Welcome to the Laser Safety Training presented by Environment, Health, and Safety Services. Any employee of the university that plans on working with Class 3b and Class 4 Lasers are required to take this initial Laser Safety Training and be trained by their PI or appointee for more lab specific training.

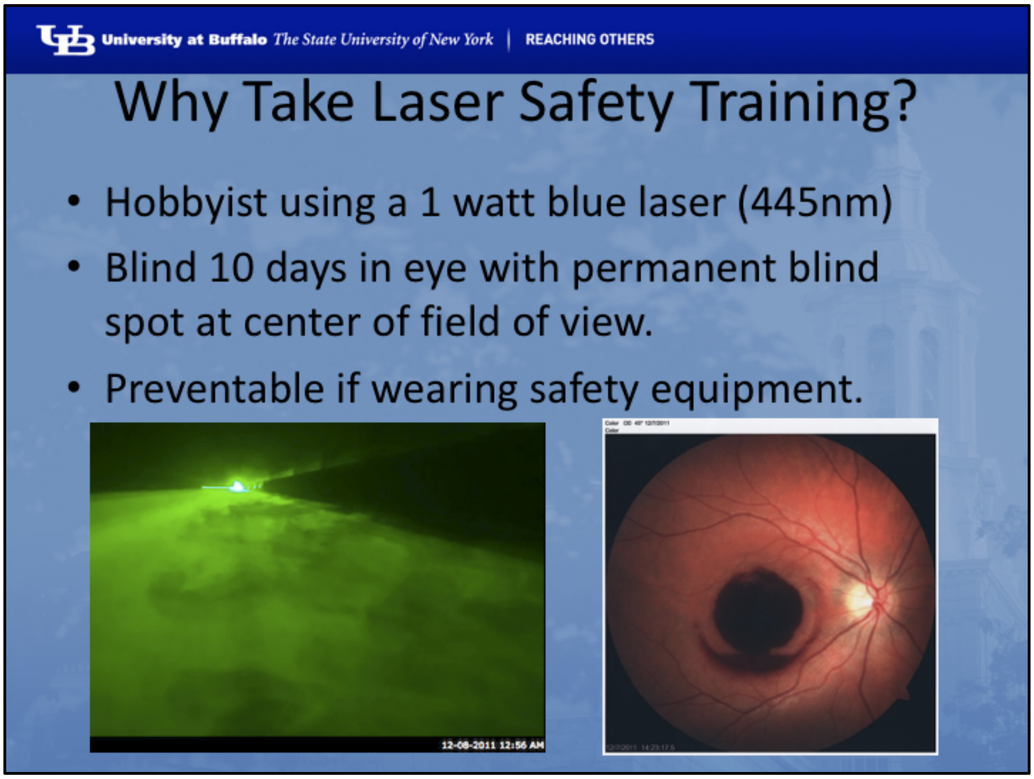
This presentation will touch upon the hazards that one may encounter when working with lasers in a laboratory setting. We will discuss why any laser user must be trained and what organizations regulate laser use.

Many different types of lasers are used throughout the University at Buffalo, so a simple description of lasers, their components, characterizations, and modes will be shown.

The potential hazards associated with lasers are directly related to their classification. Knowing the classification of laser you are using is necessary to determine the safety precautions that should be observed.

Then we will discuss the possible results of an exposure to either the human eye or human skin directly from a laser beam, as well as the possible hazards a laser can create in the lab.

Finally, we will present laser users with the appropriate safety equipment that they should be using when working with lasers.



A laser hobbyist was injured by a 1 watt, 445 nanometer (blue) laser on December 6th, 2011. The hobbyist's laser was on a chair, creating a "liquid sky" effect. This involves having the beam scan or expand into a line, in order to illuminate a thin cross-section of smoke or fog. The laser fell off the chair. As it fell, the beam hit the hobbyist for "about 1 second" in his right eye. He experienced a dark red blur in the center of his vision. There was no pain.

The injury required an unspecified surgery, possibly removal of intraocular blood via needle, to help restore the hobbyists vision. Two days after the surgery, the hobbyist reported a blurry dark circle in his central vision. His doctor told him he would always have a small off-center blind spot, and that his brain would "auto-correct" to fill in the spot.

This incident could have been prevented if the hobbyist used appropriate laser safety equipment to protect his eyes from a direct laser beam exposure and used equipment to secure the laser in a position that would not possibly expose his eye to the beam.

Lasers have been in use for a number of years and they can be found in products that people use everyday. Powerful lasers can also be purchased over the internet quite easily. Because of their abundant use, many people do not anticipate the hazards lasers might present to themselves or others. This is why there are established regulations to govern users in the safe use of lasers.

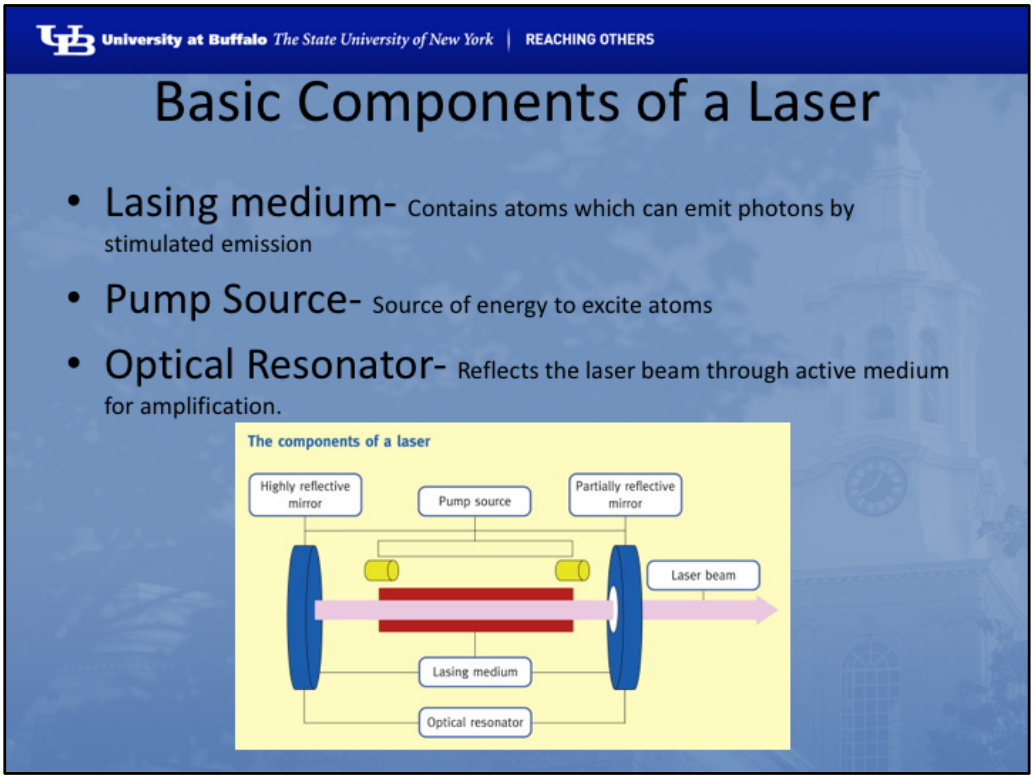
The Laser Institute of America has been the secretariat and publisher of the American National Standard Institute (ANSI) standard since 1986. They have worked with many professionals in research and development, manufacturing, industry, medicine, communications, and the military for years to develop a comprehensive laser safety standard.

The ANSI guidelines for the safe use of lasers is known as ANSI Z136 and has 9 parts. The University at Buffalo strives to comply mainly with Part 1 for general laser safety use.

ANSI can not enforce these standards, but unsafe practices can be regulated by the Occupational Safety and Health Administration, or "OSHA", under the "General Duty Clause". In other words, OSHA inspectors could charge fines to an institution for not meeting ANSI Z136 guidelines.

The Food and Drug Administration or "FDA" has their own standards which mainly apply to the production of lasers. This might apply to a laboratories that may be manufacturing their own lasers.

The University at Buffalo also falls within the jurisdiction of the New York State Department of Labor, who also wrote regulations for laser use under Code Rule 50. Complying with ANSI Z136 satisfies most of the NYSDOL guidelines.



Atoms possess a central nucleus of protons and neutrons surrounded by electrons which encircle the nucleus in different orbitals. Bohr theorized that electrons can jump from one orbit to another, if they are able to absorb or release well-defined amounts of energy in the form of a photon.

Absorption occurs when an electron in its ground-state absorbs a photon and moves to a high-energy orbital leading to atomic excitation.

Spontaneous emission occurs when an electron in the upper level decays spontaneously to the ground-state releasing a photon, which has random phase and direction and whose wavelength depends upon the difference in energy of the two states.

Stimulated emission occurs if a photon collides with an atom in the excited state, releasing a second 'stimulated' photon, identical to the incident photon in its direction, phase, polarization and energy (wavelength).

The components of a laser include:

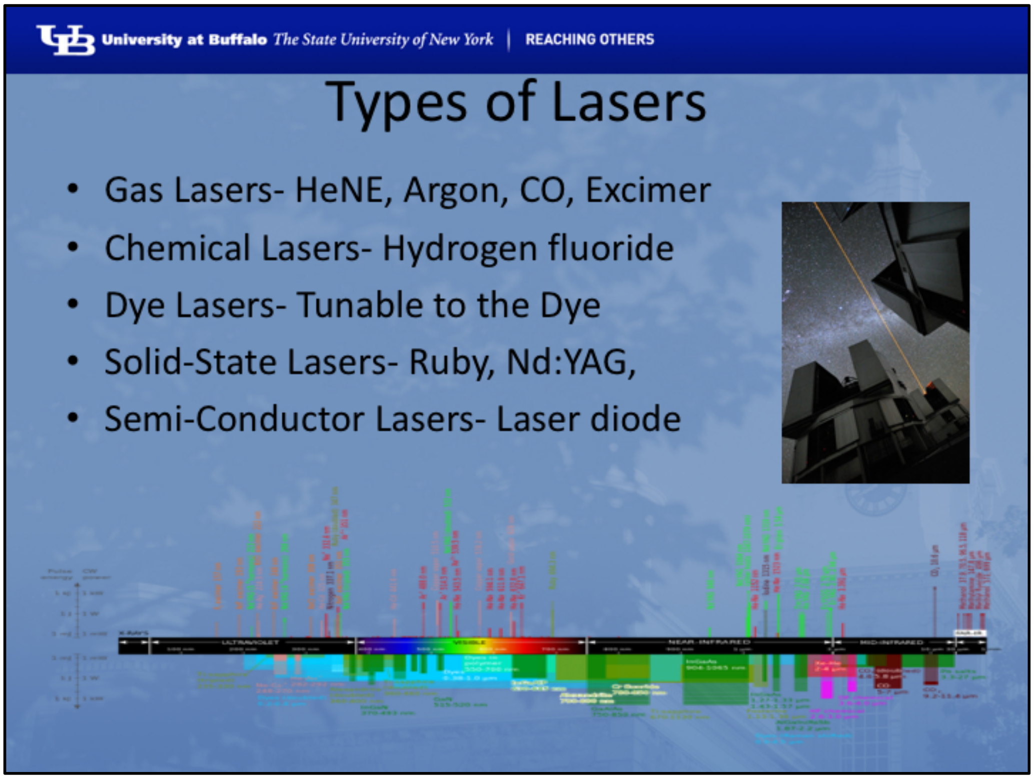
- A lasing medium, capable of undergoing population inversion. This determines the wavelength and gives its name to the type of laser. The medium may be solid gas, or liquid.

- A ‘pump’ or excitation source, which provides the necessary energy. Different kinds of pumps include: optical (flash lamp, continuous arc lamps), electrical discharge, and chemical.

- An optical resonator with two parallel mirrors, which produce repeated travel of photons to and fro through the length of the lasing medium.

- A delivery system in the form of a free beam, optical fiber, or articulated arm.

Within the optical resonator of the laser, a cascade of stimulated emission of photons occurs, resulting in amplification. The majority of atoms must be maintained in the excited state, called population inversion. This is achieved by the input of energy from the pump, which may be continuous (continuous wave laser) or intermittent (pulsed wave laser). These properties form the basis of the name LASER, which is an acronym for Light Amplification by Stimulated Emission of Radiation.



The lasers active medium determines the wavelength of energy that is created by the laser. Some mediums can create beams with two wavelengths and some types of lasers can be tunable.

Typically, lasers are named for their active medium.

A Gas laser is a laser in which an electric current is discharged through a gas to produce coherent light.

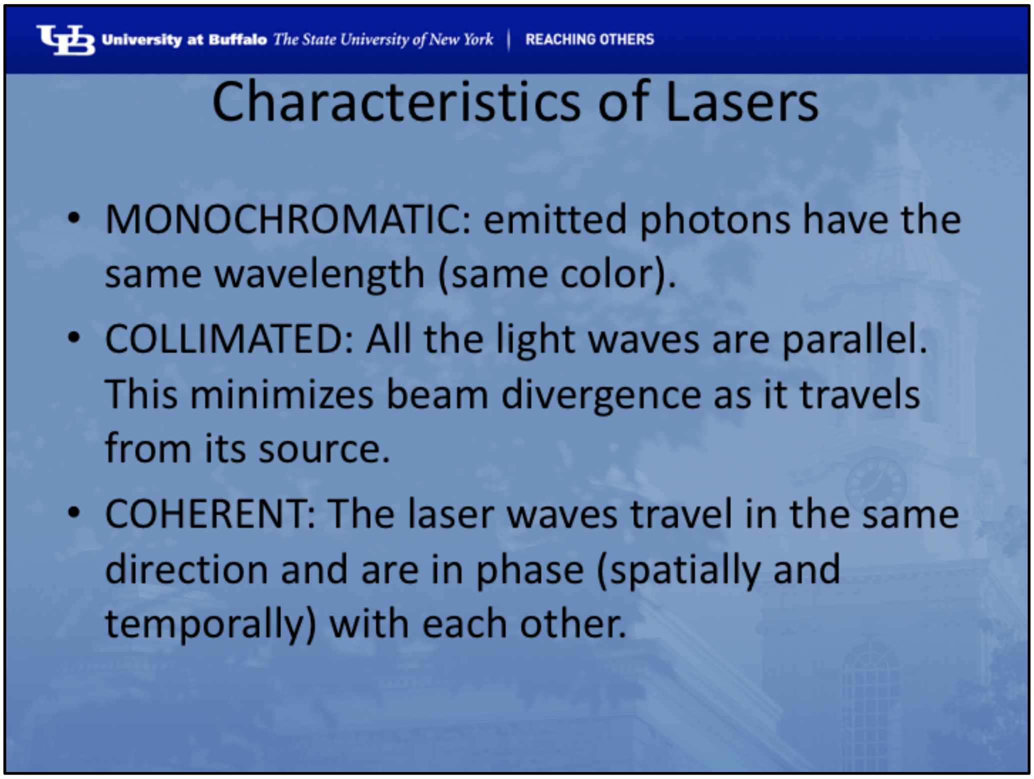
A Chemical laser is a laser that obtains its energy from a chemical reaction. Chemical lasers can reach continuous wave output with power reaching to megawatt levels. They are used in industry for cutting and drilling.

A Dye laser is a laser which uses an organic dye as the lasing medium, usually as a liquid solution.

A Solid-state laser is a laser that uses a gain medium that is a solid, rather than a liquid, such as glass or crystalline "host" material to which is added a "dopant".

A Laser diode, or LD, is an electrically pumped semiconductor laser in which the active laser medium is formed by a p-n junction of a semiconductor diode similar to that found in a light-emitting diode. They can be tuned by varying the applied current, temperature or magnetic field.

This is only a small list of possible laser systems that can produce coherent light energy across the electromagnetic spectrum from the Ultra Violet to the Far Infrared.

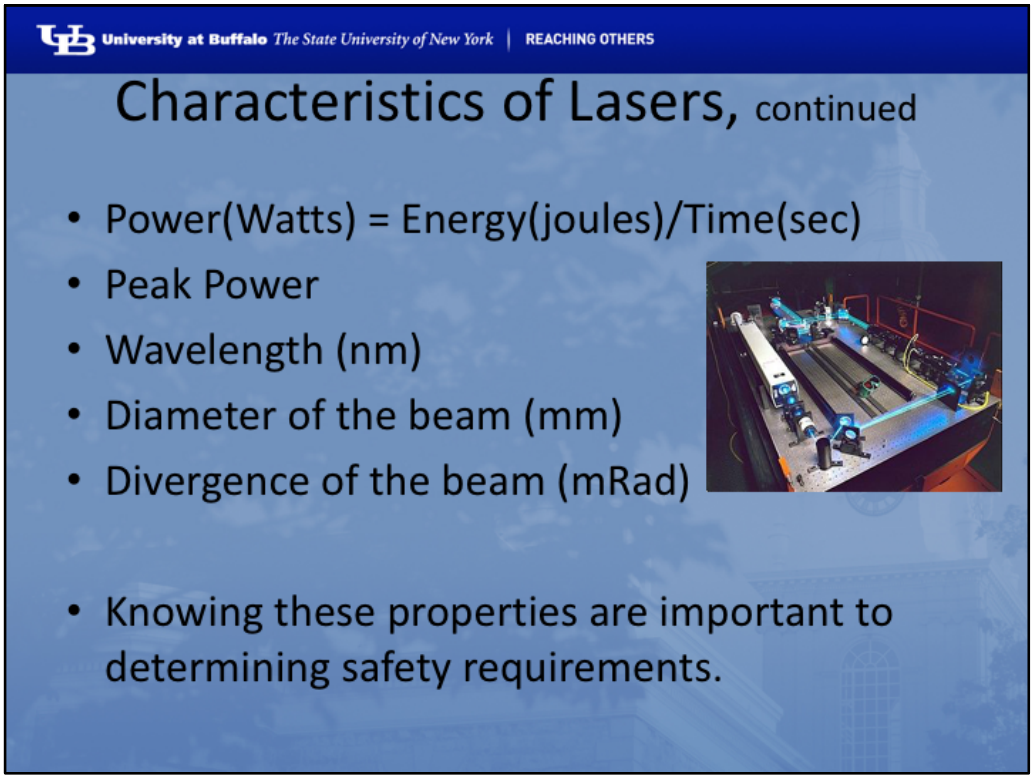


Photons leaving the resonating chamber are different than ordinary light.

The light is monochromatic. The light from a laser typically comes from one atomic transition with a single precise wavelength. This means the laser light has a single spectral color and is almost the purest monochromatic light available.

The light is collimated. Because of bouncing back between mirrored ends of a laser cavity, those paths which sustain amplification must pass between the mirrors many times and be very nearly perpendicular to the mirrors. As a result, laser beams are very narrow and do not spread very much.

The light is coherent. Different parts of the laser beam are related to each other in phase. These phase relationships are maintained over long enough time so that interference effects may be seen or recorded photographically. This coherence property is what makes holograms possible.. This coherence property is what makes holograms possible.



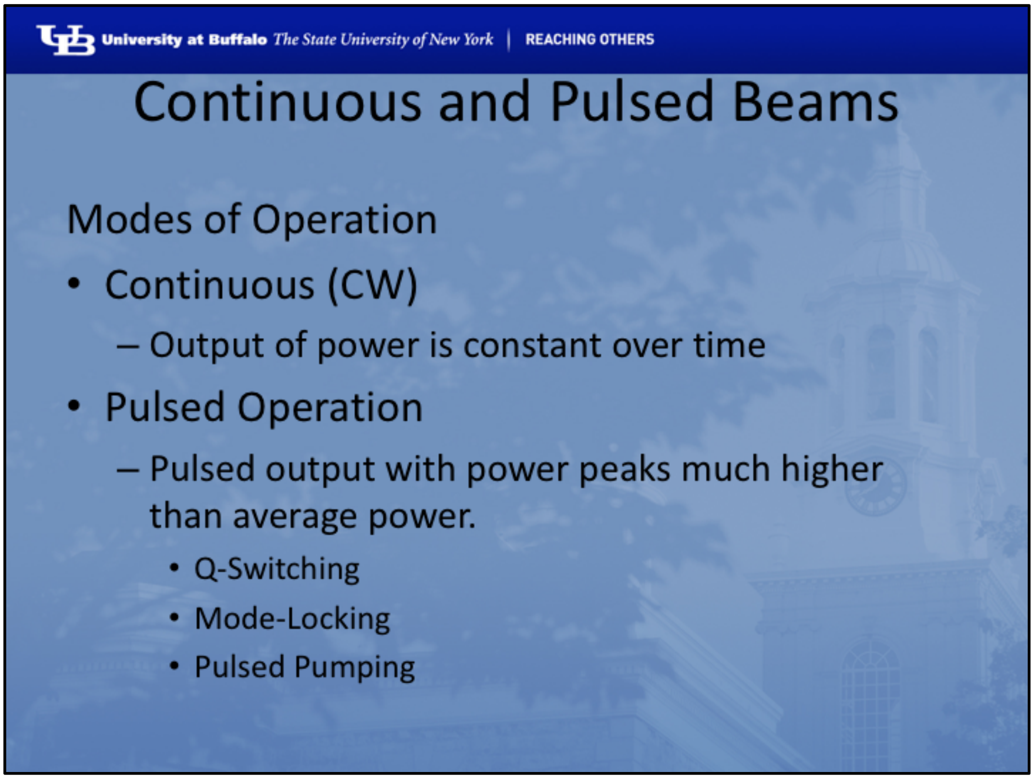
The characteristics of a laser can be described by these terms listed here. The characteristics of the output of the laser will help to determine its interaction with a target and help to determine safety requirements needed to operate the laser safely. There properties must be recorded to register a laser with the University at Buffalo.

The power is the rate at which energy is emitted by a laser and is described in units of watts. The greater the power of the laser, the more energy that will be delivered to the target and the greater the possibility of injury.

Peak energy is a term used to describe the energy produced by a pulsed laser, where the time energy of the laser is delivered to a target over a short section of a pulse

Lasers produce electromagnetic radiation (light) that typically propagate at a uniform wavelength. The wavelength is measured in nanometers. Laser beam wavelengths can vary from the invisible (near-ultraviolet to far-infared) spectrum and includes the visible light spectrum.

The diameter of the beam is measured at the aperture of the laser. Typically, once the beam leaves the aperture, the laser beam will begin to slowly spread in a widening column as the distance from the aperture increase. This is known as the divergence of the beam.



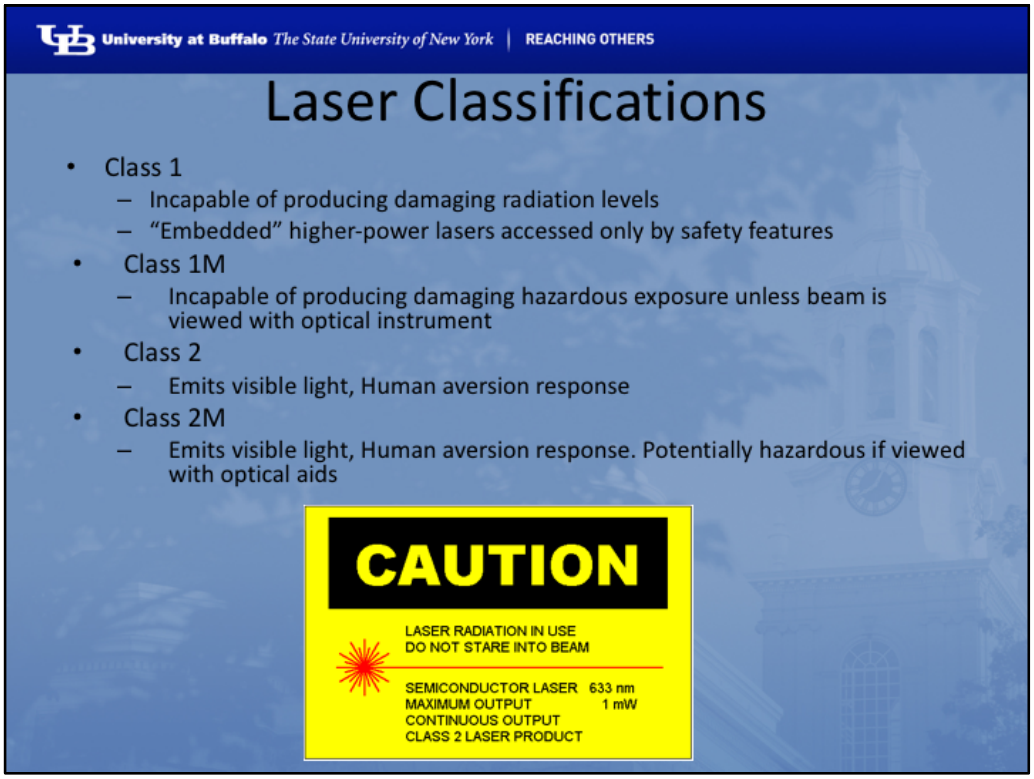
There are different modes in which lasers may produce laser beams. A Laser that can emit laser light continually without any fluctuation in peak energy is know as a Continuous Wave laser, or CW. The CW laser has an output of power that is constant over time.

Depending on the lasing medium, laser light may not be produced at a constant power because the medium may be damaged due to over heating. These types of lasers discharge their energy in short bursts and then excite the lasing medium again.

Q-switched laser, the population inversion is allowed to build up, then the pump energy stored in the laser medium has approached the maximum possible level, the devise is allowed to begin lasing which rapidly obtains the stored energy in the gain medium.

Mode-locked laser is capable of emitting extremely short pulses on the order of tens of picoseconds down to less than 10 femtoseconds.

Pulsed pumping uses a source that is pulsed to pump the lasing material.



Lasers are rated based on their power and their ability to result in injury to personnel. The ranking goes from Class 1, the safest, to Class 4 where serious eye and skin injuries may occur.

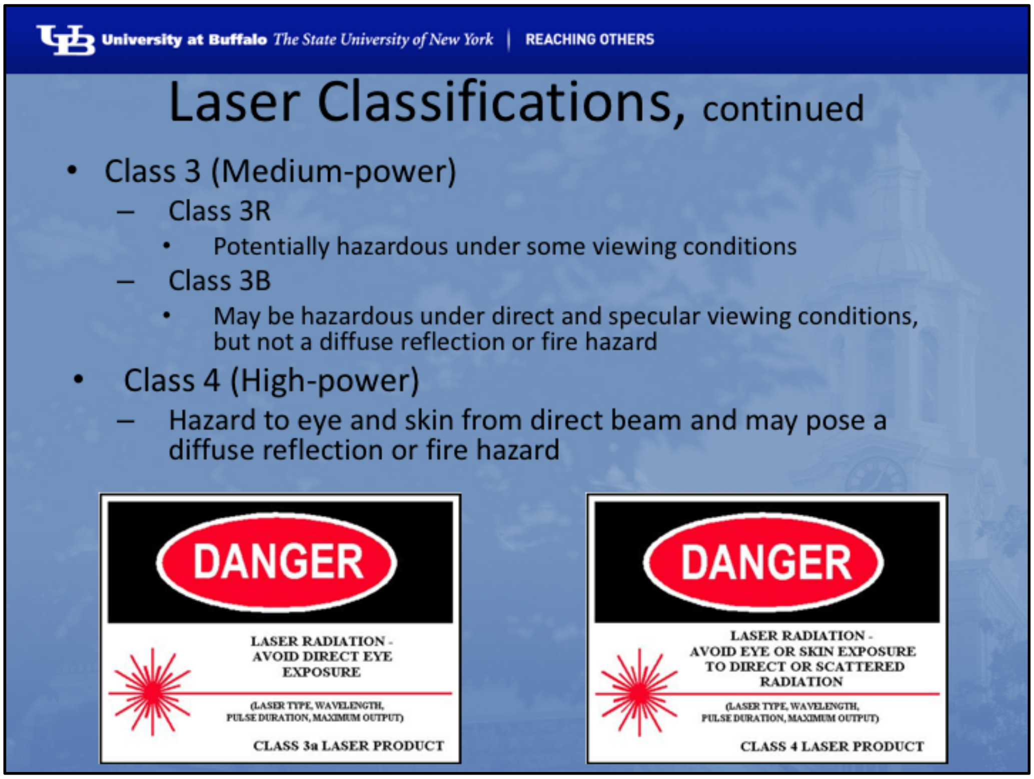
The manufacturer of lasers and laser products are required to certify that a laser is designated as one of four general classes, or risk categories, and label them accordingly.

Class 1- Lasers are incapable of producing damaging radiation levels during operation, and exempt from any control measures. Most Class 1 lasers may also have embedded higher powered laser that can only be accessed if important safety features are deliberately bypassed. If that is the case the system reverts back to original laser classification.

Class 1M- Incapable of producing damaging hazardous exposure unless beam is viewed with optical instrument such as an eye-loupe or a telescope. Control measures should be in place to prevent potentially hazardous optically aided viewing.

Class 2- Laser emits in the visible portion of the spectrum (400-700nm). Eye protection is normally afforded by the human aversion response (Blinking or turning head away) which is 0.25 seconds.

Class 2M- Laser emits visible light. Eye protection is normally afforded by the human aversion response. Potentially hazardous if viewed with optical aids. Control measures should be in place to prevent potentially hazardous optically aided viewing.



Class 3- Lasers potentially hazardous under direct and specular (mirror or lens) reflection viewing conditions, but are normally not a diffuse (not mirror like) reflection hazard or fire hazard.

Two subclasses:

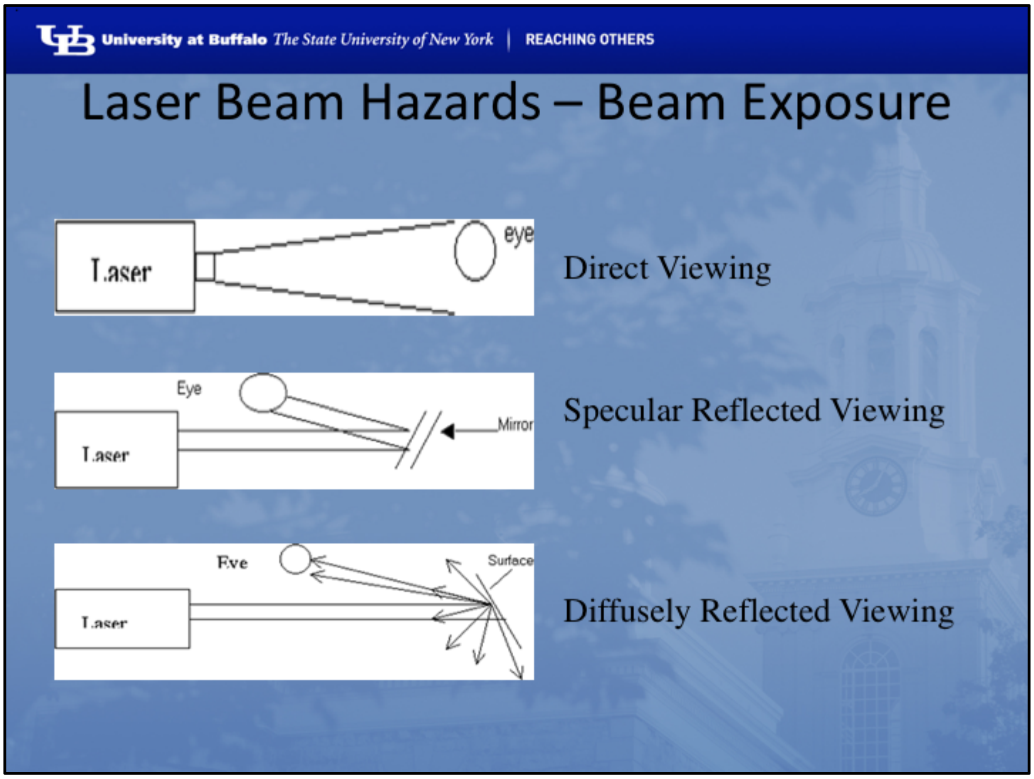
Class 3R- Lasers potentially hazardous under direct and specular (mirror or lens) reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small.

Class 3B- May be hazardous under direct and specular viewing conditions, but not a diffuse reflection or fire hazard.

Class 4- Lasers systems that are a hazard to eye and skin from direct beam and may pose a diffuse reflection or fire hazard. May also produce laser generated airborne contaminants (plumes) and hazardous plasma (from cutting).

In the laser laboratory setting, all personnel should be aware of the hazards that working with a laser may present.

A laser produces an intense and highly directional beam of light. If directed, reflected, or focused upon an object, laser light will be absorbed. This will raise the temperature of the surface and/or interior of the object, potentially causing an alteration of deformation of the material. The human body is vulnerable to the output of certain lasers, and under certain circumstances, exposure can result in damage to the eye and skin.



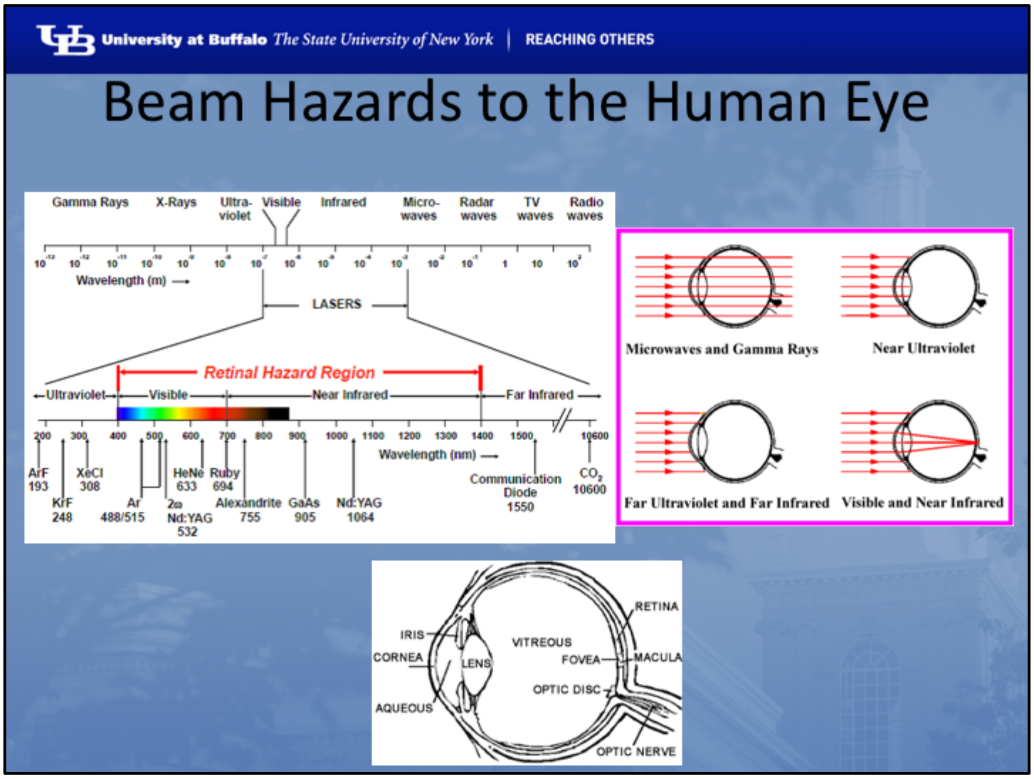
Lab personnel should be aware of beam operation and beam paths. Never intentionally place eyes or limbs in the path of the beam. Even reflected light can cause injury. Mirrors, lens, and viewing aids should be carefully used near lasers. Diffuse (non-mirror like) surface reflections are less likely to cause injury, but around high-powered laser system, injury is possible.

Exposure to beam path-

Intrabeam viewing of direct (primary) beam. This type of viewing is most hazardous. Note that the diagram also illustrates that a laser beam may diverge as it propagates.

Intrabeam viewing of a specularly reflected (secondary) beam from a flat surface reflector.

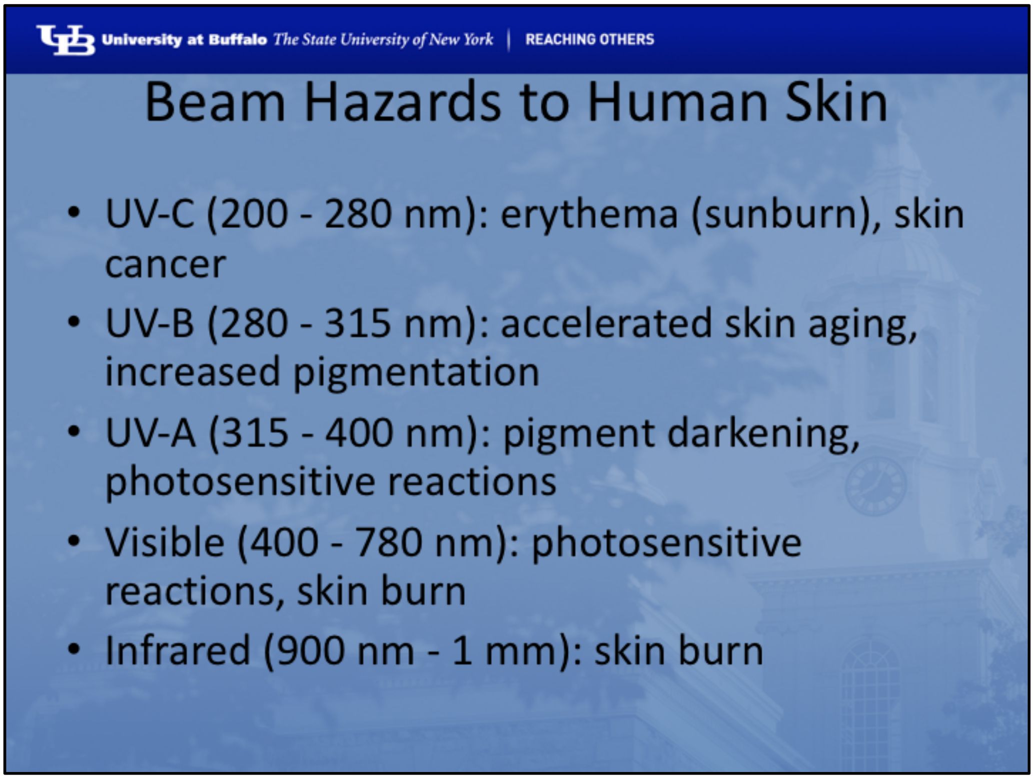
Diffuse viewing of a diffusely reflected (secondary) beam from a rough surface in which a collimated beam is reflected in all directions.



When working with lasers, the human eye is almost always more vulnerable to injury than human skin. Parts of the human eye are more susceptible to certain wavelengths of laser light. For instance, in the far-ultraviolet and far-infrared regions of the optical spectrum, the Cornea absorbs the laser energy and may be damaged. This type of exposure to the Cornea could cause Photokeratitis and Corneal Thermal Burns.

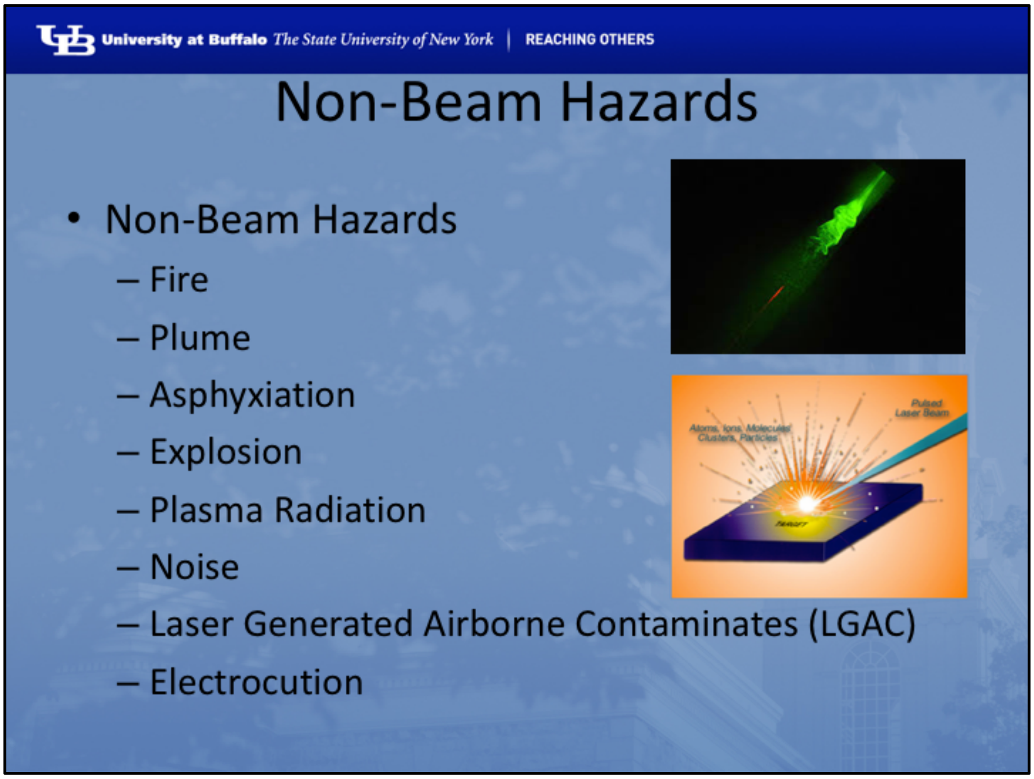
At wavelengths in the near-ultraviolet and in the near-infrared region, the Lens of the Eye may be vulnerable to injury. Damage to the lens of the eye can cause Cataracts.

The greatest concern is laser exposure is in the retinal hazard region of the optical spectrum (approximately 400nm to 1400nm and including the entire portion of the optical spectrum). Within this spectral region, collimated laser rays are brought to focus on a very tiny spot of the Retina and under certain conditions can cause great damage such as Scotoma (Blind Spots).



The human skin can be at risk from laser exposure. Exposure of the skin to high power laser beams (1 or more watts) can cause burns. At under the five watt level, the heat from the laser beam will cause a flinch reaction before any serious damage occurs. The sensation is similar to touching any hot object, you tend to pull your hand away or drop it before any major damage occurs. With higher power lasers, a burn can occur even though the flinch reaction may rapidly pull the affected skin out of the beam. These burns can be quite painful as the affected skin can be cooked and forms a hard lesion which takes ages to heal.

Like the human eye, the human skin can have a different reaction to exposures of laser emissions at various wavelengths.

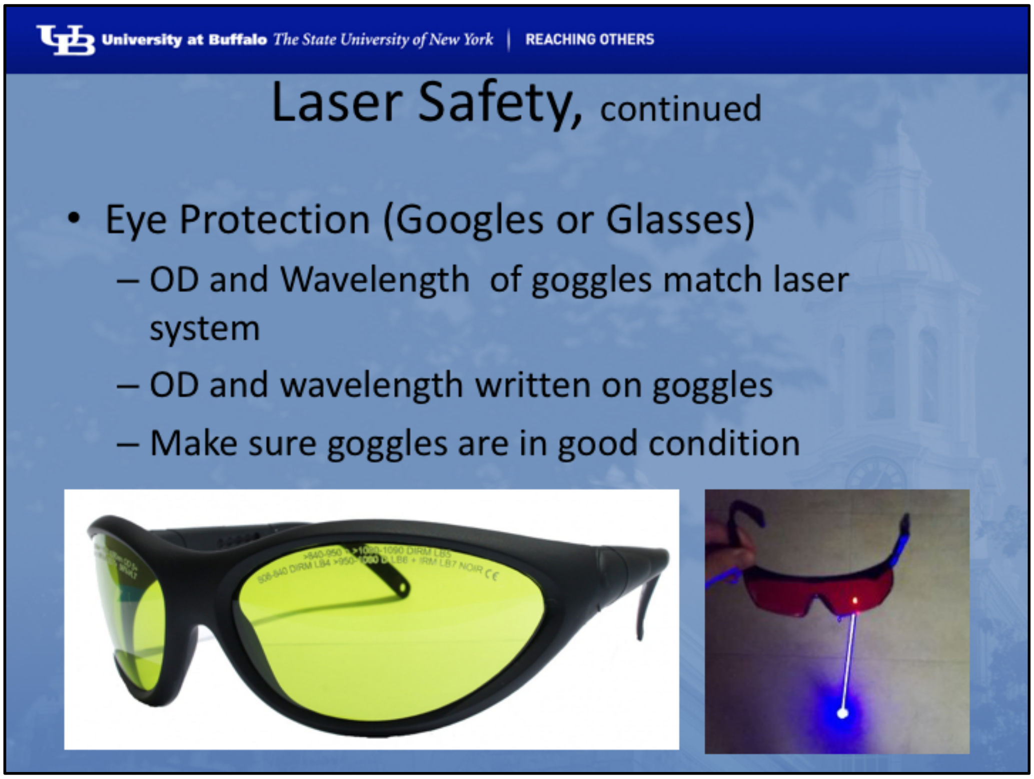


In addition to the direct hazards to the eye and skin from the laser beam itself, it is also important to address other hazards associated with the use of lasers. Non-beam hazards can be caused by the target of the laser system or by just not operating the laser system as intended.

It is important to be aware of what will happen to the targeted material and prevent any unintended consequences. Depending on the power of the laser, and if the target material is unable to absorb all the energy that the laser delivers, there could be a possibility that the material could explode, melt, or vaporize. Laser users should be aware of the reaction that is intended to happen.

Some laser systems operate using a high voltage power supply. The laser systems should be used as specified by the manufacturer. Systems components (cords, pumps, cooling systems) should also be checked on a regular basis and maintained for proper operation. Failure to due so could result in accidental electrocution or explosions.

Any lab personnel working with laser systems should take precautions and learn the effects of using a laser on other materials before proceeding with a procedure.



How can we protect the eye?

Lab personnel must wear appropriate eye protection when working with a laser. Eye protection is necessary for anyone working with a class 3b or 4 laser. Appropriate eye wear is determined by the laser system you are using. Eye protection is specific to the wavelength of the laser beam and the Ocular Density (OD) is calculated from the power of the laser beam.

The OD (Ocular Density) and wavelength, for which the lens will protect against, must be clearly written on the frames. Lens designed to stop 523nm wavelength light will not stop 1064nm laser beam. Goggles or glasses with an OD of 4 will not stop a beam from a laser rated for OD of 7. Be sure your safety equipment is compatible with the system you are working with.

It is also important to make sure the lens are intact and in good working condition. Cracks in the lens or loose fitting straps or frames will lead to accidental exposures.

Good Lab Practices $

Use appropriate equipment: $

- Optical tables are designed to support systems used for optics and engineering. The surfaces of these tables are designed to be very rigid so that the alignment of optical elements remains stable over time.

- Beam traps and Beam Stops are common laser lab safety devices that are designed to absorb a laser beam's energy.

- Laser rated curtains help protect others in the lab.

Beam Placement:

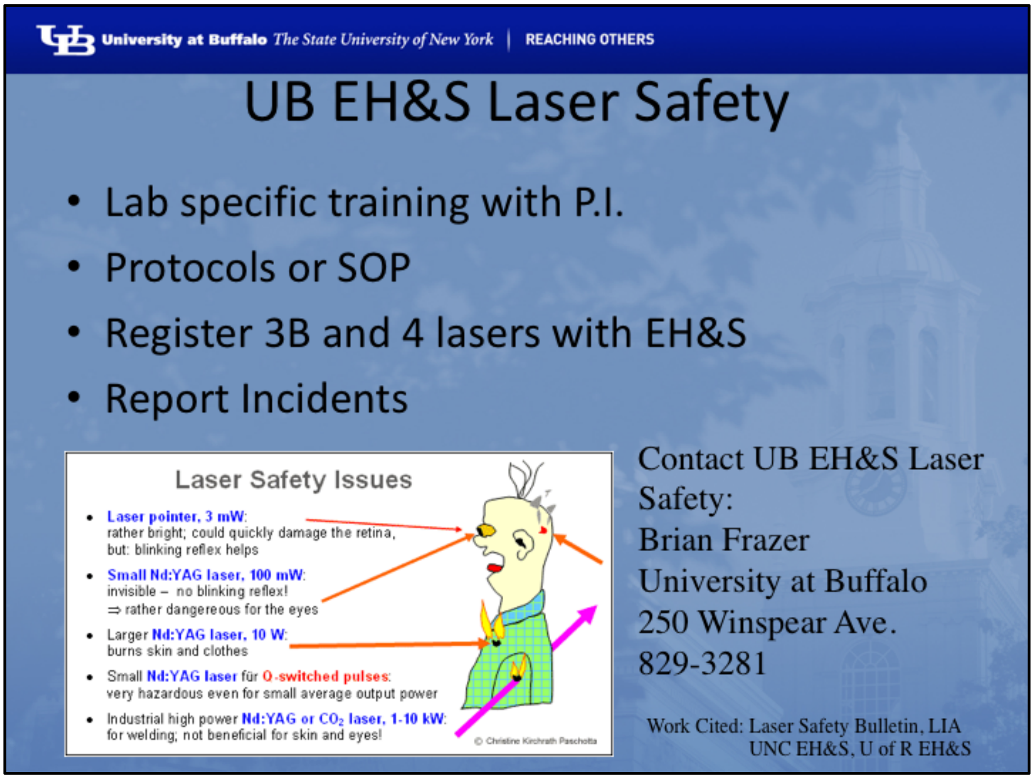
Laser Beams should never be placed at or near eye level. Adjust table heights to below eye level and never use your unprotected eye to align a target to prevent accidental exposures.

Nominal Hazard Zone:

Laboratories at the University at Buffalo, which operate lasers, are generally small enough to have the entire room be considered the Nominal Hazard Zone. The nominal hazard zone describes the space within which the level of the direct, reflected or scattered radiation during operation exceeds the applicable MPE (Maximum Permissible Exposure). This means that personnel working within the lab must be trained and aware of laser operation and safety procedures.

Signage

Use appropriate signage to warn personnel outside the NHZ that lasers are in use.

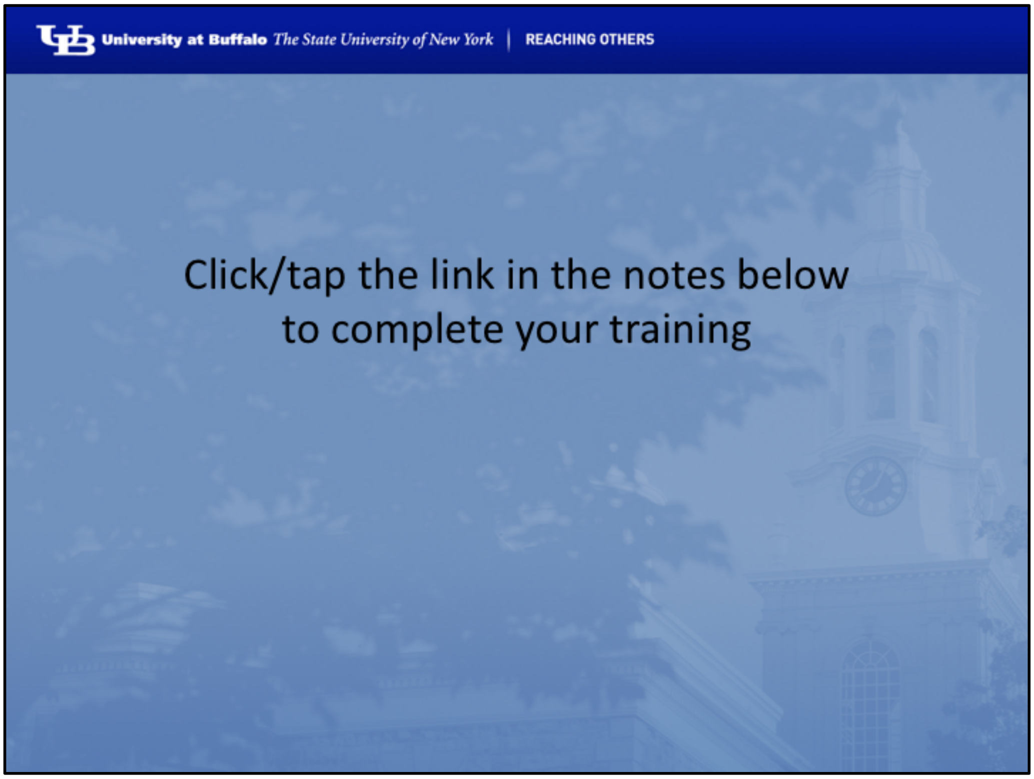


All personnel working with lasers must have lab specific training by the Principle Investigator. It is the PI's responsibility that the machines are working appropriately and that all safety equipment is provided.

According to the ANSI standard, PI's should write a protocol or Standard Operating Procedure (SOP) for each laser that may be used in their lab. Protocols are a good training tool and reference for lab personnel who may be using a laser without direct supervision.

All Class 3B and Class 4 lasers at UB must be registered with EH&S. If you are unaware of you lasers registration, please contact Brian Frazer EH&S at 829-3281.

Please report all laser related incidents to EH&S.



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