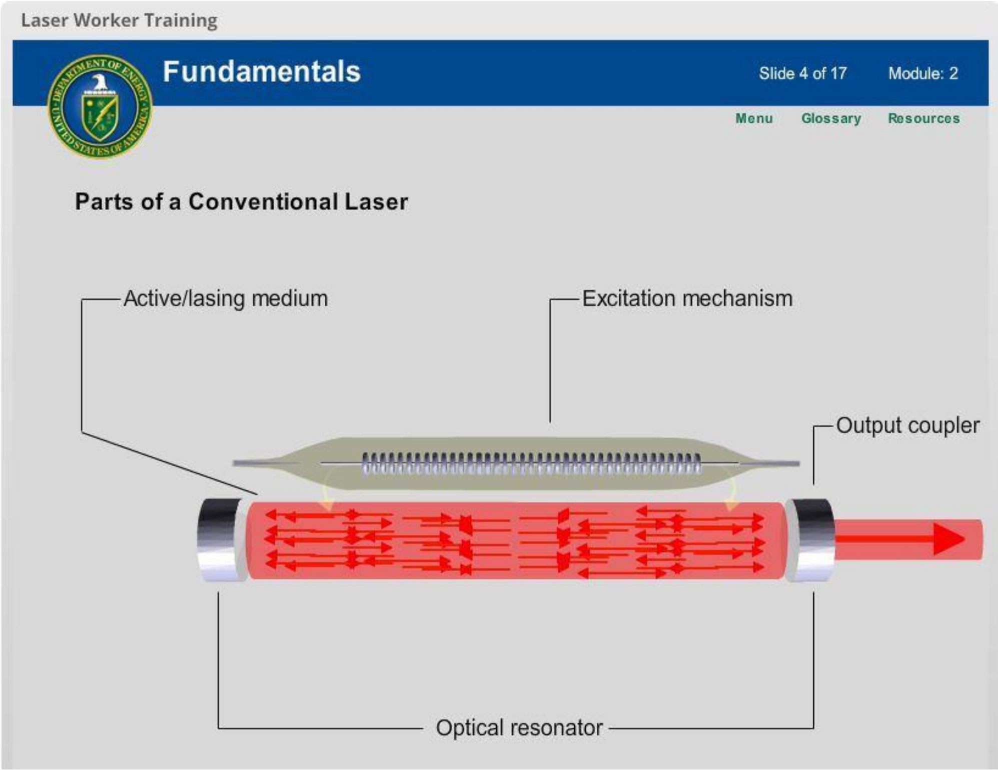


LASER is an acronym that stands for Light Amplification by Stimulated Emission of Radiation. Laser light has unique properties that distinguish it from ordinary light such as the sun or room lighting. Conventional sources of light, such as light bulbs, radiate light in all directions and in varying wavelengths.

Laser light may consist of one or several discrete colors or wavelengths, or a band of wavelengths. It is also highly directional, which means that laser light is emitted as a relatively narrow beam in a specific direction.

Laser light is also coherent, which means the wavelengths of the laser light are in phase in space and time. It is this property of laser light that allows it to be focused to a tight spot or propagated over long distances with little change in beam size.

Slide 4 Fundamentals



There are three fundamental parts in a conventional laser. An excitation mechanism, an active medium or lasing medium, and an optical resonator.

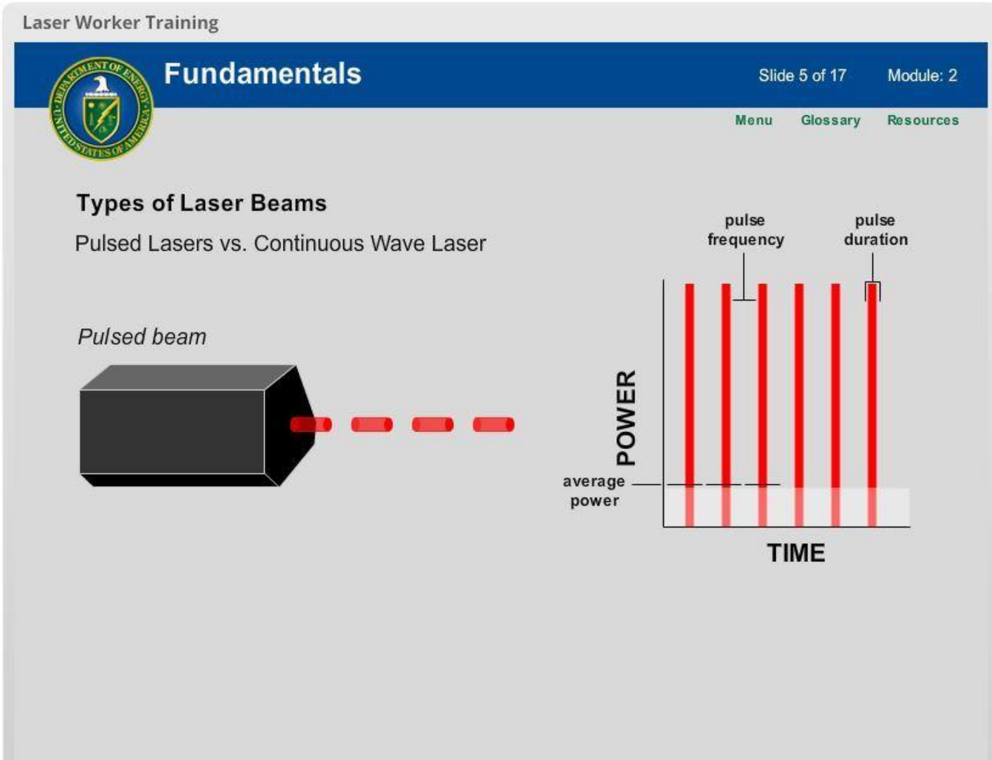
The excitation mechanism provides the energy used to excite the lasing medium. It is the initial source of energy input. Examples of energy sources include flash lamps, electricity, chemical reactions, or even another laser.

The lasing medium of a laser is a substance that emits coherent light as a result of exposure to the excitation mechanism. Lasers are often described by the kind of lasing medium they use. The medium can be a gas, liquid, solid, or semi-conducting material.

At this point, known as the fluorescence phase, light is emitted in all directions.

The optical resonator, or optical cavity, serves to reflect light from the lasing medium. It contains 100% reflective and partially reflective mirrors at opposite ends. The light bounces back and forth between the mirrors, amplifying its energy. Some of the light is not reflected back into the lasing medium and passes through the partially reflecting end of the optical cavity. This is known as the output coupler, and is usually a semi-transparent mirror. The resulting escaping light is the actual laser beam.

Slide 5 Fundamentals



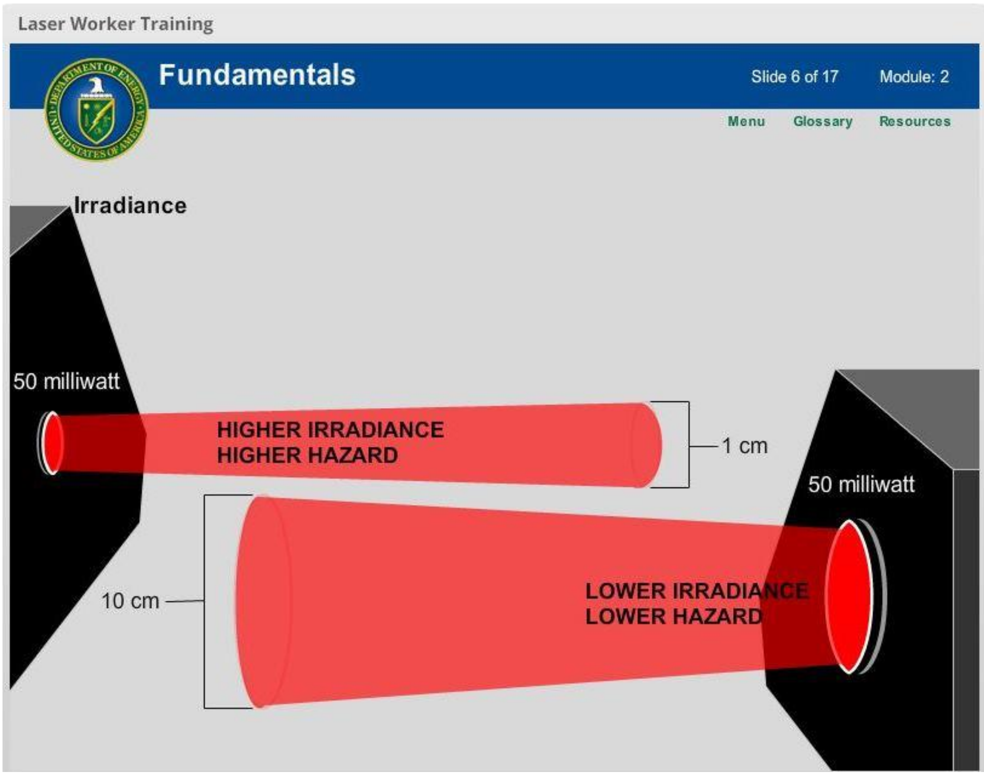
Lasers may be operated either as pulsed systems or as systems that emit continuous waves. A pulsed beam delivers power in a single pulse or train of pulses. A continuous wave beam is a constant, steady-state delivery of laser power. A pulsed laser emits short light pulses. These pulses are usually just fractions of a second, with pulse length depending on the actual application. Pulse duration and pulse frequency describe pulsed laser operation.

Pulsed lasers generally are more hazardous than continuous wave lasers. But why?

If you measure the output power of a laser over time, you obtain the average output power of that particular laser. However, for a pulsed laser the energy is delivered in pulses of short duration with intervals of no power. Thus, the peak power output during a pulse may be much higher than the average power.

Let's examine a pulsed laser that emits one pulse per second with pulse duration of one microsecond. If the average output is 1 watt per second, the resulting peak power of each pulse is 1 million watts. This is a very significant amount of energy that could cause biological damage to your skin or eyes.

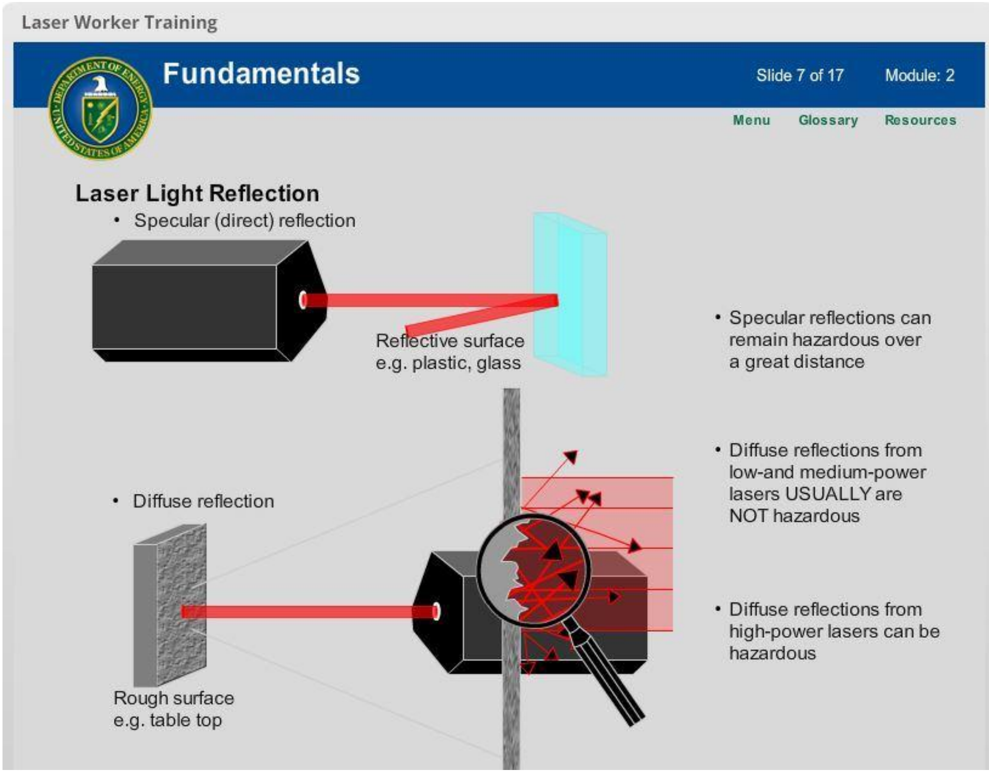
Slide 6 Fundamentals



Irradiance is the incident power per unit area upon a surface, usually expressed in watts per square centimeter. Beam area depends on the size of aperture, divergence of the beam, and distance from the aperture.

The greater the beam irradiance, the greater the potential hazard. For example, a 50 milliwatt beam with a diameter of 1 cm will have much higher irradiance and, therefore, be more hazardous than that of a 10 cm beam at the same power.

Slide 7 Fundamentals

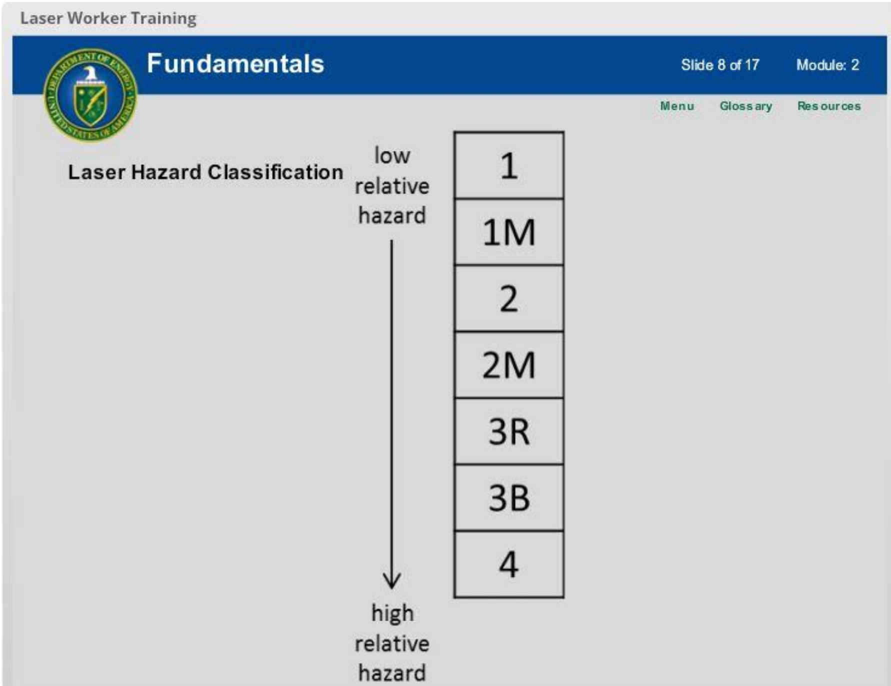


How a laser beam is reflected contributes to its hazard level. Laser reflections can be diffuse or they can be specular, also known as direct. Whether a reflection is specular or diffuse depends on the light beam's wavelength. For example, surfaces that are "rough" and produce diffuse reflections at short wavelengths may be "smooth" or mirror-like at longer wavelengths and thus produce specular reflections.

Specular reflections are created when a beam hits a mirror-like reflecting surface. Specular reflections from lasers that result in very little change to the beam other than direction can remain hazardous over a great distance.

Diffuse reflections result when a laser beam strikes an uneven surface. The surface irregularities scatter the light in many directions. Diffuse reflections from low- and medium- power lasers usually are not hazardous. Diffuse reflections from high-power lasers can be hazardous.

Slide 8 Fundamentals

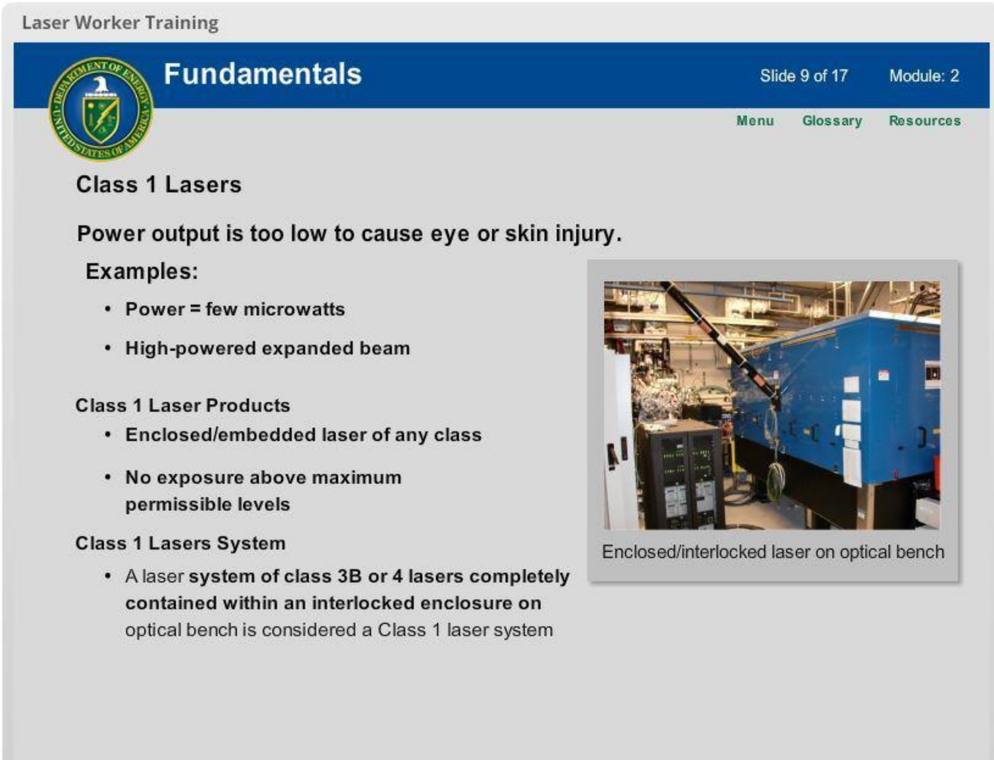


To help warn people about the possible hazard of a laser or laser system, a Laser Hazard Classification System has been established and almost universally adopted throughout the world.

Lasers are classified as Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B, and Class 4.

You may also see manufacturer labels use 3a instead of 3R; or 3b with a lower case b rather than an upper case B. Manufacturer labels may also use Roman numerals instead.

Slide 9 Fundamentals

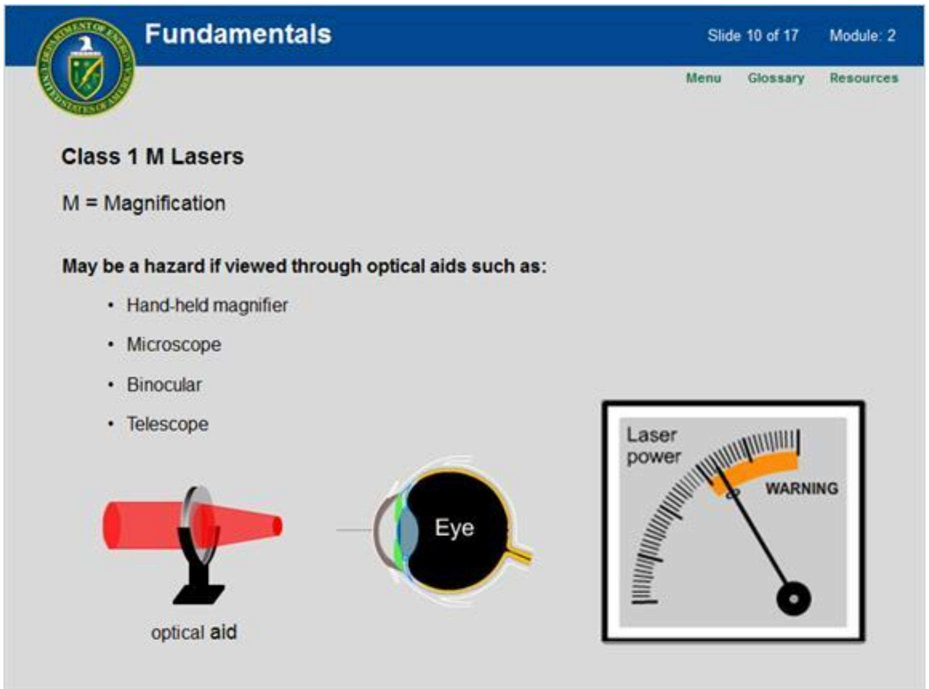


A Class 1 laser or laser system is one whose power output is too low to cause eye or skin injury. Examples include a laser that generates only a few microwatts or a high-powered beam that is expanded such that its power per unit area is so low it does not present an eye or skin hazard.

Class 1 products are more common than Class 1 lasers. A Class 1 product is a product that encloses or embeds a laser of any class, but during normal operation no operator exposure above maximum permissible levels is possible. For example, a laser printer is a Class 1 product.

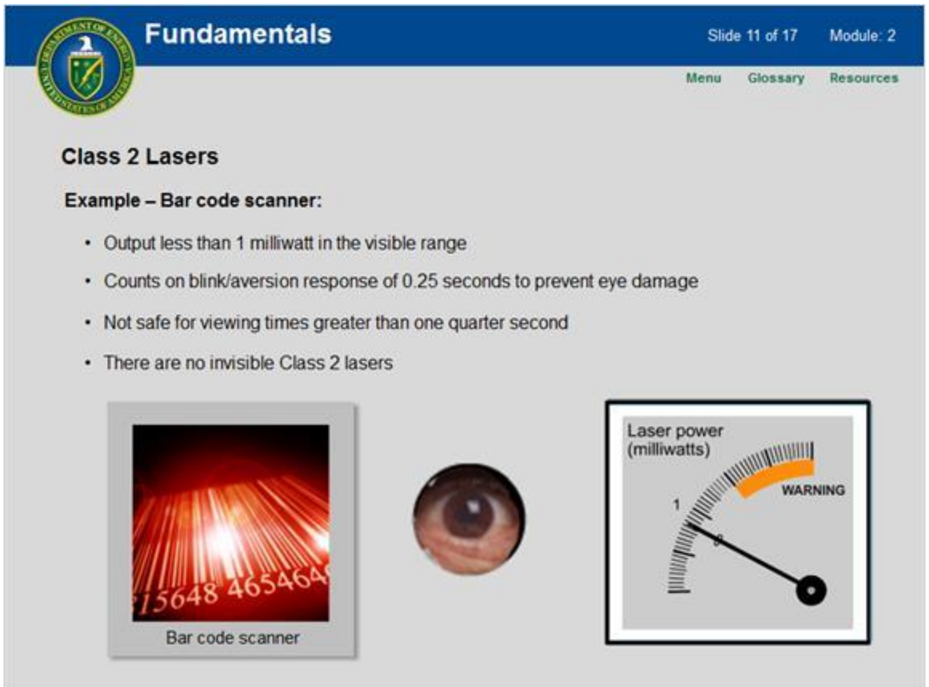
Although technically not a product, a laser system consisting of Class 3B or Class 4 lasers that are completely contained within an interlocked enclosure on an optical bench is considered a Class 1 laser system.

Slide 10 Fundamentals



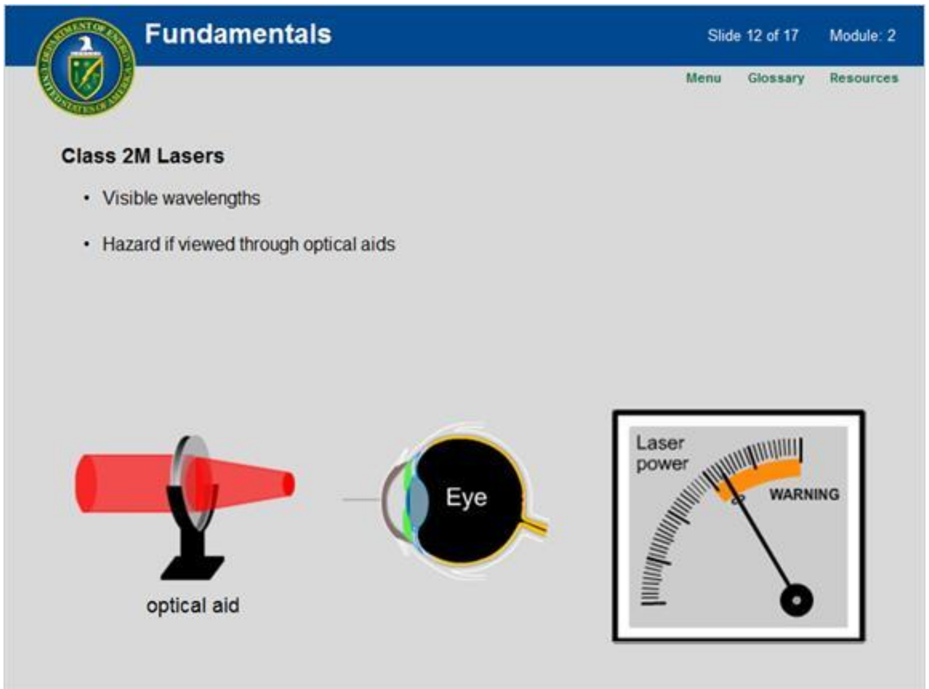
"M" stands for magnification. Class 1M lasers may be a hazard if viewed with an optical aid, such as a hand-held magnifier, microscope, binocular, or telescope.

Slide 11 Fundamentals



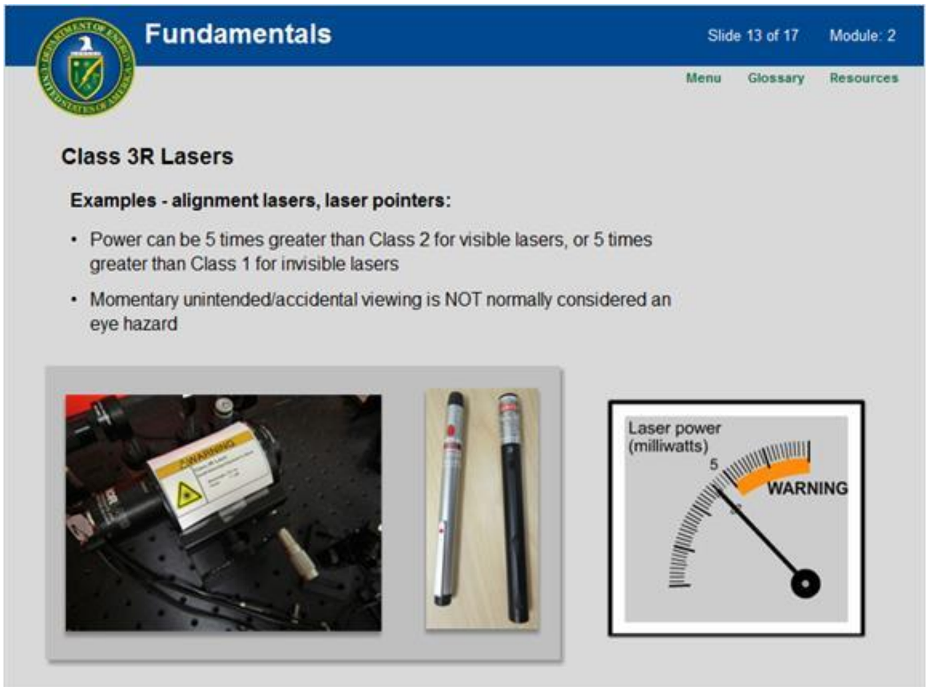
A visible laser with an output of up to one milli-watt (1/1000th of a watt) is a Class 2 laser. A Class 2 laser relies on the blink or aversion response for laser safety. If struck in the eye by a Class 2 laser, one will normally blink or turn away. This response takes less than one quarter of a second, which is adequate time to protect the eye. Since the eye must SEE the light to cause the aversion response, there are no invisible Class 2 lasers.

Slide 12 Fundamentals



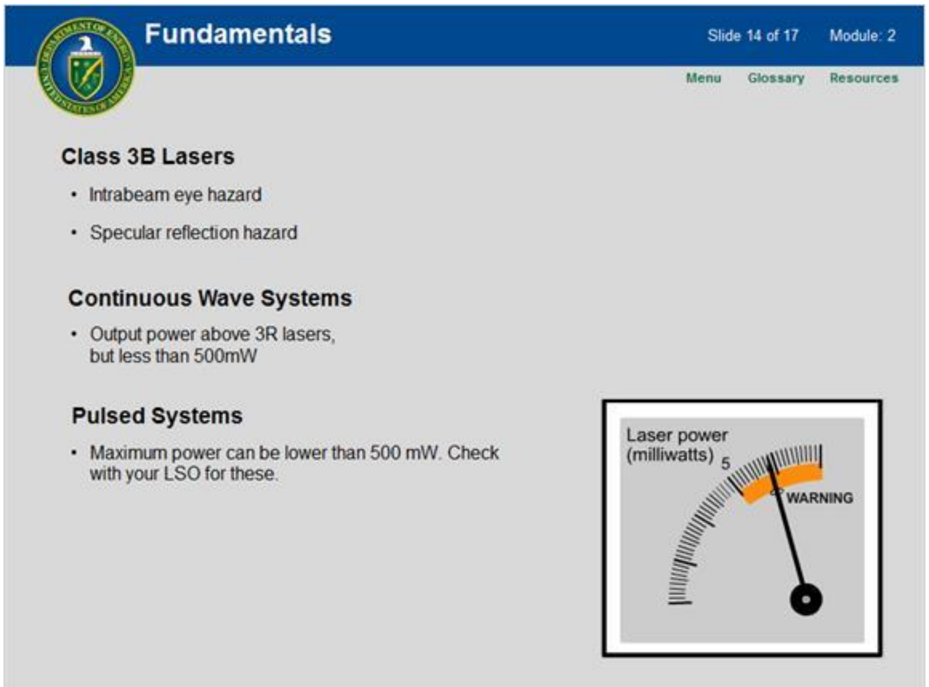
Just like Class 2, a Class 2M laser is safe because of the blink/aversion response, so long as it is NOT viewed through optical aids.

Slide 13 Fundamentals



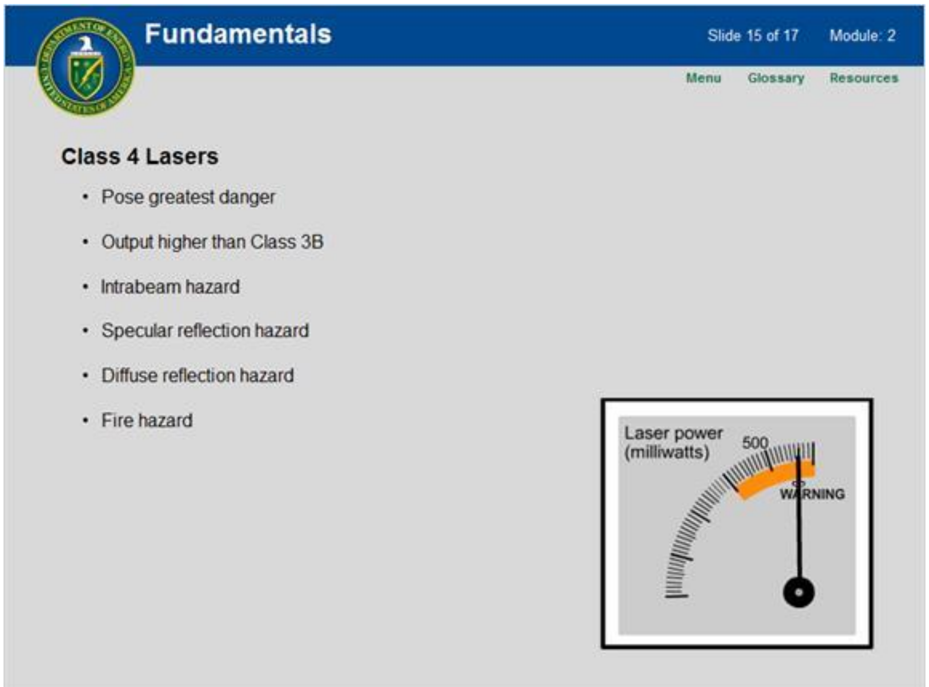
Class 3R laser beams are above the MPE limit, but not by very much. They can be 5 times greater than Class 2 for visible lasers, or 5 times greater than Class 1 for invisible lasers. Momentary unintended or accidental viewing is not normally considered to be an eye hazard.

Slide 14 Fundamentals



Class 3B lasers present a hazard to the eye if their beams are viewed directly or from specular reflections. Their output powers are above 3R lasers, but are lower than 500 milliwatts for continuous wave lasers. Class 3B maximum average power can be lower than 500 milliwatts for pulsed laser systems. Check with your LSO for these.

Slide 15 Fundamentals

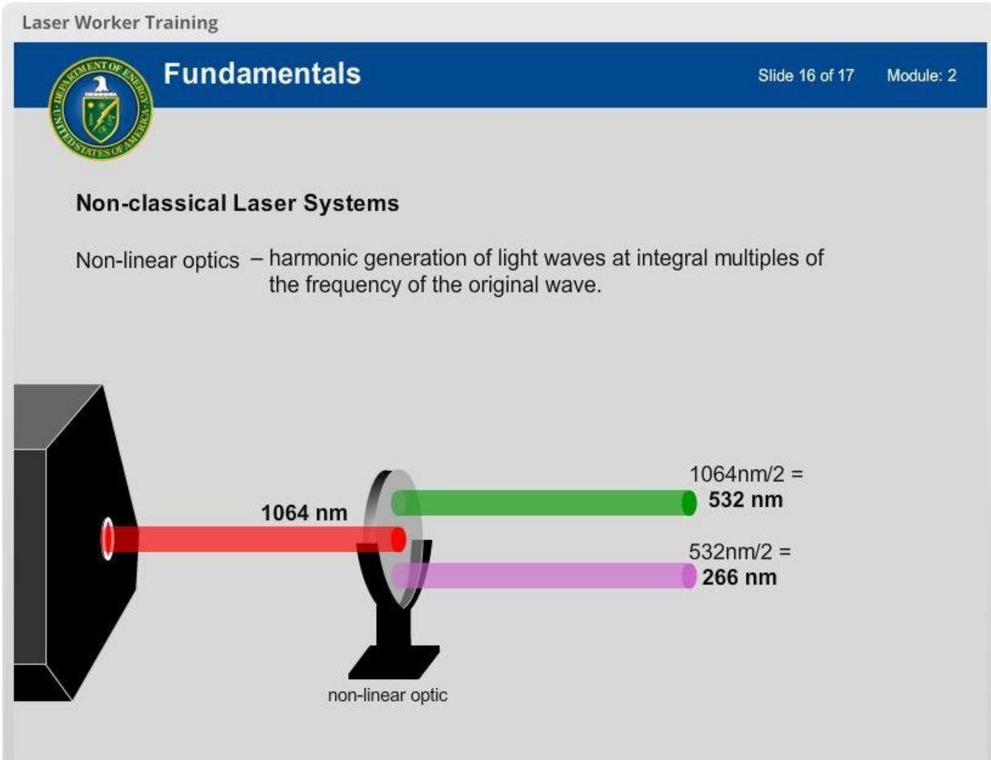


Class 4 lasers are like Class 3B, but pose a greater danger. Any output higher than Class 3B is Class 4.

Damage can occur from momentary direct beam exposure, specular reflections, and even diffuse reflections to the eyes and skin. Diffuse reflections from Class 4 lasers are hazardous depending on your distance from the reflecting surface. A hazard evaluation from a Laser Safety Officer (LSO) can tell you the distances that specular or diffuse reflections remain hazardous.

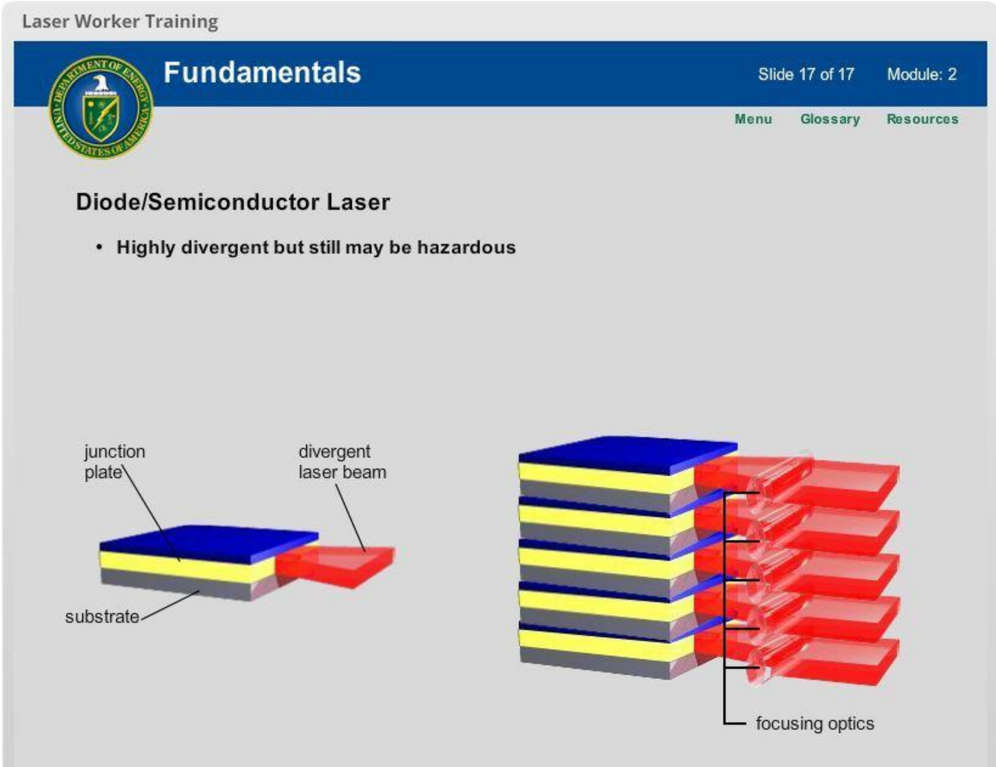
Also, Class 4 lasers can produce fires.

Slide 16 Fundamentals



Up to this point, all the lasers we have talked about meet the classical definition of a laser. Non-linear optics have opened up a new regime for lasers. These optics enable the harmonic generation of light waves at integral multiples of the frequency of the original wave. Second, third, fourth and greater harmonic generation are possible. This is why the neodymium YAG Near Infrared laser can yield a visible wavelength of 532 nanometers and an ultraviolet wavelength of 266 nanometers. This is important in that you may have to protect yourself simultaneously from multiple wavelengths, depending upon the circumstances.

Slide 17 Fundamentals



Diode or semiconductor lasers have become vital to the expansion of laser and laser product applications. Diode lasers have become a highly desirable excitation mechanism for all types of laser applications.

The typical single diode laser produces a beam that is highly divergent, which might make one think that a distance of a few centimeters provides more than adequate safety for the user.

Remember, diodes can be stacked together to form bars or rectangular sources. Focusing optics can be a part of laser diode configurations, therefore increasing the hazard even at significant distance.