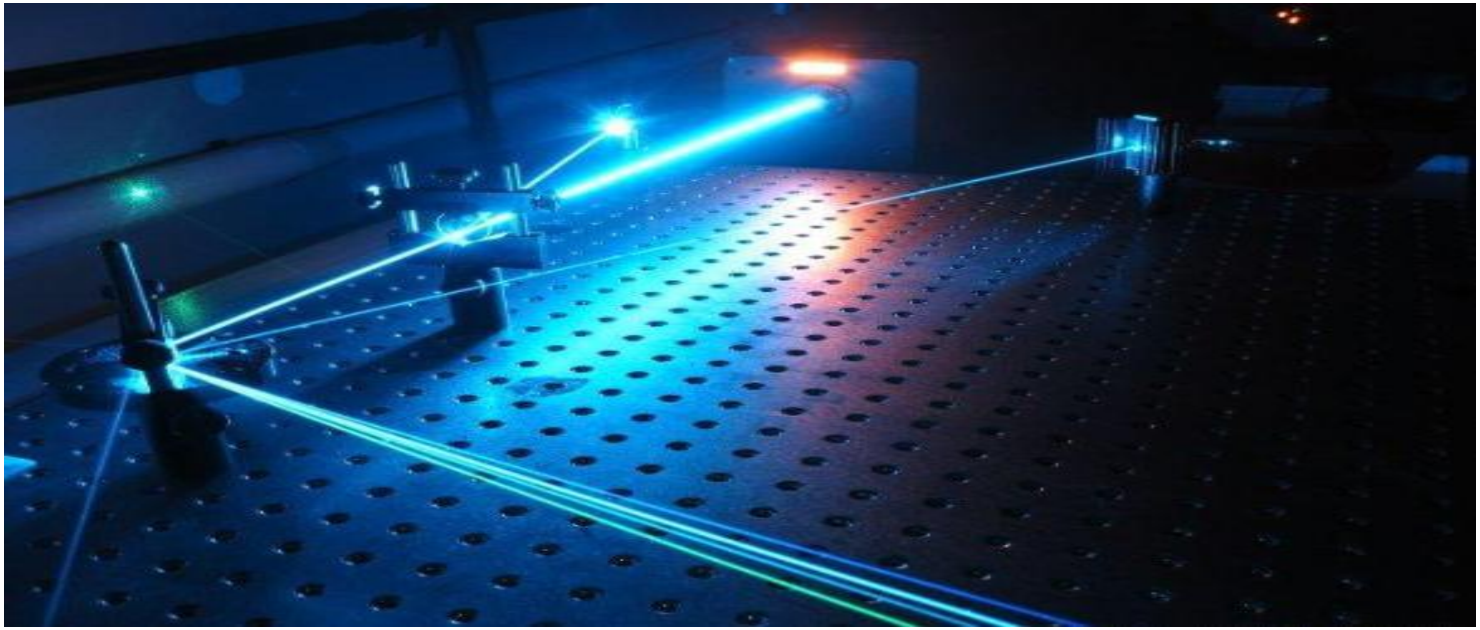
Laser

- Is an acronym of Light Amplification by Stimulated Emission of Radiation
- Is a device that produces radiant energy predominantly by stimulated emission
- The light emitted by a laser is non-ionizing, electromagnetic radiation.



LSU Health New Orleans

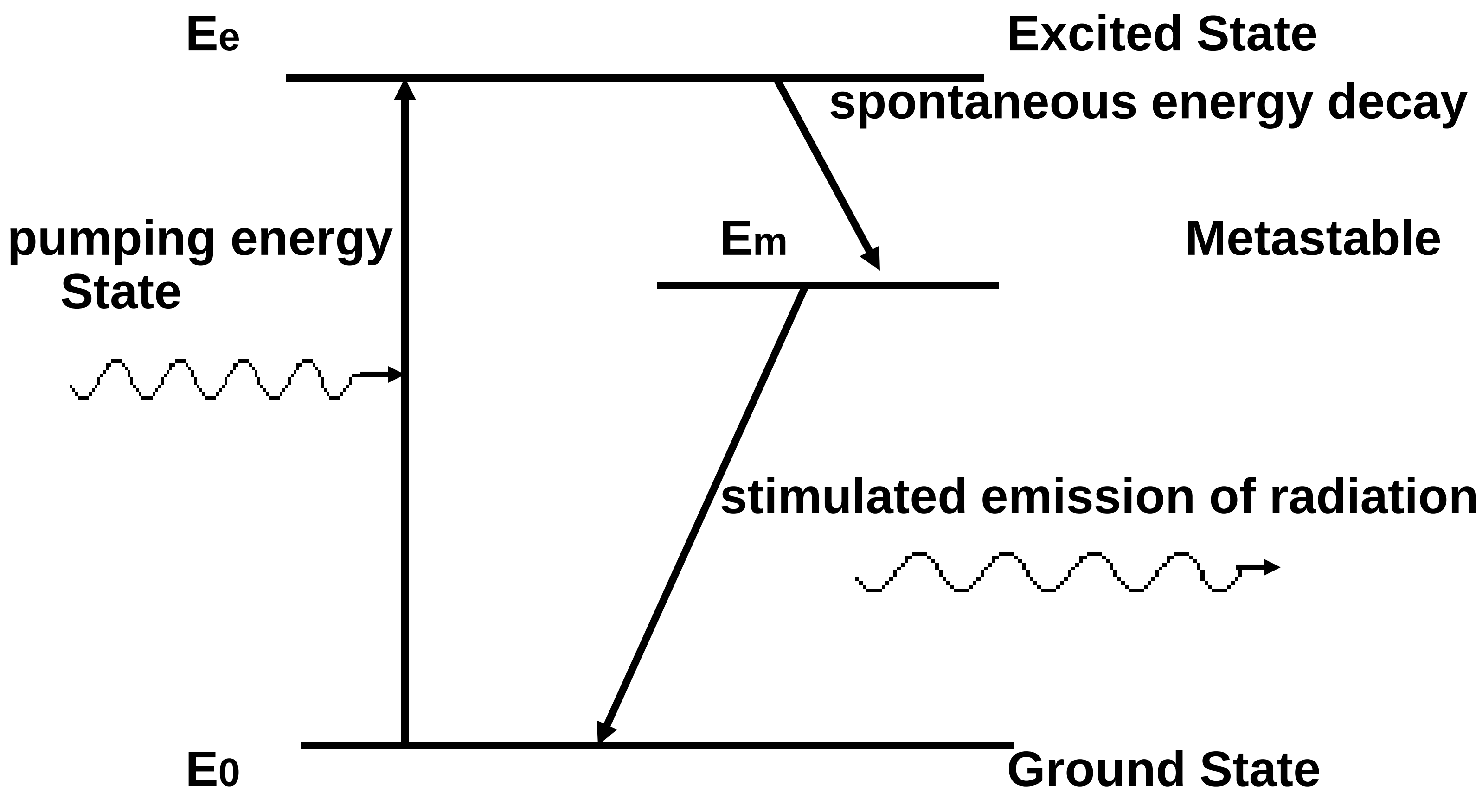
Laser

- Types of Laser
  - Continuous wave (CW) laser
    - Operates in a continuous output for a period ≥ 0.25 secs rather than a pulsed mode
  - Pulsed laser
    - Delivers its energy in the form of a single pulse or a train of pulses with duration of a pulse ≤ 0.25 secs
  - Q-switched laser
    - Emits short (10 nsecs – 250 nsecs) high-power pulses by means of a Q-switch

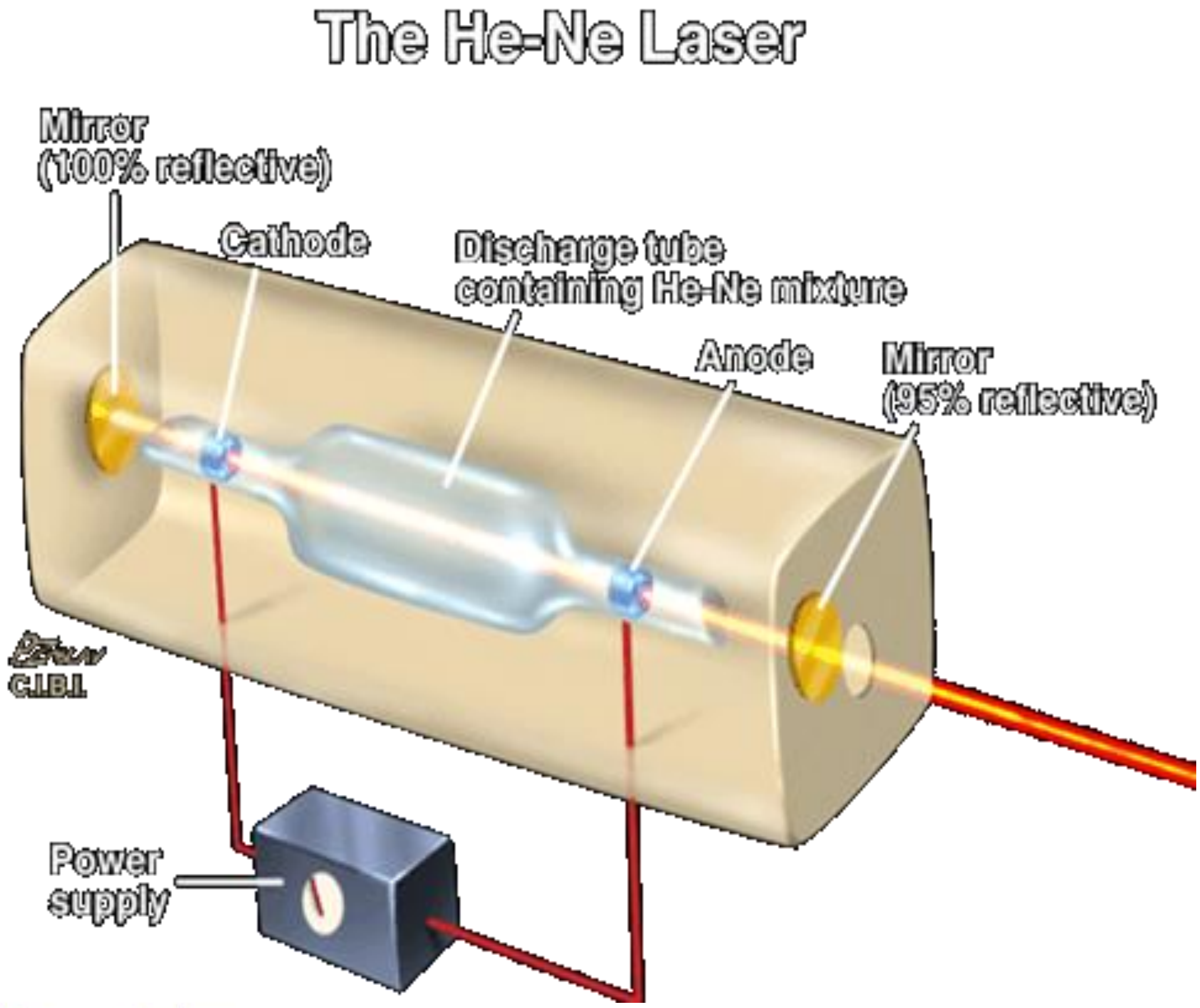
Stimulated Emission

- Albert Einstein theorized and proposed that a photon passing near an excited electron of the same energy would cause the approached electron to return to its ground state and in so releasing a photon of light.
- Two identical photons would exist and travel as a coherent pair in the exact same direction.
- This mechanism would be repeated over and over again as each of the triggered photons approached other excited electrons.

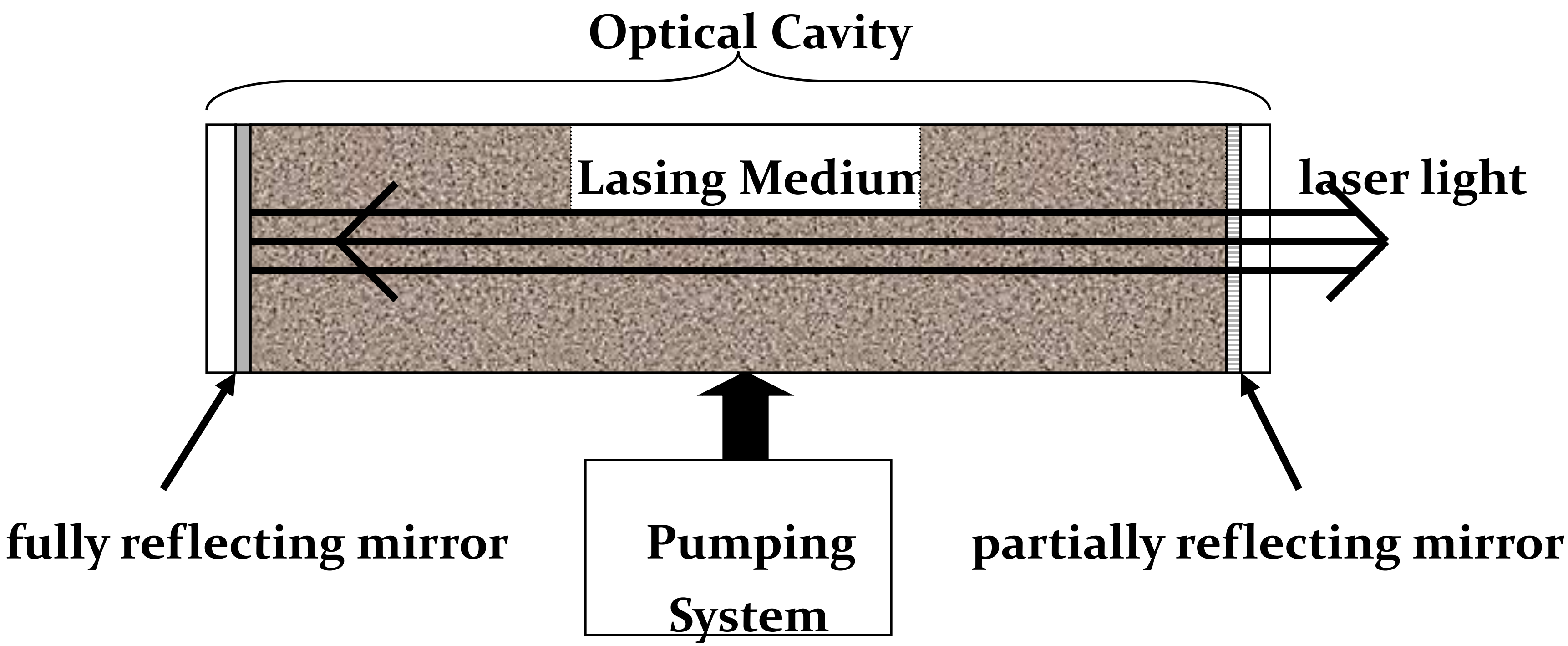
Stimulated Emission



Fundamentals of Laser Operation



Laser Basic Components



Laser Basic Components

- Lasing Medium (Active Medium)
  - Have suitable energy levels
  - Have at least one metastable state long enough for a population conversion to occur
  - More electrons in the excited state than in the lower state to which these electrons decay when stimulated emissions occur

Laser Basic Components

- Lasers are commonly designated by the type of lasing medium employed.
  - solid state
  - gas
  - excimer (<u>excited</u> & <u>dimers</u>)
  - dye
  - semiconductor (diode)
- <u>The wavelength from a laser depends on the medium being excited.</u>

LSUHealthNewOrleans

Laser Basic Components

- Pumping System (Excitation Mechanism)
  - Raise electrons in the lasing medium to a higher energy level
  - Increase the number of electrons trapped in the metastable state to achieve the population inversion
  - Optical pumping
  - Electron collision pumping
  - Chemical pumping

Laser Basic Components

- Optical Cavity (Optical Resonator)
  - Contain the lasing medium to be excited and mirrors to redirect the emitted laser photons back along the same path
  - One mirror is placed at each end of the lasing medium (a high reflectance mirror and an output coupler).
  - Laser beam passes through the lasing medium many times and the number of the emitted laser photons is amplified at each passage.

Laser Generation

1) Atoms of the lasing medium become “excited” by an energy pumping system.
2) Excited atoms undergo de-excitation promptly and then stay at metastable state.
3) Some atoms at metastable state eventually drop back to their ground state and radiate photons.
4) These photons pass other atoms at metastable state and cause stimulated emission.

Laser Generation

5) A chain reaction of photon amplification starts. The emitted photons are of the same wavelength, phase, and direction.
6) The photons reach the end of the lasing medium and are reflected along the optical cavity between the mirrors where the chain reaction continues.
7) A portion of the photons arrives at the partially reflecting mirror and emerges as a laser beam.

Laser Characteristics

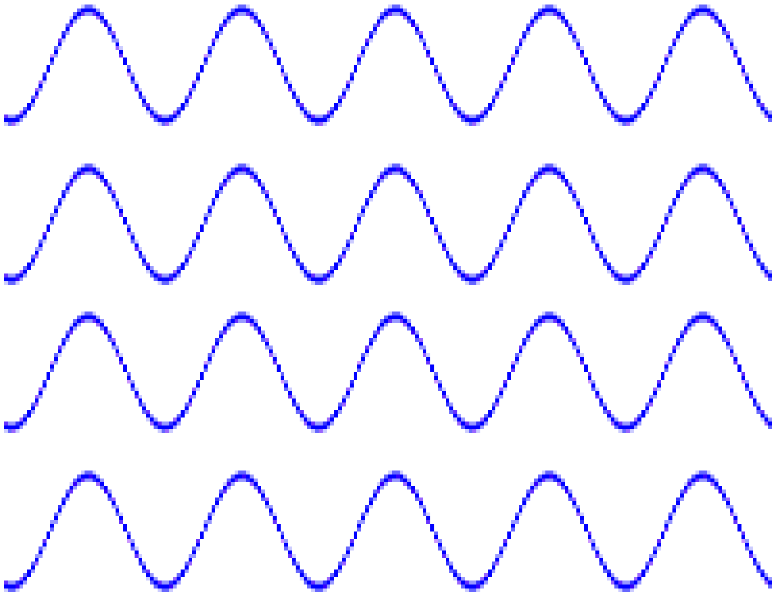
- Monochromatic
  - Laser beams are made up of light waves of identical wavelength (in a very narrow wavelength band).
  - Since each wavelength represents a specific color, the laser beam is monochromatic.
  - Not all lasers generate only one monochromatic wavelength. Depending on the atomic structure of the lasing medium, some lasers can generate more than one narrow wavelength band of color, simultaneously or one at a time.

Laser Characteristics

- Directional
  - Laser beams do not expand as fast as ordinary light.
  - Ordinary light spreads out in all directions and fades quickly as it travels.
  - The light waves in a laser beam all travel in the same direction forming a straight, intense, and nearly parallel “rod” of light, even over long distances.

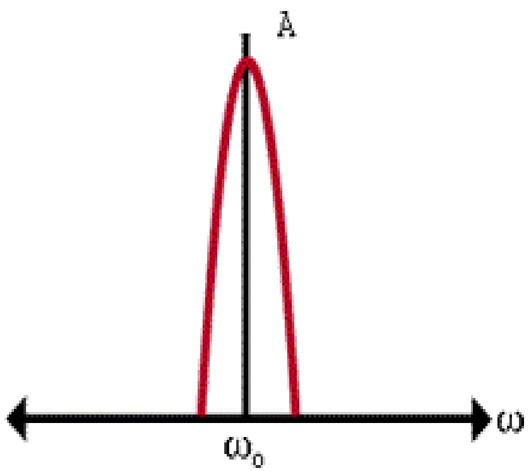
Laser Characteristics

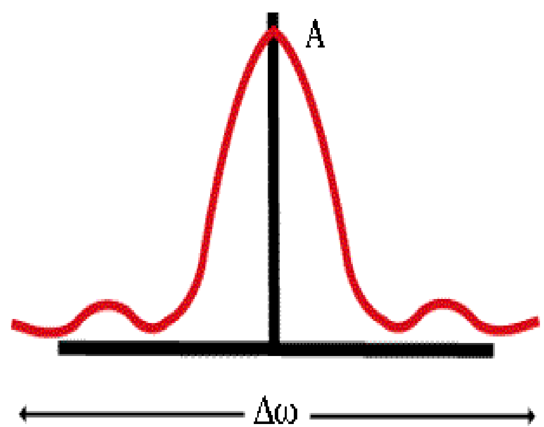
- Coherent
  - All the light waves are identical and in phase



Laser Characteristics

- Temporal coherence
  - How coherent a beam is in regards to its spread of frequencies ($\Delta\omega$)
  - The smaller the spread, the greater the coherence of the beam

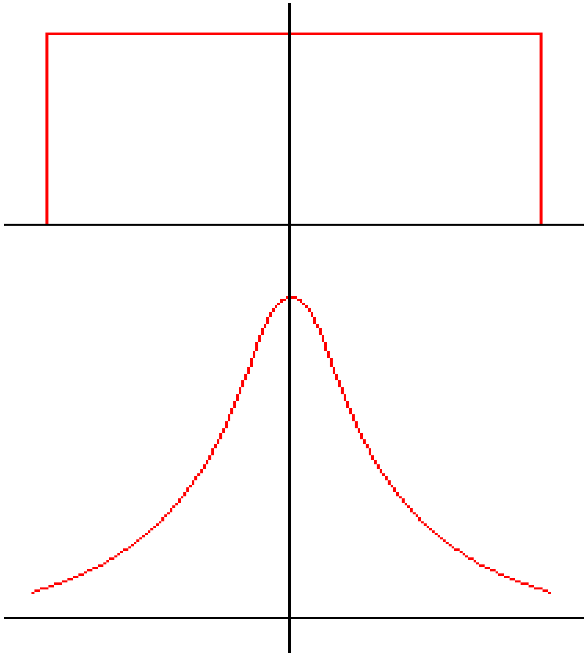




LSUHealthNewOrleans

Laser Characteristics

- Beam Profile
  - Rectangular profile
  - Gaussian profile

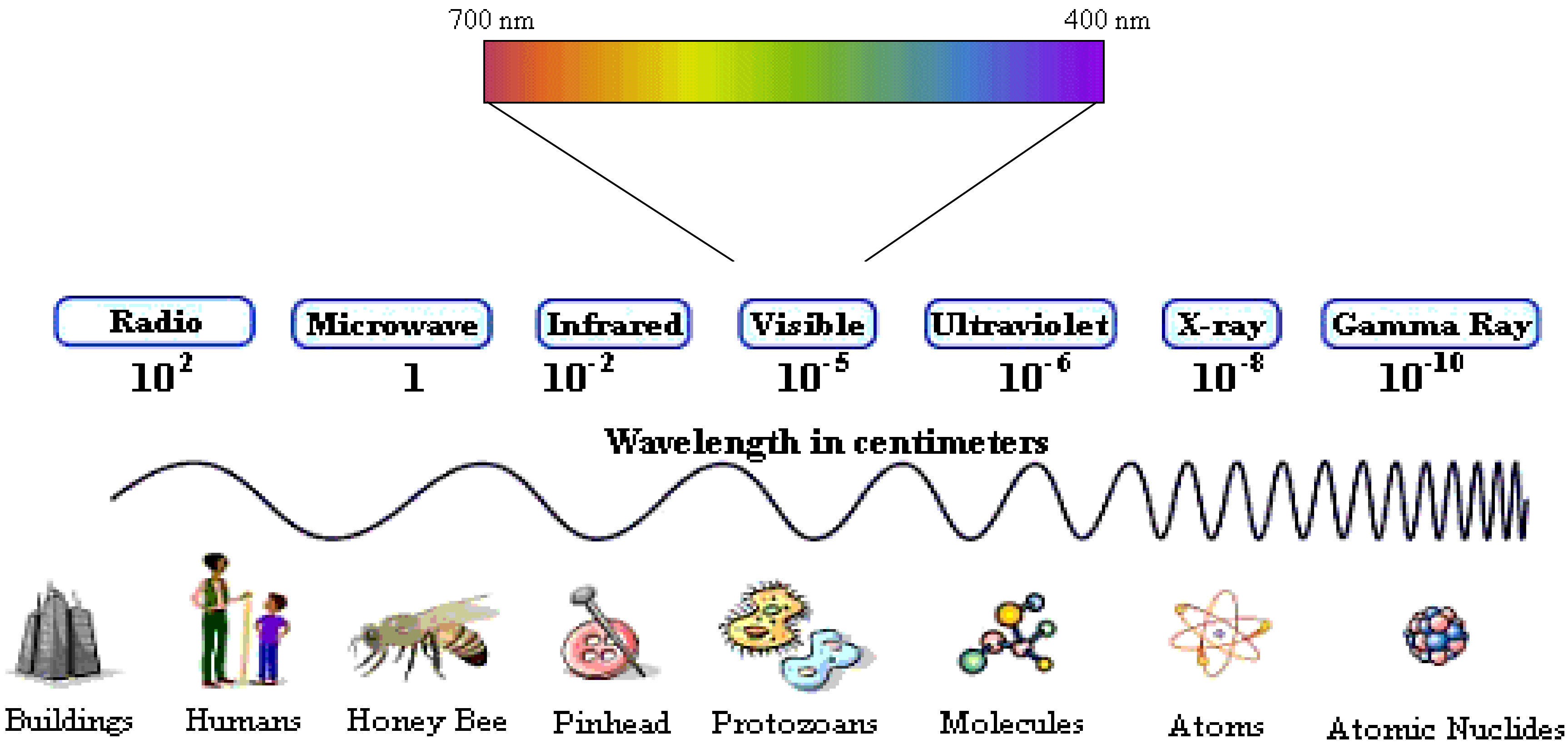


beam diameter
relative irradiance

Laser Characteristics

- Based on ANSI Z136.1 Safe Use of Lasers
  - Beam diameter (a): the distance between diametrically opposed points in that cross-section of a beam where the power per unit area is 1/e times the peak power per unit area
  - Beam divergence (ϕ): emergent beam divergence is the increase in the diameter of the laser beam with distance from the exit aperture, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/e times the maximum value.

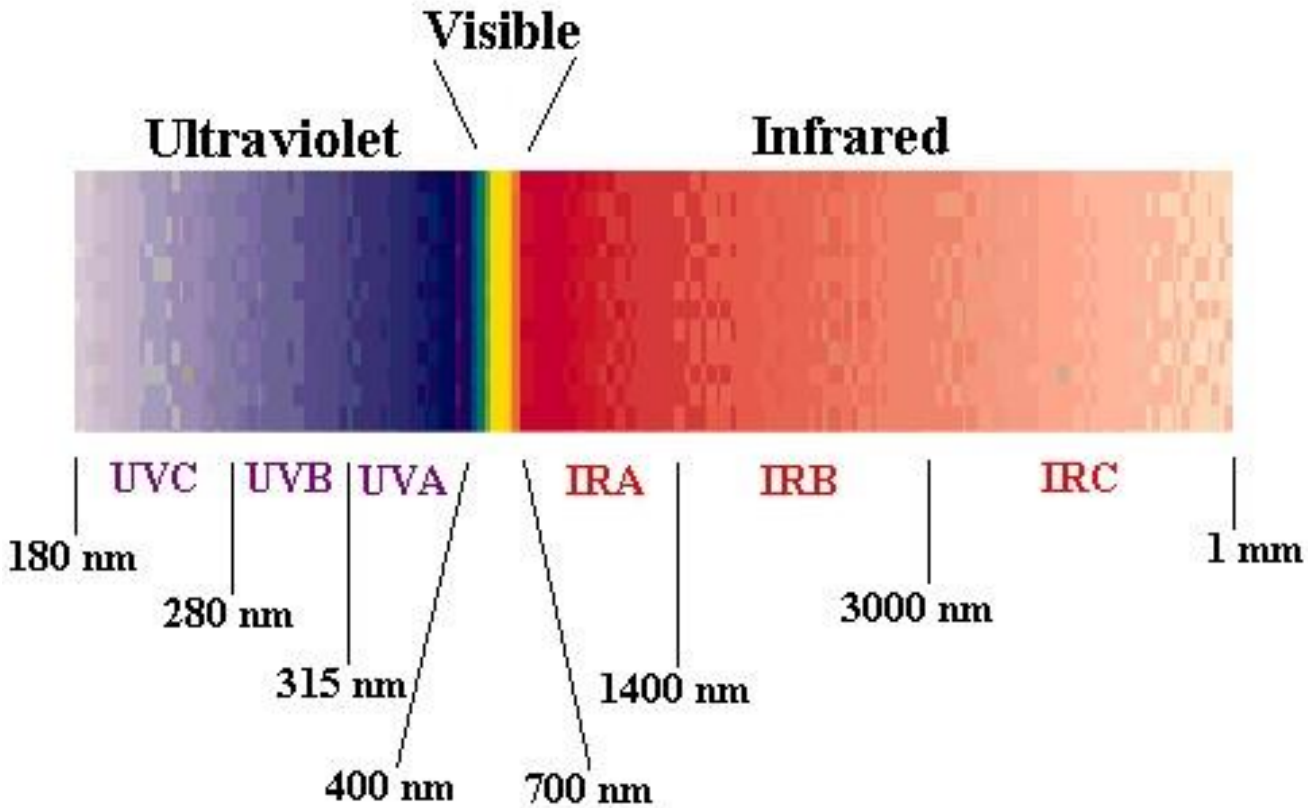
Electronmagnetic Spectrum



Electronmagnetic Spectrum

Region	**Wavelength (cm)**	**Energy (eV)**
Radio	> 10	$< 10^{-5}$
Microwave	$10 – 0.01$	$10^{-5} – 0.01$
Infrared	$0.01 – 7\times10^{-5}$	$0.01 – 2$
Visible	$7\times10^{-5} – 4\times10^{-5}$	$2 – 3$
Ultraviolet	$4\times10^{-5} – 10^{-7}$	$3 – 10^{3}$
X-rays	$10^{-7} – 10^{-9}$	$10^{3} – 10^{5}$
Gamma rays	$< 10^{-9}$	$> 10^{5}$

Laser Spectrum (ANSI Z136.1)



LSU Health New Orleans

Biological Interaction with Laser

- Photochemical Effect
  - The transfer of light energy to chemical energy
    - Photons from a laser have sufficient energy to break chemical bonds between molecules at the target site.
    - Photon energy in excess of that needed for bond breakage ejects molecular fragments from the target site at supersonic velocity.
    - Since the etch depth per pulse is predictable, the tissue surface can be removed layer by layer in an accurate and precise manner.

Biological Interaction with Laser

- Can be achieved by lasers which produce light in the UV wavelength region
  - UV radiation at wavelength shorter than 320 nm produces primarily photochemical reactions in biological tissues.
  - The tissues are opaque in this UV wavelength region.
  - The tissue is exposed to a very high irradiance in a very short exposure time.
  - Photoablation is defined as a pure ablation of the tissue without thermal lesions on the edges.

Biological Interaction with Laser

- Thermal Effect
  - The conversion of laser energy into heat
    - The optical reflection of the tissue determines the proportion of the laser beam which will effectively penetrate the tissue.
    - The optical diffusion, which is an interaction of the light with the medium, serves an important role in the spatial distribution of the energy absorbed in the tissue.

Biological Interaction with Laser

- The transfer of heat into the tissue
  - The absorption of photon energy produces a vibration excited state in molecules.
  - The conduction takes place randomly from the most energetic molecules to the less energetic neighboring molecules through elastic scattering to expand the heated volume.
  - The increasing kinetic energy from the molecules results in a temperature rise in the target volume.

Biological Interaction with Laser

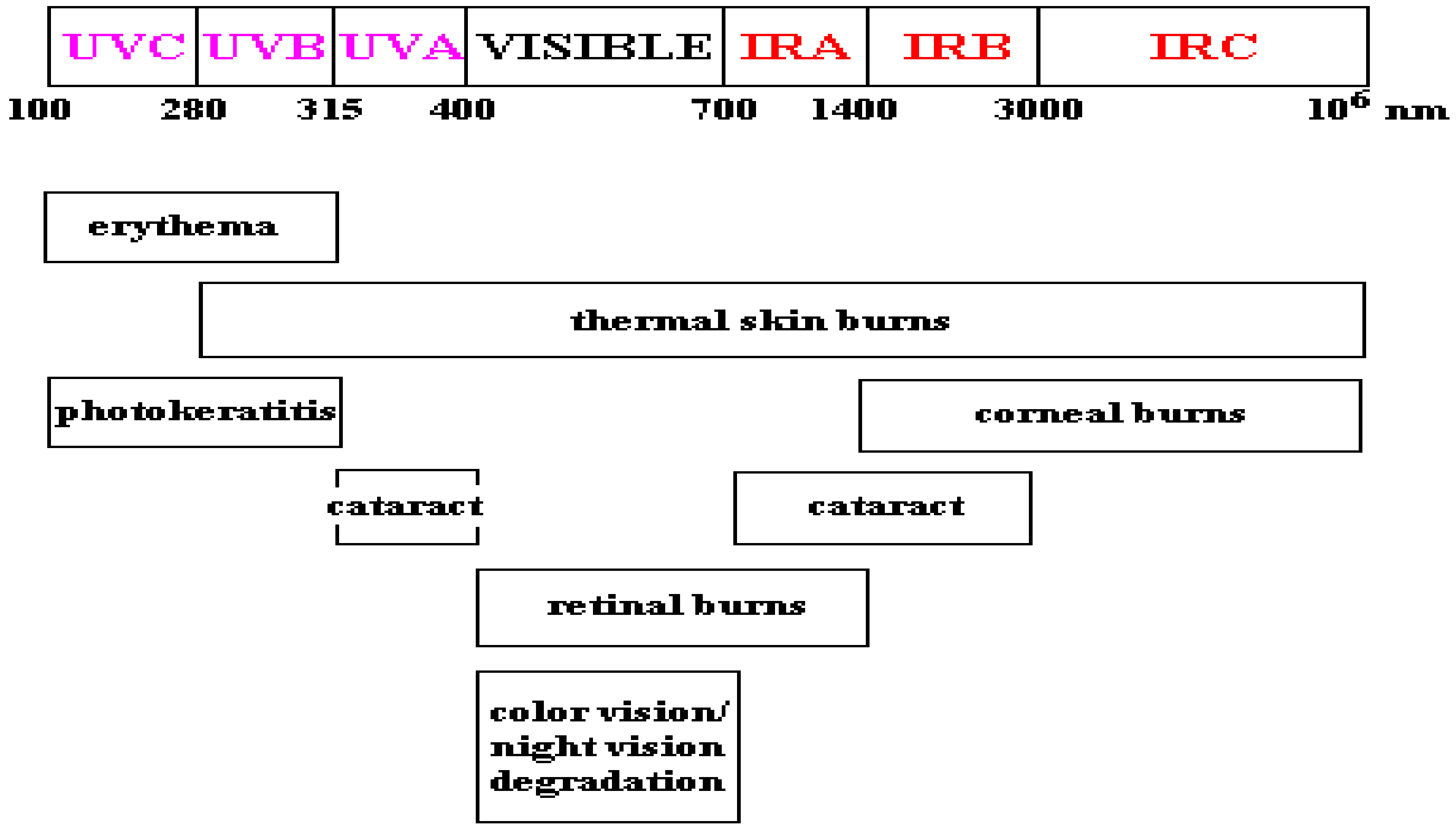
- Denaturing/destruction of the tissue
  - Thermal damages are largely controlled by the content of free water, hemoglobin, collagen, melanin, and nucleic acid in the molecular target.
  - *Photocoagulatio*n is an irreversible necrosis without immediate destruction of the tissue. The tissue will be eliminated during the healing processes. The extent of the injury is proportional to the magnitude and duration of a temperature increase.
  - *Photovaporization* is a loss of substance. The tissue constituents disappear in smoke at a temperature of over 100ºC. On the edges of the vaporized zone, a coagulation necrotic zone can be observed.

LSUHealthNewOrleans

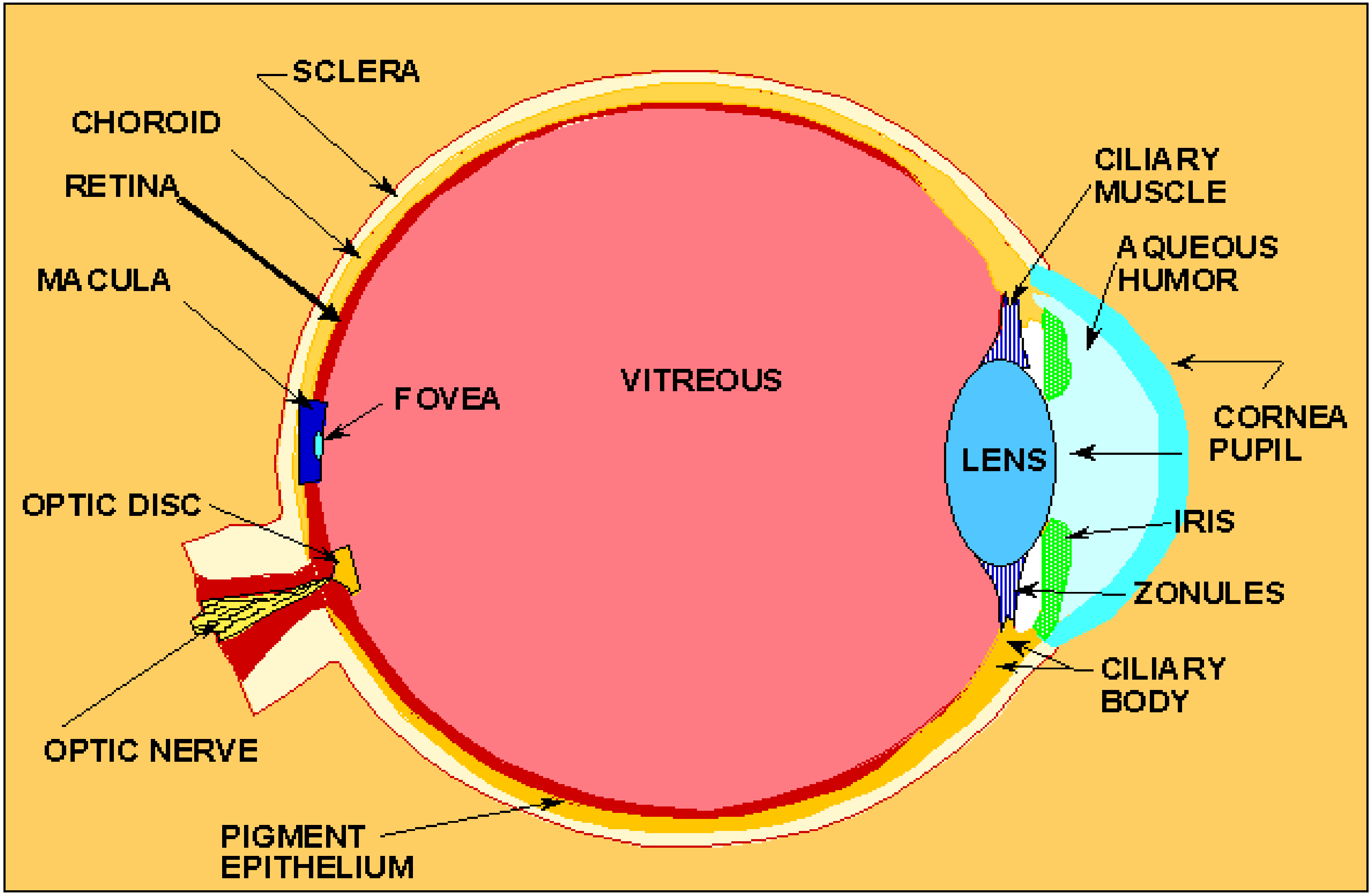
Biological Interaction with Laser

- Electromechanical Effect
  - Requires extremely high irradiance beams with extremely short pulses
    - The high irradiance ionizes the tissue resulting in microplasma.
    - At the boundary between the ionized medium and the external medium, a pressure gradient appears that induces the propagation of a shock wave.
    - A localized mechanical rupture adjacent to the target region occurs due to the shock wave associated with the plasma expansion.

Laser Hazards to Eye and Skin



Eye Anatomy


SCLERA
CHOROID
RETINA
MACULA
FOVEA
VITREOUS
OPTIC DISC
OPTIC NERVE
PIGMENT
EPITHELIUM
CILIARY
MUSCLE
AQUEOUS
HUMOR
CORNEA
PUPIL
LENS
IRIS
ZONULES
CILIARY
BODY

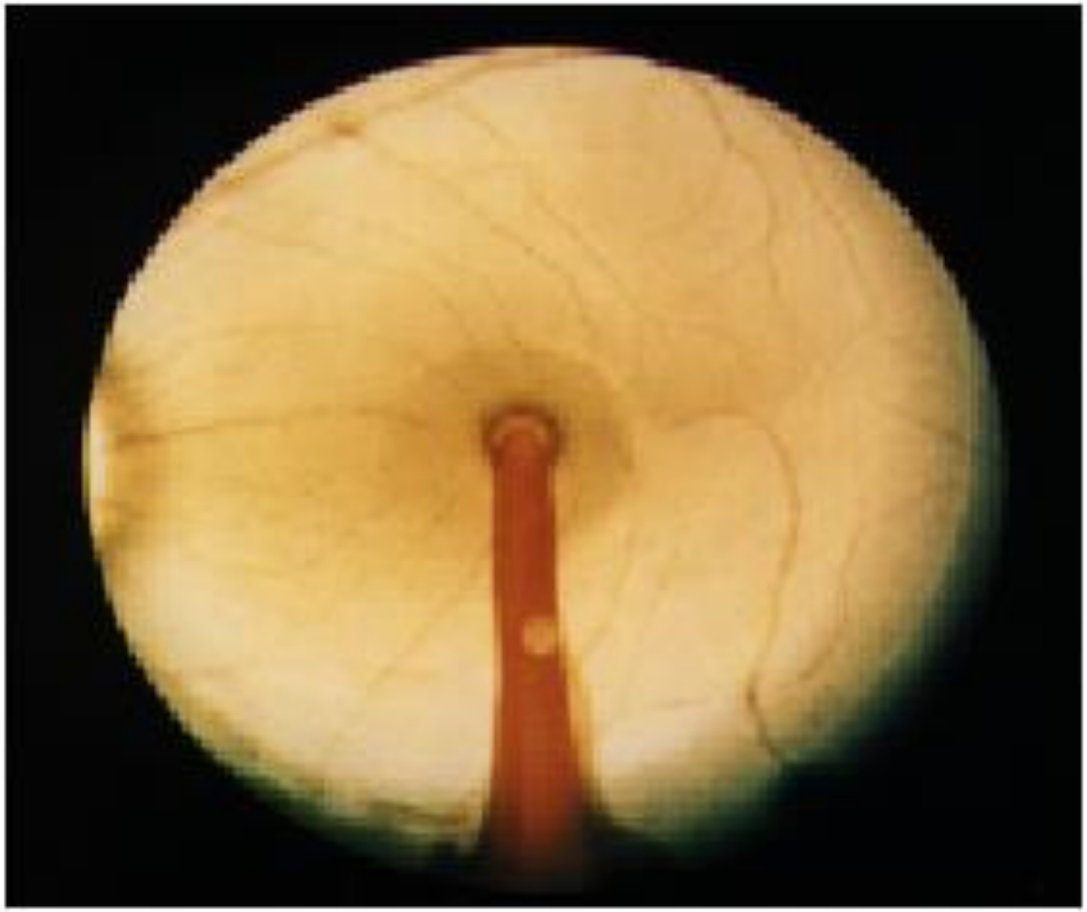
Retinal Injury

- Photoretinitis is a photochemical effect from a lengthy (duration ≥ 10s) and intense exposure to laser radiation between 0.400 μm and 0.500 μm
- Retinal Burns
  - Chorioretinal burns is photocoagulation of retina by a brief (normally pulsed) and intense exposure to laser radiation between 0.400 μm and 1.400 μm

Retinal Injury

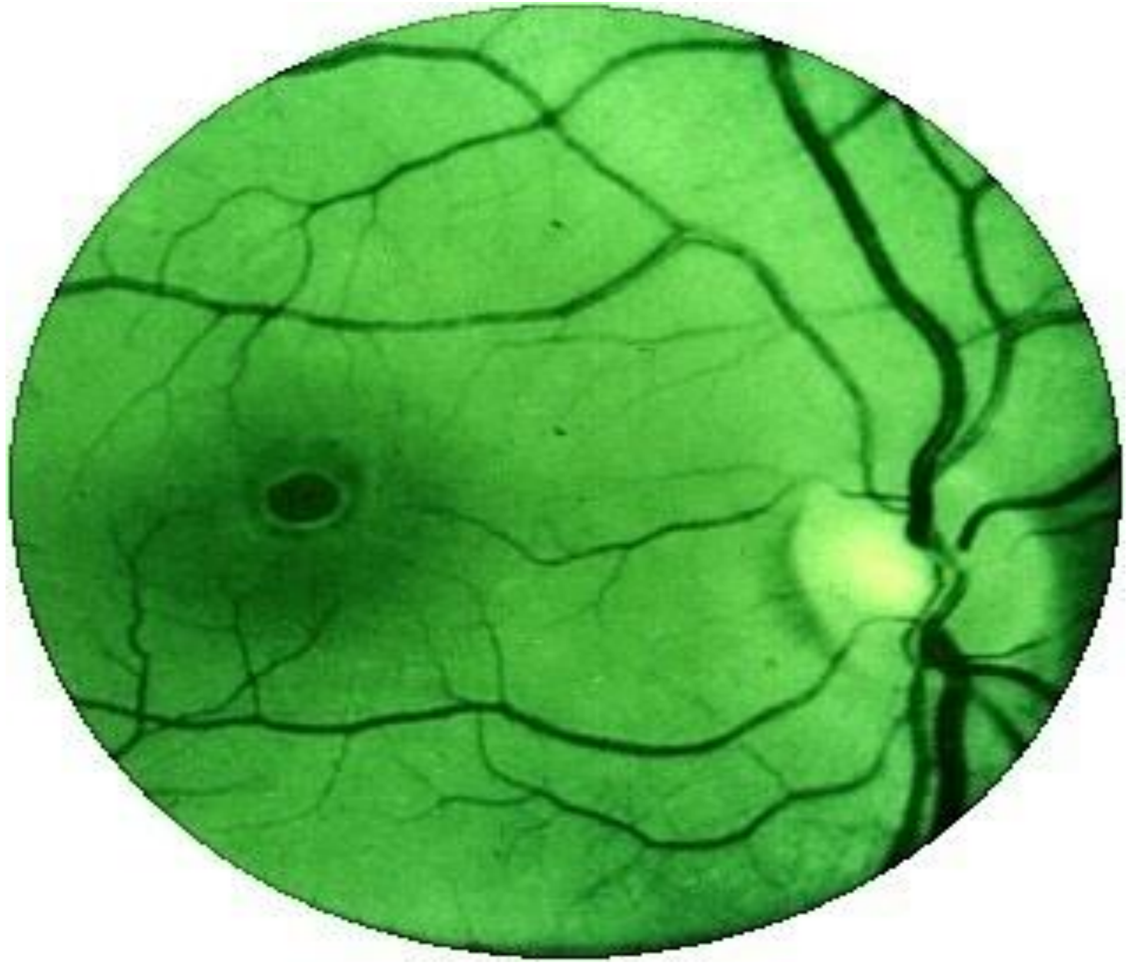
- Photodisruption of Retina
  - Retinal hemorrhage from the Q-switched laser pulse
- Visual Effect
  - Scotoma: blind spot in the visual field
- Retinal damage can cause permanent loss of vision.

Retinal Injury

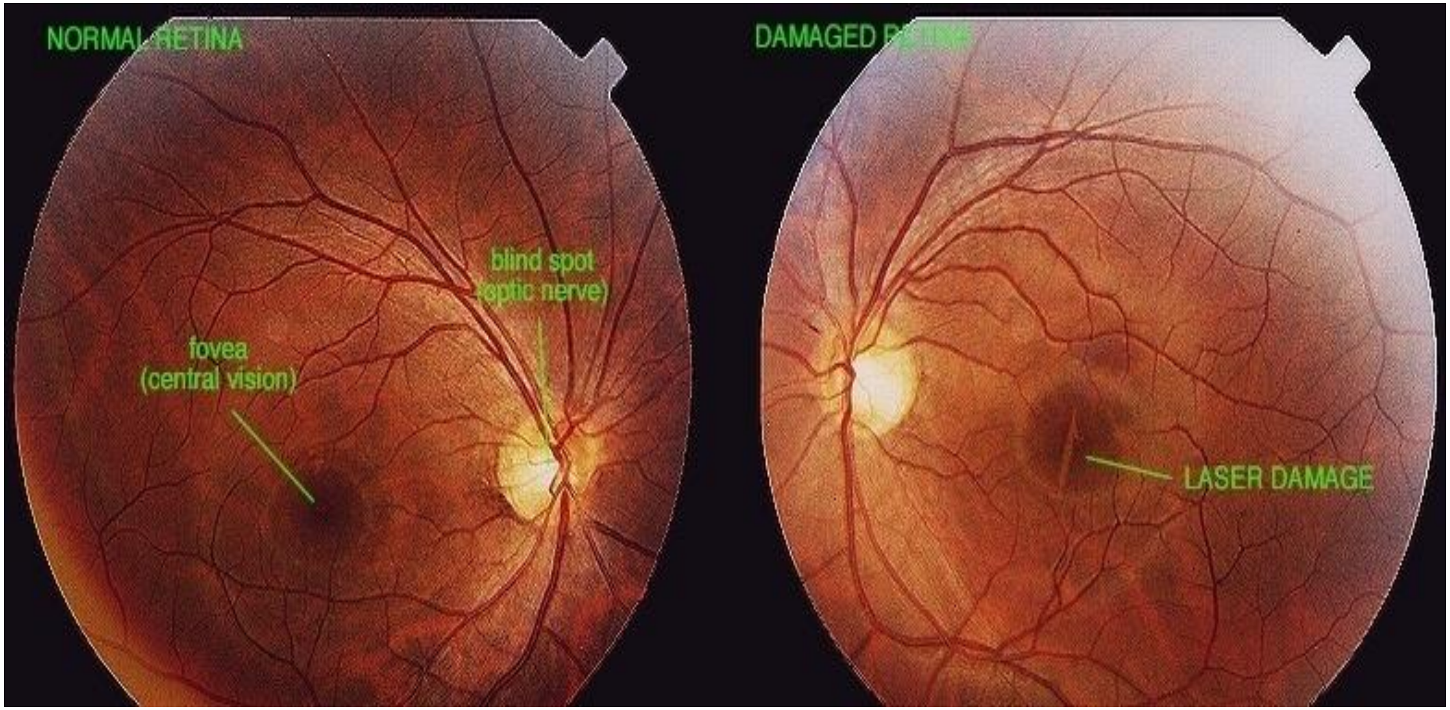


LSUHealthNewOrleans

Retinal Injury



Retinal Injury



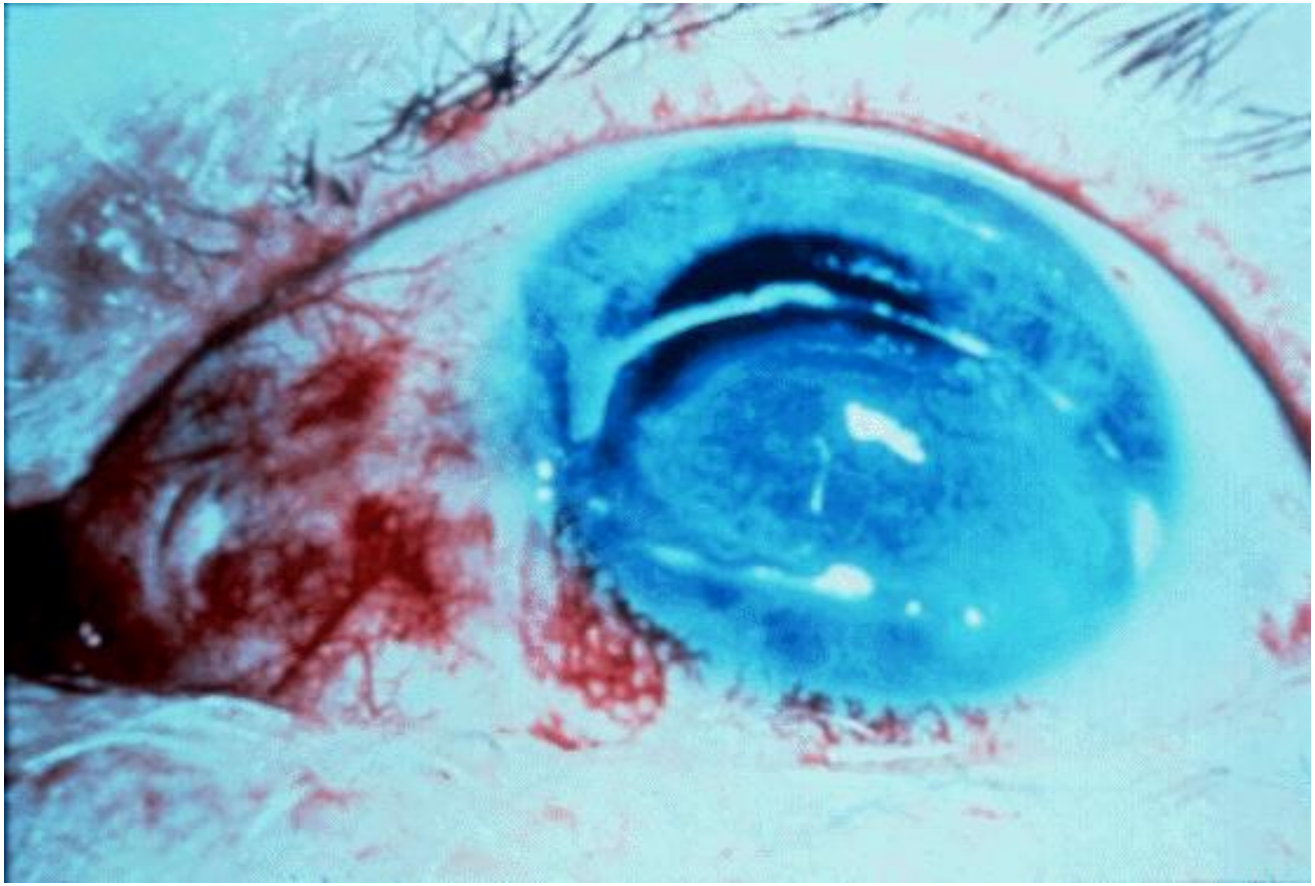
Corneal Injury

- Photokeratitis
  - Welder’s flash or snow blindness is caused by photochemical effect on corneal epithelium by UVB or UVC laser radiation
- Corneal Burns are caused by thermal effect on corneal epithelium by IRB or IRC laser radiation

Corneal Injury

- Superficial Injury
  - Epithelium renews itself continuously.
  - Lesion clears within 24 hours to 48 hours.
- Deep Burns
  - Penetrating burns produce a permanent damage.
  - Cornea transplant for repair may be required.

Corneal Injury



Skin Injury

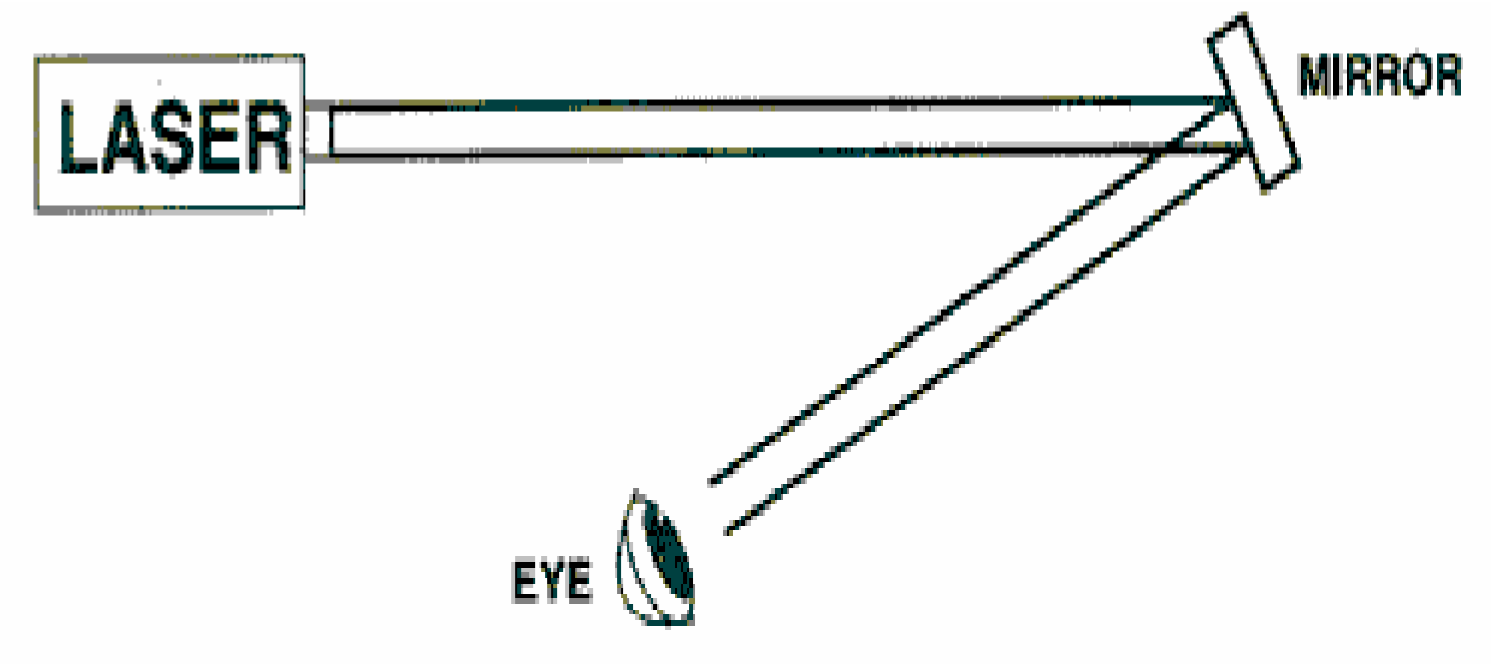
- UV Sunburn
  - Erythema: skin reddening
  - is caused by photochemical effect on skin epithelium by UVB or UVC laser radiation
- UV Delayed Effects
  - Accelerated skin aging
  - Skin cancer
- Thermal Skin Burns
  - is caused by thermal effect on skin epithelium typically by IR laser radiation

Viewing Laser Radiation

- Direct Beam

Viewing Laser Radiation

- Specular Reflection (flat surface)

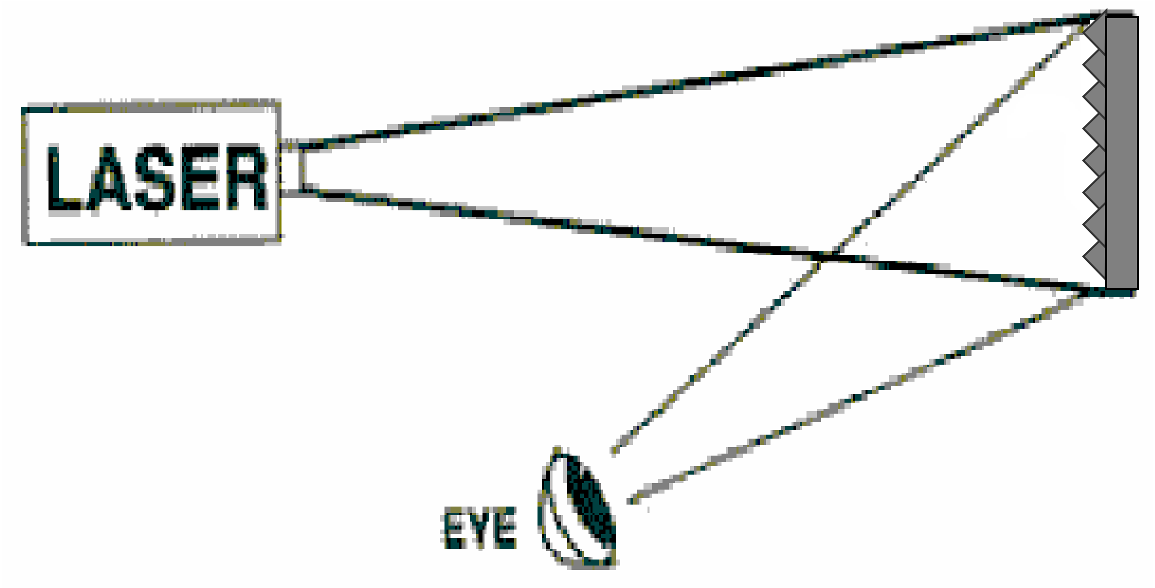


Viewing Laser Radiation

- Specular Reflection (curved surface)

Viewing Laser Radiation

- Diffuse Reflection



Non-Beam Hazards

- Non-beam hazards are a class of hazards that do not result from direct human exposure to a laser beam. These hazards
  - are from subsequent exposure of a material to a laser beam
  - or are associated with
    - components of a laser system
    - materials used to generate the laser beam
    - how and where a laser system is used

Non-Beam Hazards

- Physical Agents
  - Electrical, plasma and collateral radiation, noise
- Chemical Agents
  - Laser generated airborne contaminants (LGACs), compressed gases, laser dyes and solvents
- Biological Agents
  - LGACs, infectious materials

Non-Beam Hazards

- Electrical Hazard
  - More than a dozen electrocutions of individuals from laser-related accidents have been reported in America.
  - The principle factors influencing the accidents in order of their frequencies are:
    - fatigue
    - hunger
    - medication
    - alcohol
    - drug

Non-Beam Hazards

- Fire
  - One of the most common causes of laser-related accidents due to the ignition of flammable materials from accidental exposure to laser.
- Noise
  - Noise levels from certain lasers, such as pulsed excimer lasers, may be intense enough to require noise control. The primary source of noise around laser systems is from the capacitor bank discharge.

Non-Beam Hazards

- Collateral Radiation
  - It may be produced by system components such as power supplies, discharge lamps, and plasma tubes.
  - It may take the form of X-ray, ultraviolet, visible, infrared, microwave, and radio-frequency radiation.

Non-Beam Hazards

- Plasma Radiation
  - During the laser-material interaction processes, plasma emissions containing sufficient ultraviolet and blue light (180 to 550 nm) are called plasma radiation.
  - This bright white light has been observed most frequently in applications of welding, cutting, and drilling metallic materials and raises concern about long-term viewing without protection.

Non-Beam Hazards

- Explosion
  - High-pressure arc lamps, filament lamps, capacitor banks, and cryogenics in laser equipment pose explosion hazards.
  - The laser target and elements of the optic train may shatter during laser operation.
- Ergonomics
  - Painful arm, hand, and wrist injuries may result from repetitive motions during the use of lasers.
  - Positioning of the laser system and area illumination are neglected in facility designs.

Non-Beam Hazards

- Mechanical Hazards Associated with Robotics
  - Robots can punch holes in protective housing, damage the beam delivery system, and cause a laser beam to be aimed at operators.
  - Mechanical safety of the robot installation is overlooked.

Non-Beam Hazards

- Compressed Gases
  - Presently many hazardous gases are used in laser application including chlorine, fluorine, hydrogen chloride, and hydrogen fluoride.
  - Excimer lasers in particular may use mixtures of highly reactive/toxic gases and inert gases.
  - Rapid release of compressed gases may turn a cylinder into an unguided missile if the cylinder is not properly restrained.
  - Release of inert gases may displace enough oxygen to cause asphyxia.
  - Different categories of gases are not stored separately.

Non-Beam Hazards

- Cryogenics
  - Liquid nitrogen may damage eyes and skin on contact.
  - Expansion of liquid cryogen to a gas and displacement of hundreds of times the volume of the liquid are explosion and asphyxia hazards.
  - Liquid oxygen caused by atmospheric condensation poses explosion and fire hazards.

Non-Beam Hazards

- Laser Dyes and Solvents
  - Laser dyes
    - are complex fluorescent organic compounds.
    - may be highly toxic or carcinogenic.
  - Solvents
    - are organic compounds.
    - may be irritants, anesthetics, and/or absorbable through skin.
    - may be flammable.

Non-Beam Hazards

- Laser Generated Airborne Contaminants
  - A variety of airborne contaminants are present when certain Class 3B and 4 laser beams interact with matters.
  - When the target irradiance reaches about 10^7 W/cm^2**,** target materials including plastics, composites, metals, and tissues may liberate carcinogenic, toxic, and noxious contaminants.
  - Exposure to these airborne contaminants can cause airway and eye irritation as well as bronchial and pulmonary congestion.

Laser Safety Standard

- American National Standards Institute, Inc. (ANSI)
  - ANSI Z136.1: Safe Use of Lasers
    - Provides recommendations for the safe use of lasers and laser systems that operate at wavelengths between 0.180 μm and 1mm

Laser Safety Standard

- ANSI Z136.3: Safe Use of Lasers in Health Care Facilities
  - Provides guidance for the safe use of lasers for diagnostic and therapeutic applications in health care facility
- ANSI Z136.4: Recommended Practice for Laser Safety Measurements for Hazard Evaluation
  - Contains clearly written definitions, examples, and other practical information

Laser Safety Standard

- ANSI Z136.5: Safe Use of Lasers in Educational Institutions
  - Provides guidance for the safe use of lasers in educational settings at all levels
- ANSI Z136.6: Safe Use of Lasers Outdoors
  - Provides guidance for the safe use of lasers in an outdoor environment

Laser Safety Standard

- Food and Drug Administration (FDA)
  - 21CFR800-1299: Medical Device Amendments to the Food and Drug Act
    - Regulate all medical lasers
    - Require manufacturers to classify the medical laser system based primarily on its ability to cause damage to the eye and skin
    - Enforced by the Center for Devices and Radiological Health (CDRH)

Laser Classification

- Class 1 & Class 1M
  - Lasers are considered to be incapable of producing damaging radiation levels during operation or maintenance.
- Class 2 (Low Power) & Class 2M
  - Lasers are emitted in the visible spectrum.
  - The eye is protected by its aversion response (blink reflex), but it may be damaged by viewing directly for an extended period of time.
  - The upper limit of the power output is 1 mW. Class 1
  - Lasers are considered to be incapable of producing damaging radiation levels during operation or maintenance.

Laser Classification

- Class 3 (Medium Power)

  Lasers are hazardous under direct and specular reflection viewing. Diffusive reflection and fire are not normally hazards.
  - Class 3R
    - The eye may be protected by the blink reflex unless the beam is viewed with optical aids.
    - The upper limit of the power output is 5 mW.
  - Class 3B
    - Eye damage can occur in less than 0.25 second.
    - The upper limit of the power output is 500 mW.

Laser Classification

- Class 4 (High Power)
  - Both direct and scattered beams can cause eye and skin damage.
  - These lasers can ignite flammable materials, and also may produce LGACs and hazardous plasma radiation.
  - The power output is above 500 mW.

Laser Classification

AMERICAN NATIONAL STANDARD Z136.1-2007

Requirements by Laser Classification

Class	Procedural & Administrative Controls	Training	Medical Surveillance	LSO
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent (2)	Application Dependent (2)	Application Dependent (2)
2	Not Required (1)	Not Required (1)	Not Required	Not Required
2M	Required	Application Dependent (2)	Application Dependent (2)	Application Dependent (2)
3R	Not Required (1)	Not Required (1)	Not Required	Not Required (1)
3B	Required	Required	Suggested	Required
4	Required	Required	Suggested	Required

Laser Warning Signs

- Class 3B

Laser Warning Signs

- Class 4

Laser Warning Signs

Laser Safety Control

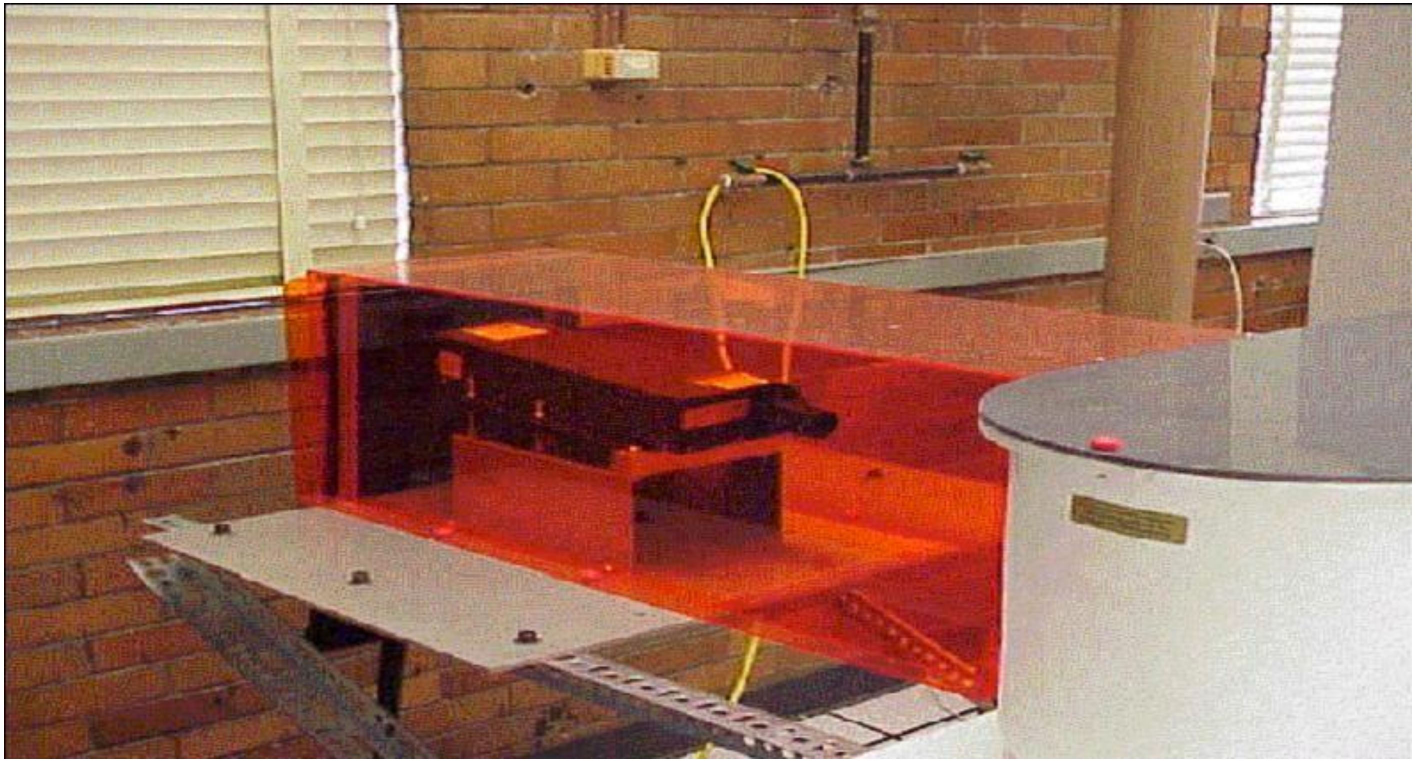
- Engineering Controls
  - They are devices that are incorporated into the laser systems and are designed to limit the potential for accidental exposure to the laser beams.
- Administrative Controls
  - They are methods or instructions which specify operating procedures and rules that supplement engineering controls.

Engineering Control Measures

- Intra-Beam
  - Protective housings
  - Interlocks on protective housings
  - Service access panels
  - Key control
  - Full/Limited open beam path (NHZ)
  - Beam stop or attenuator
  - Activation warning systems
  - Controlled area and warning signs
  - Scram button (panic button)

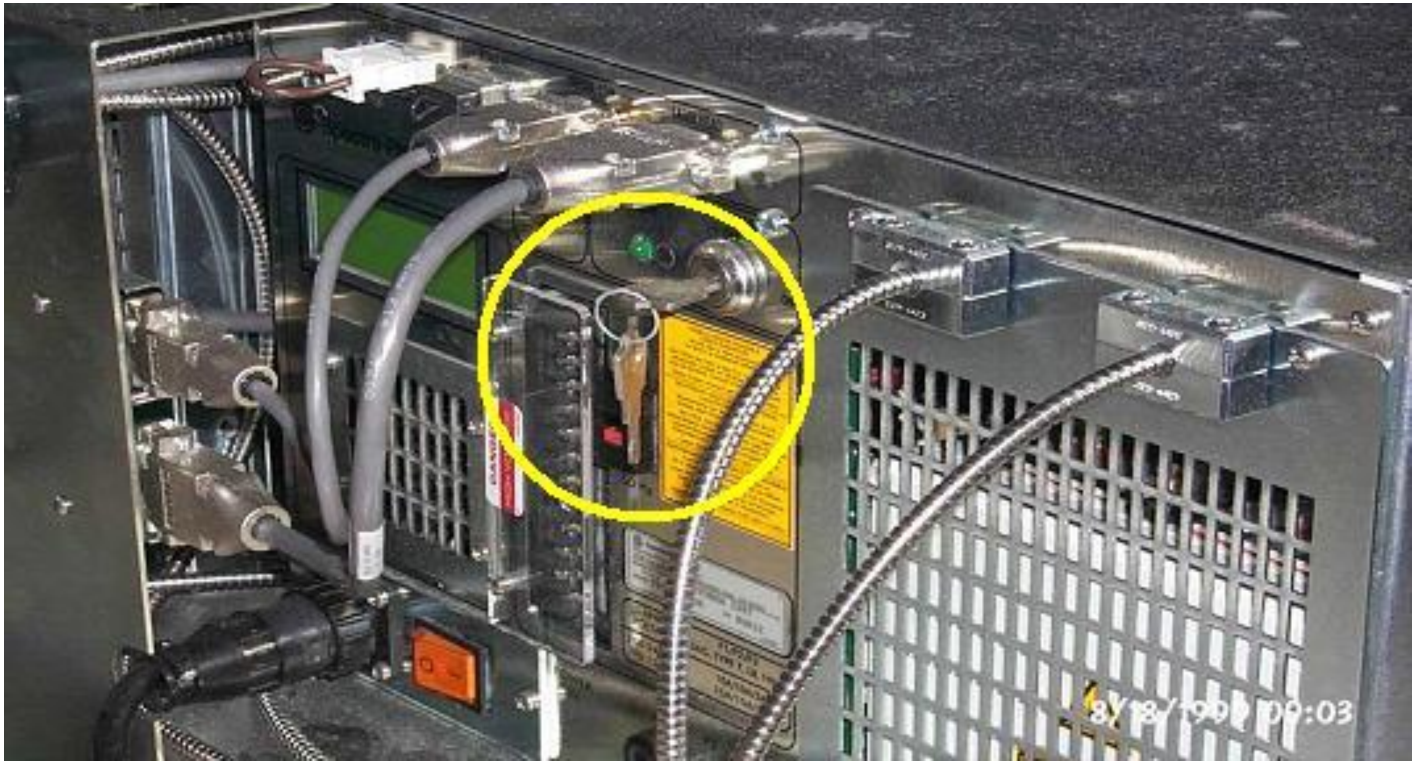
Engineering Control Measures

- Protective housings



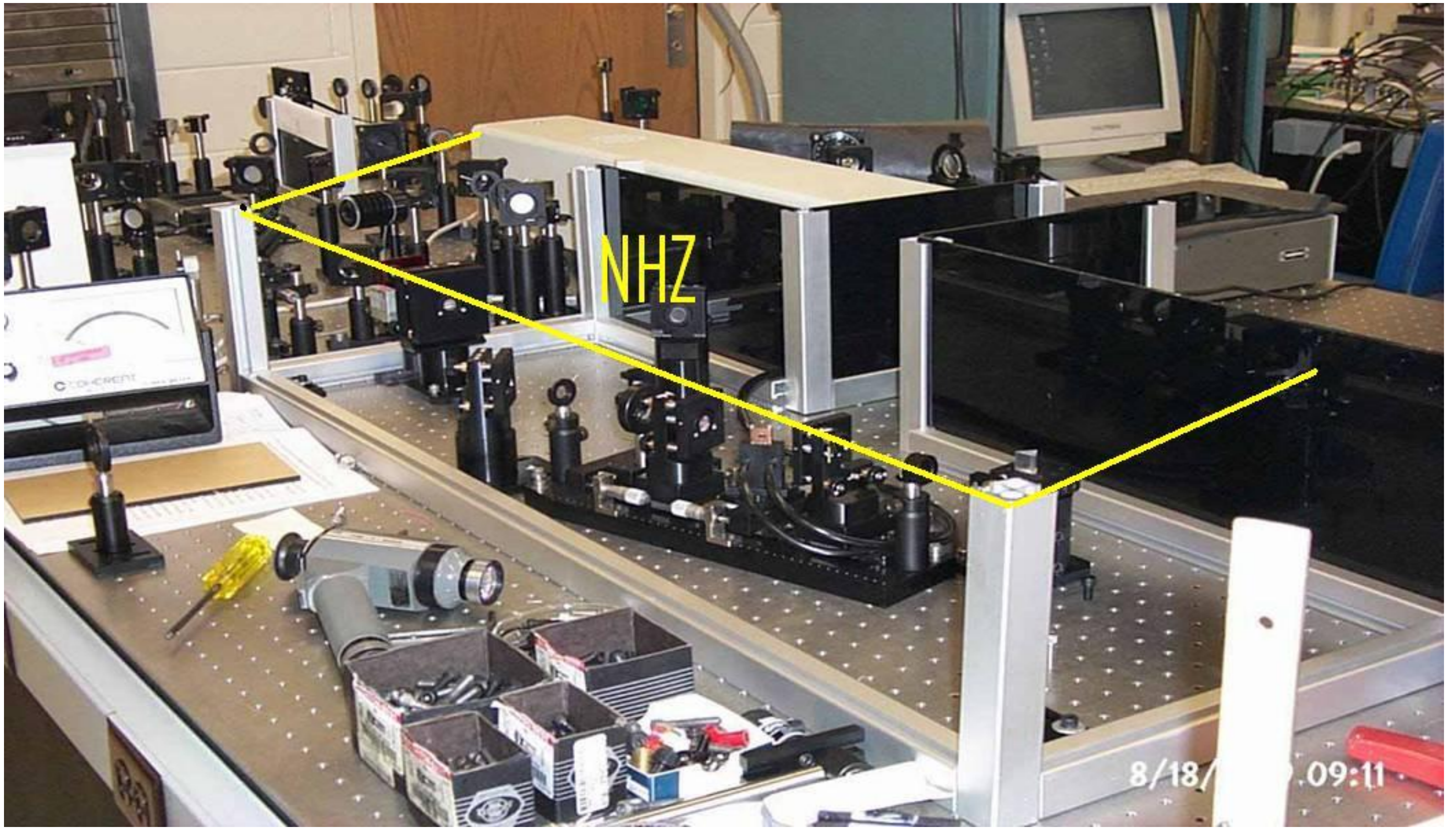
Engineering Control Measures

- Key control



Engineering Control Measures

- Open beam path (NHZ)



LSU Health New Orleans

Engineering Control Measures

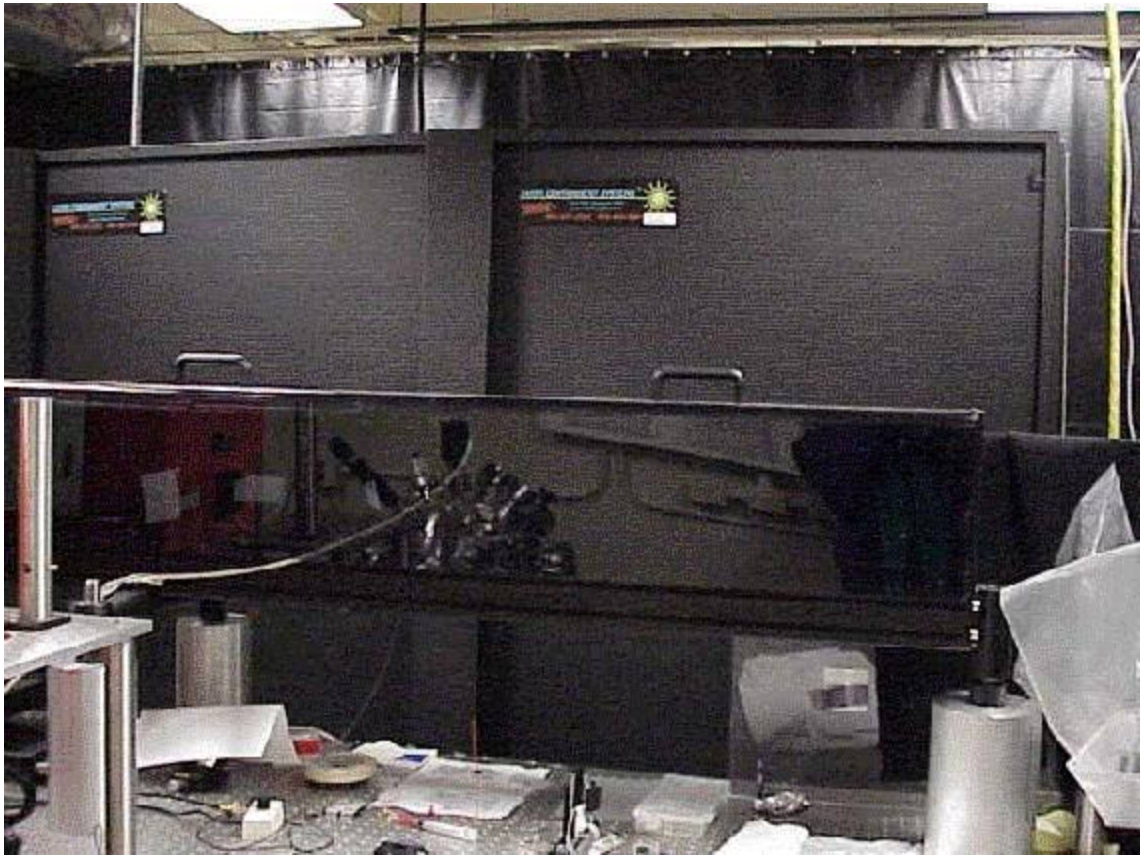
- Nominal Hazard Zone (NHZ)
  - The space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable maximum permissible exposure (MPE). Exposure levels beyond the boundary of the NHZ are below the appropriate MPE levels.
- Maximum Permissible Exposure (MPE)
  - The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.

Engineering Control Measures

- Protective window

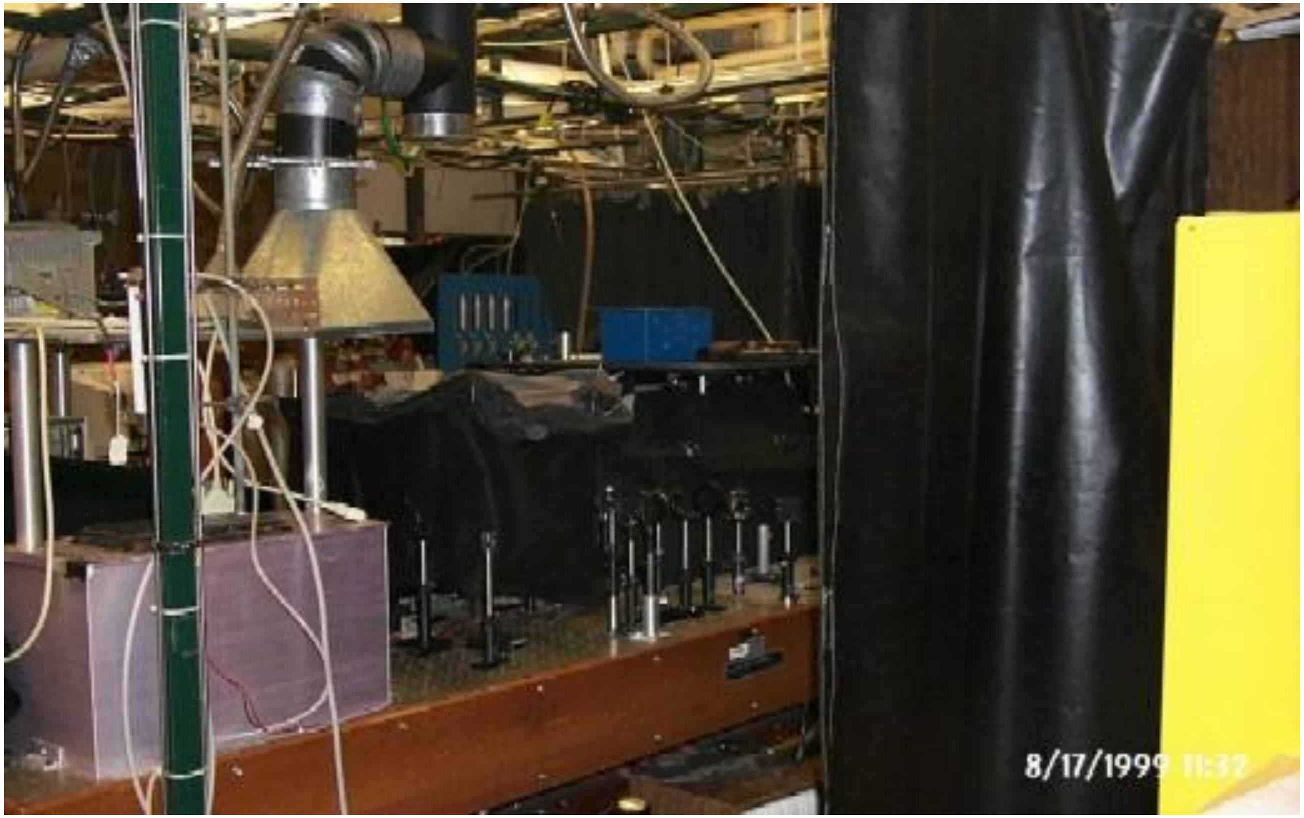
Engineering Control Measures

- Protective partitions



Engineering Control Measures

- Protective curtain



LSU Health New Orleans

Engineering Control Measures

- Beam stop

Engineering Control Measures

- Activation warning light

Engineering Control Measures

- Activation warning light with interlock

Engineering Control Measures

- Controlled area and warning signs

Engineering Control Measures

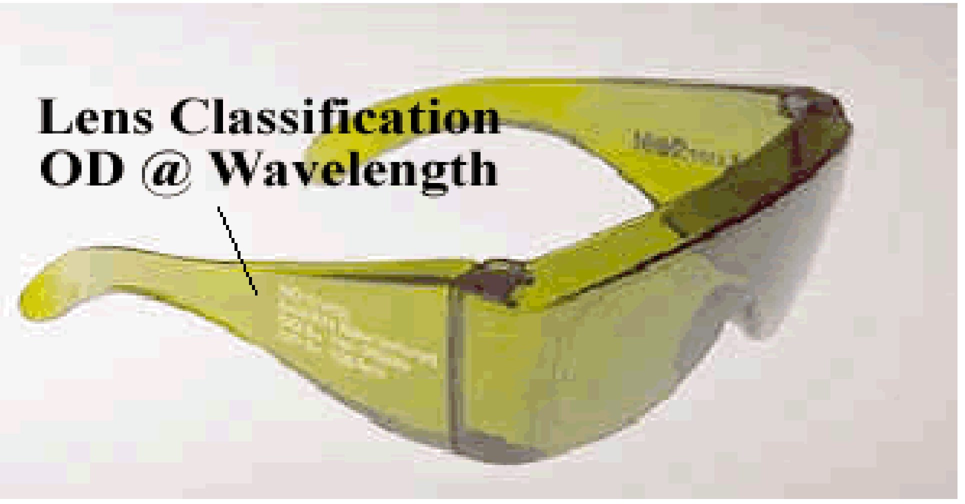
- Scram button

Administrative Control Measures

- Intra-Beam
  - Standard operating procedures (SOPs)
  - Output emission limitations
  - Education and training
  - Authorized personnel
  - Alignment procedures
    - Laser accidents occur most commonly during alignment activity.
  - Protective equipment
  - Eye and skin protection

Administrative Control Measures

- Eye protection: Ensure that appropriate laser protective eyewear must be worn in the laser environment before turning on the laser. Do not remove the eyewear until the laser is off.



- Skin protection: gloves, clothing

Administrative Control Measures

- Optical density (OD) for laser protective eyewear

$$D_\lambda = -\log_{10} \tau_\lambda$$

$$\text{where } \tau_\lambda = \frac{\text{MPE}}{\Phi_d}$$

  - Logarithm to the base ten of the reciprocal of the transmittance.
  - Transmittance is the ratio of transmitted power to incident power.
  - The higher the optical density, the lower the transmittance.

Administrative Control Measures

- Considerations for laser protective eyewear
  - Multiple wavelengths
  - Optical density (OD)
  - Field of view
  - Visible light transmission
  - Color vision effect
  - Laser filter deterioration
  - Aging
  - Break resistant
  - Fit and comfort

Administrative Control Measures

- Non-Beam
  - To avoid electrical hazards
    - A barrier system for the energized conductors is the primary methodology to prevent electric shock accidents with laser equipment.
    - Restrict access until capacitors are discharged, shorted, and grounded.
    - All accessible non-current-carrying parts of laser equipment shall be grounded by reliable, continuous metallic connection with grounding conductor of a wiring system.

Administrative Control Measures

- To avoid electrical hazards
  - Hazard warnings and safety instructions are properly posted.
  - Do not use extension cords to power lasers.
  - Check the functional integrity of all cords, footswitches, and circuit breakers periodically.
  - Do not wear highly conductive items on hands or arms.
  - Allow only properly trained and approved users to work on lasers.

Administrative Control Measures

- To prevent fire
  - Use flame retardant materials wherever applicable.
- To reduce noise
  - Use earplugs and muffs.
  - Enclosure/isolation of the laser system may be required.
- To minimize collateral and plasma radiation
  - Install effective shielding.
  - Increase distance between the radiation source and the personnel.
  - Reduce the exposure duration.

Administrative Control Measures

- Explosion
  - Lamps and capacitor banks shall be enclosed in housing which can withstand the maximum explosive pressure resulting from component disintegration.
  - The elements of the optic train shall be enclosed or equivalently protected to prevent injury to operators and observers.
- Ergonomics
  - Design a work environment to promote ease and efficiency for the person working.

Administrative Control Measures

- Mechanical hazards associated with robotics
  - Use surface interlock mats and interlocked light curtain.
  - Follow the recommendations in ANSI/RIA R15.06-1999 *Standard for Industrial Robots and Robot System-Safety Requirements*.

Administrative Control Measures

- Compressed gases
  - Room dilution reduces reactivity and/or corrosivity.
  - Local exhaust ventilation on protective housing surrounding the laser may be employed.
  - Toxic gas storage cabinets and gas handling/restraining manifolds are useful for containing gas mixtures.

Administrative Control Measures

- Cryogenics
  - Insulated handling gloves and proper personal protection equipment (PPE) should be worn.
  - Ensure adequate ventilation in the room.
  - Keep all combustibles away from the liquid oxygen.
  - No smoking or open flame is permissible in areas where liquid oxygen is used or stored.

Administrative Control Measures

- Laser dyes and solvents
  - Take special care when handling, preparing, and operating dye lasers.
  - Wear low permeability gloves and appropriate PPE when contacting dyes and/or solvents.
  - Prepare laser dye in a laboratory fume hood.
  - Place dye pumps and reservoirs in secondary containment vessels to minimize leakage and spills.

Administrative Control Measures

- To minimize exposure to laser generated airborne contaminants (LGACs)
  - Use exhaust ventilation/smoke evacuation systems with in-line filters to ensure all personnel exposures to hazardous concentrations of LGACs are in compliance with the regulatory limits.
  - Avoid re-circulation of LGACs.
  - Appropriate PPE should be worn.
  - The laser process may be isolated by physical barriers or remote control apparatus.
  - Disinfect or sterilize the working area and PPE immediately after biomedical applications.

Laser Safety Program

- Components
  - Policies and procedures
  - Laser safety manual
  - Purchase and disposal- please notify the Laser Safety Officer of all Class 3B and Class 4 laser systems.
  - Location and operation
    - Laser systems
    - Laser area personnel
    - Control measures

LSUHealthNewOrleans

Laser Safety Program

- Components (continued)
  - Training
    - Approval for laser users is required for use of Class 3B and Class 4 lasers
    - On-Line Laser Safety Training required for all Class 3B and Class 4 laser users at LSU Health – New Orleans
  - Medical surveillance- (not required at this time)
  - Self-audit and compliance enforcement
  - Recordkeeping

Laser Safety Program

- Responsibility

"The ultimate success of a laser safety program lies in responsible actions by the laser area personnel."

- Think "safety first".

Common Causes of Accidents

- Use improper laser protective eyewear
- Place reflective objects into or near the beam path
- Alter the beam path
- Bypass interlocks
- Turn on laser accidentally
- Turn on laser beam accidentally

Good Laser Safety Practices

- Use minimum power or energy
- Use appropriate laser protective eyewear
- Remove unnecessary objects near the beam
- Keep beam path away from eye level
- Terminate laser beam with beam trap
- Get hands-on training for each laser
- Follow standard operating procedures

References

- CLSO's Best Practices In Laser Safety Chapter 5.2.1.1 Training Modules, Laser Institute of America, First Edition CD ROM 2008.
- American National Standards Institute, Inc. ANSI Z136.1 Safe Use of Lasers. Orlando, FL: Laser Institute of America; 2007.
- Barat K. Laser Safety Management. Boca Raton, FL: CRC Press; 2006.
- Hecht J. Understanding Lasers. NY: IEEE Press; 1994.
- Henderson R, Schulmeister K. Laser Safety. Bristol, UK: Institute of Physics Publishing; 2004.

LSU Health New Orleans

References

- Laser Institute of America. Laser Safety Manual. Orlando, FL: Laser Institute of America; 2005.
- Matthes R, Sliney DH, Didomenico S, Murray P, Phillips R, Wengraitis S. Measurements of optical radiation hazards. München, Germany: ICNIRP; 1998.
- René M, Michel R, Kerns K, Zimmerman TL. Managing a sound laser safety program. Health Phys 77:S2-S8; 1999.

References

- Sliney DH, Wolbarsht ML. Safety with Lasers and other Optical Sources. NY: Plenum Press; 1980.
- Syess MJ, Benwell-Morison DA. Non-ionizing radiation protection. Copenhagen, Denmark: WHO Regional Office for Europe; 1989.
- Wang WH, McGlothlin JD, Smith DJ, Matthews II, KL. Evaluation of a radiation survey training video developed from a real-time video radiation detection system. Health Phys 90:S33-S39; 2006.
- Dan Van Gent, OSU Laser Safety Training, slide # 6.

LSUHealthNewOrleans