OBJECTIVES

At the conclusion of the program the student will be able to:

- Define the acronym LASER
- Describe the major components of medical lasers
- List the unique properties of a laser
- Discuss the required safety protocols for operating a medical laser
- Explain the benefits of lasers in medicine and give examples of the various types of lasers and how they are used

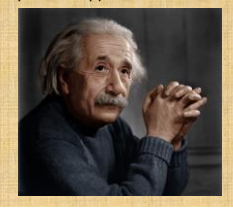
LASER SCIENCE

BASICS OF LASERS AND LASER LIGHT

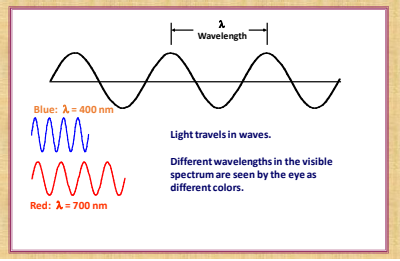
L ight
A mplification by the
S timulated
E mission of
R adiation

Laser Science

- The theory of stimulation of radiation was developed by Albert Einstein in 1917, but no practical application of the theory was put to test until the 1950's

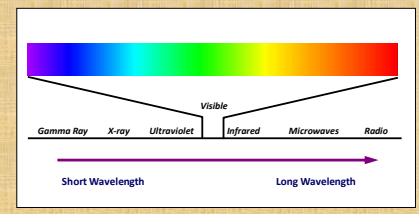


WAVE NATURE OF LIGHT – Light is an electromagnetic wave



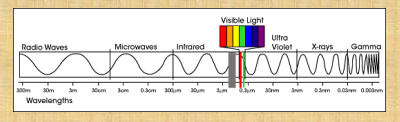
ROY G BIV

ELECTROMAGNETIC SPECTRUM



Lasers operate in the ultraviolet, visible, and infrared.

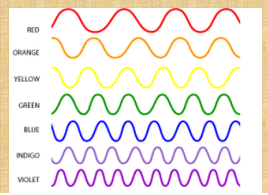
WAVELENGTHS



- Our eyes can only see a very small portion of the electromagnetic spectrum called the “Visible” wavelengths
- This visible light has a wavelength range of 400 - 700 nanometers (nm) and a color range of violet through red.
- The human eye is not capable of "seeing" radiation with wavelengths outside the visible spectrum.

WAVELENGTHS

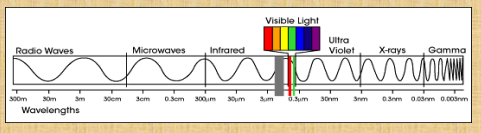
- The visible colors from shortest to longest wavelength are: violet, blue, green, yellow, orange, and red.



WAVELENGTHS

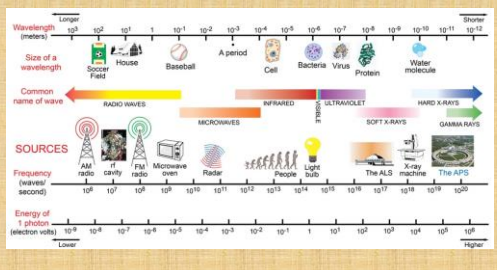
- The brightest color is green, followed by red, then blue, then violet.

WAVELENGTHS



- Ultraviolet radiation has a shorter wavelength than the visible violet light.
- Infrared radiation has a longer wavelength than visible red light.

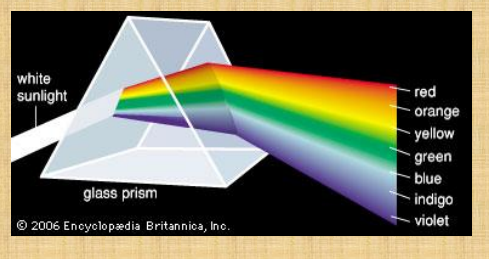
WAVELENGTHS



WAVELENGTHS

- The white light is a mixture of the colors of the visible spectrum.

WAVELENGTHS



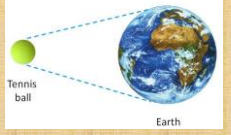
WAVELENGTHS

Black is a total absence of light

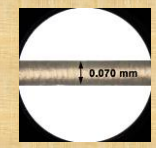
WAVELENGTHS

NANOMETER

One nanometer is to a tennis ball what a tennis ball is to the Earth



NANOMETER

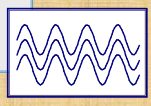


A strand of hair is 100,000 thicker than a nanometer

1 mm = 1,000,000 nanometers

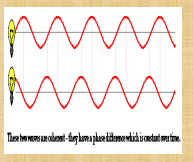
CHARACTERISTICS OF LASER LIGHT

COLLIMATED
COHERENT
MONOCHROMATIC

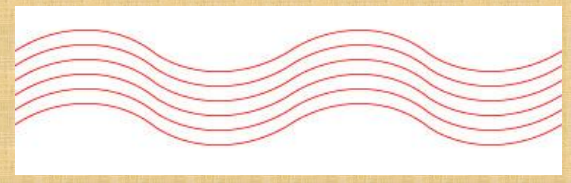


The combination of these three properties makes laser light focus 100 times more focused than ordinary light

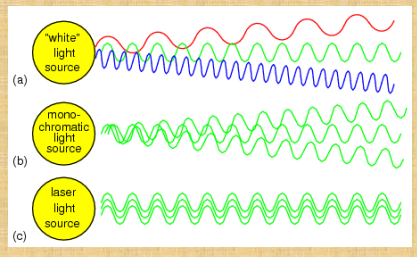
Coherent – Directional Move Together to Different Points



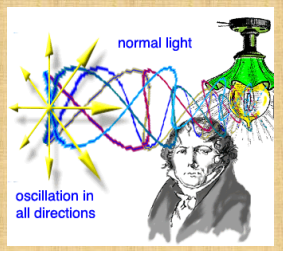
Collimated - –Waves Move Parallel to Each Other



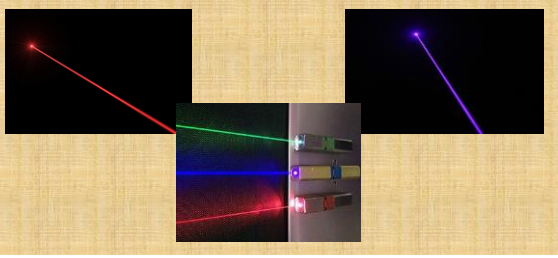
Collimated –Waves Move Parallel to Each Other



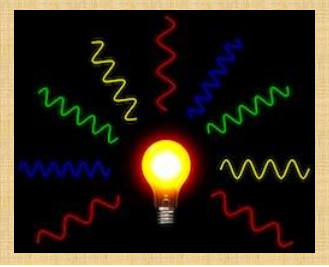
Regular Light



Monochromatic

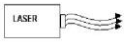


Regular Light – All Different Colors



To Summarize

Ordinary light & Laser



5.Many wavelengths
6.Multidirectional
7.Incoherent

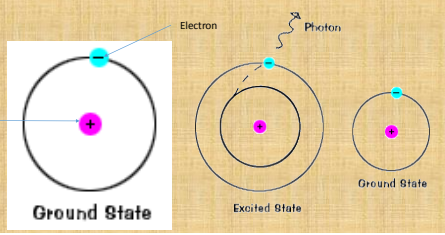
1. Monochromatic
2. Directional
3. Coherent

LASERS

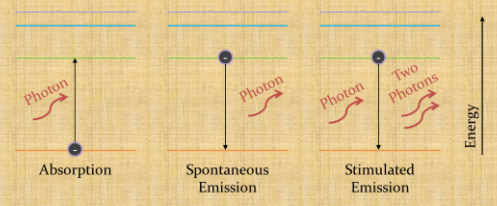
- **L** ight
- **A** mplification by the
- **S** timulated
- **E** mission of
- **R** adiation

How Lasers Work

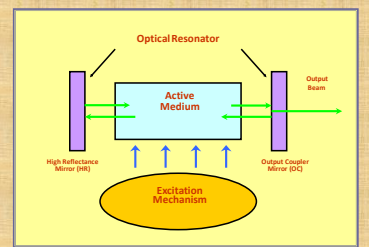
- Atoms
- Electrons
- Photons



How Lasers Work

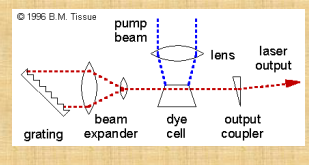


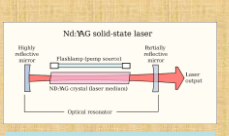
How Lasers Work

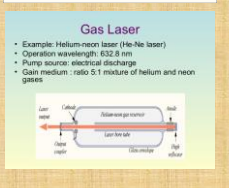


How Lasers Work

- Medium (creates identical protons)
  - Solid
  - Gas
  - Liquid







LASER COMPONENTS

ACTIVE MEDIUM

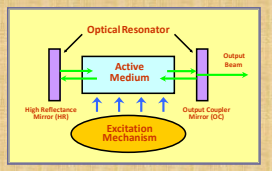
Solid (Crystal)
Gas
Semiconductor (Diode)
Liquid (Dye)

EXCITATION MECHANISM

Optical
Electrical
Chemical
Another laser

OPTICAL RESONATOR

HR Mirror and Output Coupler

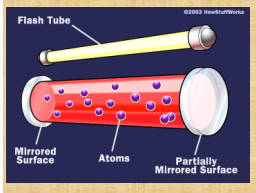


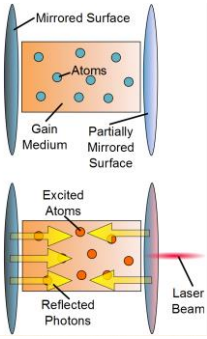
The Active Medium contains atoms which can emit light by stimulated emission.

The Excitation Mechanism is a source of energy to excite the atoms to the proper energy state.

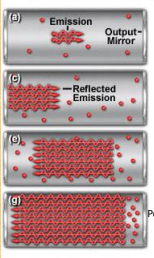
The Optical Resonator reflects the laser beam through the active medium for amplification.

How Lasers Work





How Lasers Work



LASER TELLS YOU IT'S READY.

YOU HIT THE "ACTIVE OR ON" BUTTON

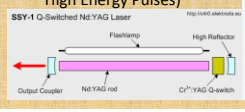
THE SURGEON PUSHES THE PEDAL AND THE PARTIALLY REFLECTIVE MIRROR ALLOWS A SMALL AMOUNT OF ENERGY TO ESCAPE

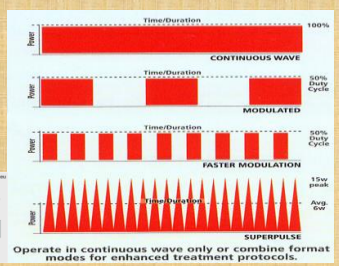
How Lasers Work

- More atoms must be in the excited state than in the resting site – population inversion
- Different lasers take different times to warm up.
  - Solid medium lasers can take 10-20 minutes
  - Gas medium lasers can warm up instantly

How Lasers Work

- Continuous
- Pulsed Single
- Pulsed Repetitive
- Super Pulsed
- Q-Switch (Extremely High Energy Pulses)





How Lasers Work

- Continuous
  - Average Power in watts
- Pulsed Lasers
  - Single Pulse
  - Repetitive Pulse
  - **Time On** (pulse duration), **Time Off** (interpulse period)
  - Hertz (Hz) represents the number of pulses per second

LASER SAFETY

Laser Regulations

- **ANSI** (American National Standards Institute, Inc)
  - Z136.1: Safe Use of Lasers
- **Laser Institute of America**
  www.laserinstitute.org
- The Laser Institute of America is a professional society that promotes laser safety and education by offering technical conferences, workshops, publications, and training to industrial, medical, research, and government communities. You can purchase the standards referenced above from their site.
- **Center for Devices and Radiological Health**
  www.fda.gov
- Center for Devices and Radiological Health (CDRH) regulates firms who manufacture, repackage, re-label, and/or import lasers (and medical devices) sold in the United States. An overview of laws and regulations for radiation-emitting products is provided on the web site.
- **AORN**
- **The Joint Commission – competency based assessments**

LASER SAFETY

- Laser Safety Officer, Laser Safety Committee
- Laser Education for any staff member in the room
- Laser equipment pre-op check
- Verify settings with surgeon.
- Surgeon must communicate “laser on” or “laser off”
- Surgeon is the only one to operate the foot pedal
- Documentation

Laser Safety

- An extra nurse is needed and is dedicated to control of the laser and laser safety considerations.
- Test fire the CO2 Laser
  - Test fire the laser through the operative system with the beam maximally focused, onto a wooden tongue blade at 5 to 10 watts to check that the He-Ne beam is well aligned with the CO2 beam.
- Post appropriate signs outside procedure room . Take down when laser procedure is completed
- Make sure everyone in the room has appropriate laser safety glasses

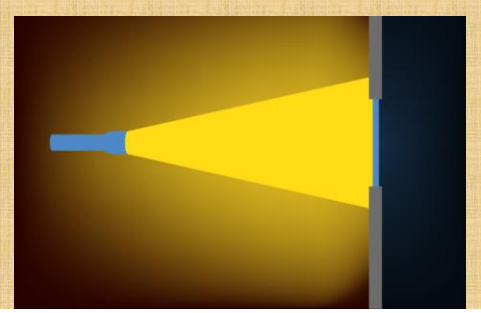
Laser Safety

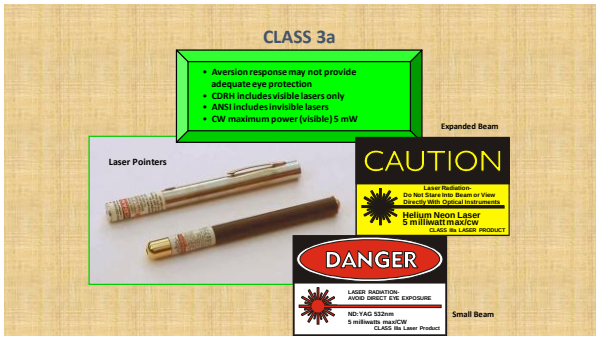
- Smoke Evacuators
- Laser Masks

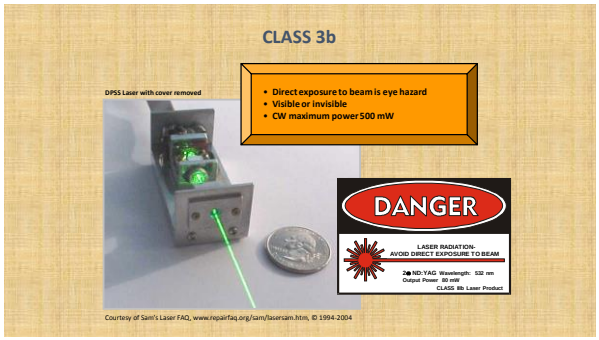
DANGER OF LASER WAVELENGTHS

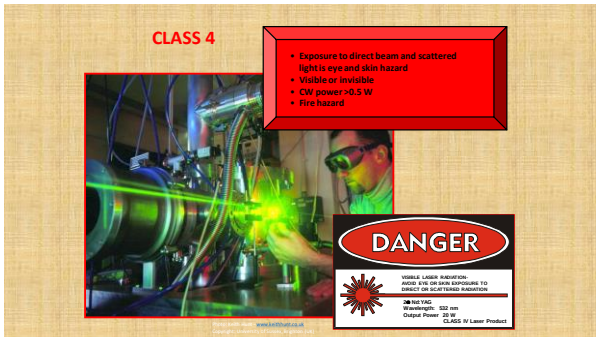
Two characteristics of laser light contribute to the hazard:

- Laser light can be emitted in a tight beam that does not grow in size at a distance from the laser.
- The eye can focus a laser beam to a very small, intense spot on its retina, which can result in a burn or blind spot.




CLASS 3a
• Aversion response may not provide adequate eye protection
• CDRH includes visible lasers only
• ANSI includes invisible lasers
• CW maximum power (visible) 5 mW
Expanded Beam
Laser Pointers
CAUTION
Laser Radiation-
Do Not Stare Into Beam or View Directly With Optical Instruments
Helium Neon Laser
5 milliwatt max/CW
CLASS IIIa LASER PRODUCT
DANGER
LASER RADIATION-
AVOID DIRECT EYE EXPOSURE
ND:YAG 532nm
5 milliwatts max/CW
CLASS IIIa Laser Product
Small Beam


CLASS 3b
• Direct exposure to beam is eye hazard
• Visible or invisible
• CW maximum power 500 mW
DPSS Laser with cover removed
DANGER
LASER RADIATION-
AVOID DIRECT EXPOSURE TO BEAM
2ω ND:YAG Wavelength: 532 nm
Output Power 80 mW
CLASS IIIb Laser Product
Courtesy of Sam's Laser FAQ, www.repairfaq.org/sam/lasersam.htm, © 1994-2004

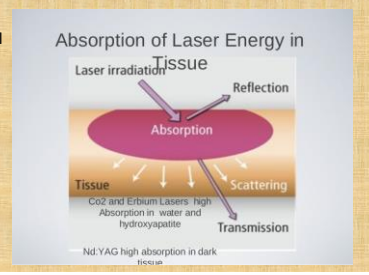

CLASS 4
• Exposure to direct beam and scattered light is eye and skin hazard
• Visible or invisible
• CW power >0.5 W
• Fire hazard
DANGER
VISIBLE LASER RADIATION-
AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION
2ω Nd:YAG
Wavelength: 532 nm
Output Power 20 W
CLASS IV Laser Product

IEC 60825 Laser Classification

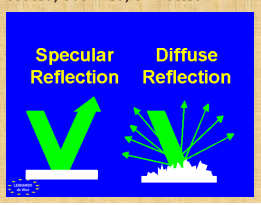
Class 1	Incapable of causing injury during normal operation (Almost the same as ANSI class 1)
Class 1M	Incapable of injury unless collecting optics are used (Currently included in class 1 under ANSI)
Class 2	Visible lasers incapable of causing injury in 0.25 s. (Same as ANSI class 2)
Class 2M	Visible lasers incapable of causing injury in 0.25 s unless collecting optics are used (ANSI visible 3a with expanded or diverging beam)
Class 3R	Marginally unsafe for intrabeam viewing; up to 5 times the class 2 limit for visible lasers or 5 times the class 1 limit for invisible lasers (ANSI visible 3a with small beam & ANSI invisible 3a)
Class 3B	Eye hazard for intrabeam viewing (Same as ANSI class 3b)
Class 4	Eye and skin hazard for both direct and scattered exposure (Same as ANSI class 4)

Laser Tissue Effects

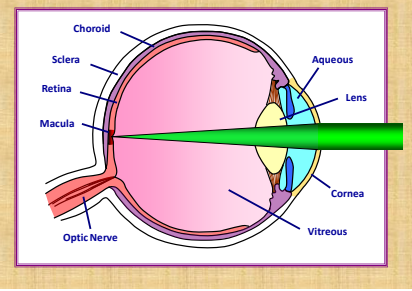
- Absorption-Goal
- Scattering
- Transmission
- Reflection



- Avoid shiny surgical instruments
- Should be coated, ebonized, or matted



HUMAN EYE -Transmission

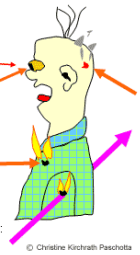


Eye Injuries from Laser Burns

- Photoretinitis
- Retinal Burns
  - Chorioretinal burns
- Photo Disruption of Retina
  - Retinal hemorrhage
- Visual Effect
  - Blind spot
- Permanent Loss of Vision
- Corneal Burns
- Deep Burns (may require corneal transplant)

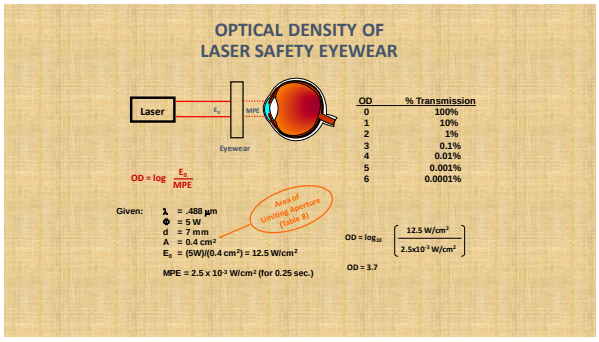
Laser Safety Issues

- **Laser pointer, 3 mW**:
  rather bright; could quickly damage the retina,
  but: blinking reflex helps
- **Small Nd:YAG laser, 100 mW**:
  invisible – no blinking reflex!
  ⇒ rather dangereous for the eyes
- Larger **Nd:YAG laser, 10 W**:
  burns skin and clothes
- Small **Nd:YAG laser** für **Q-switched pulses**:
  very hazardous even for small average output power
- Industrial high power **Nd:YAG or CO_2 laser, 1-10 kW**:
  for welding; not beneficial for skin and eyes!




DANGER
VISIBLE and/ or INVISIBLE LASER RADIATION-AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION.
ND:YAG 1064 nm
100 Watts Max. Average Power
CLASS 4 LASER


INTERNATIONAL LASER WARNING LABELS
INVISIBLE LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT
WAVELENGTH 10,600 nm
MAX LASER POWER 200 W
EN60825-1 1998
Symbol and Border: Black
Background: Yellow
Legend and Border: Black
Background: Yellow
Intro to lasers


OPTICAL DENSITY OF
LASER SAFETY EYEWEAR
Laser
E_o
MPE
Eyewear
$OD = \log \frac{E_o}{MPE}$
Area of Limiting Aperture (Table 8)
Given:
λ = .488 μm
Φ = 5 W
d = 7 mm
A = 0.4 cm²
E_o = (5W)/(0.4 cm²) = 12.5 W/cm²
MPE = 2.5 x 10⁻³ W/cm² (for 0.25 sec.)
$OD = \log_{10} \left[\frac{12.5\ W/cm^2}{2.5 \times 10^{-3}\ W/cm^2} \right]$
OD = 3.7
OD | % Transmission
0 | 100%
1 | 10%
2 | 1%
3 | 0.1%
4 | 0.01%
5 | 0.001%
6 | 0.0001%

LASER SAFETY EYEWEAR

- Check glasses for scratches

- During all laser procedure you will see a warning sign posted on the door with extra goggles/glasses for anyone who needs to enter

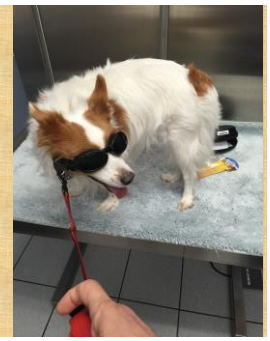
Signage

Laser Safety

- Window covering
  - Not necessary for CO2 (absorbed by glass)
  - Should be used for other wavelengths
- Keep fluids away from the laser

Patient safety

- Patient Eye Care Protection
  - Gauze, wet cotton ball and quarters
  - Metal eye shield, extra ocular and Intraocular corneal shields
  - Disposable patient shields
  - Laser Glasses



Patient Safety

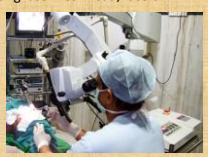
- Skin Injuries
  - UV exposure – like a sunburn
  - Thermal Injuries
  - Burns

Patient Safety

- Sponges or drapes used around a laser should be moistened
- Uses polypropylene drapes
- Use non-flammable prep solutions
- Protect teeth
- Have patient avoid mousse or hair spray
- Cover hair with wet sponge or coat with water soluble jelly

Patient Safety

- Lasers with ET Tubes
  - Endoscopic laryngeal surgery without ET tube or supplemental O2
  - Use lowest tolerable level before activating laser near head, face or neck



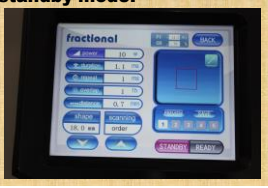
Surgical Fire Prevention in Laser Laryngeal Surgery - Department of Otorhinolaryngology Newsletter

Airway Fire Protocol

- Remove source of fire
- Stop ventilating, disconnect circuit, extubate
- Extinguish fire in bucket of water
- Mask ventilate with 100% O2, continue anesthesia IV
- Direct laryngoscopy and rigid bronchoscopy for damage and debris
- Reintubate if possible
- Trach if necessary
- CXR
- Steroids

Required Safety Practices

- **Laser should be in Ready mode ONLY WHEN THE SURGEON IS USING IT.**
- **Otherwise, it should be in standby mode.**



Required Safety Practices

- Emergency Stop Button
- Laser Signs on machine
- Key –Should never remain in the laser when not in use. Only accessible to trained laser employees.

External Safety Issues

Protective Housing
prevents access to laser radiation above safe level.

Safety Interlocks
terminate laser beam if protective housing in opened.

Only authorized personnel may operate laser with interlocks defeated.

Warning Labels
alert personnel if opening the housing might expose a laser hazard.

Viewing Windows and Optics
limit laser and collateral radiation to safe levels.

NON-BEAM HAZARDS

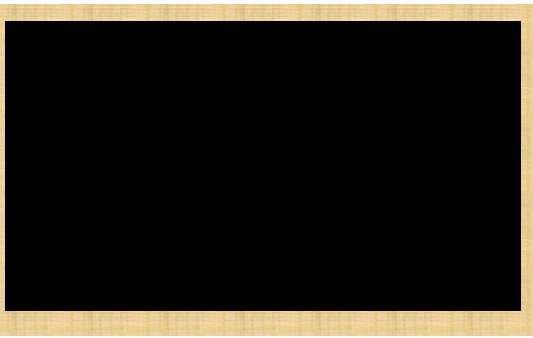
- Electrical Hazards- Check all cords including foot pedals
- Avoid multiple cords and foot pedals
- Smoke & Fumes - evaluate the need for a smoke evacuator
- Laser Fires
- Mechanical Hazards
- Flashlamp Light
- Chemical Hazards

CAUSES OF LASER ACCIDENTS

Common causes of laser injuries:

- Inadequate training of laser personnel
- Alignment performed without adequate procedures
- Failure to block beams or stray reflections
- Failure to wear eye protection in hazardous situations
- Failure to follow approved standard operating procedures or safe work practices
- Turning off audio cue when laser is activated

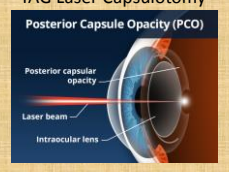
HOW LASERS ARE USED



Nd YAG Laser For Eyes

- Single pulse
- Neodymium Yttrium Aluminum Garnet
- Aiming Beam 564nm Visible (400-600nm)
- Laser – 1064 nm Invisible

- YAG Laser Capsulotomy



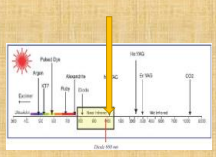
- Peripheral Iridotomy for acute angle-closure glaucoma

Blade-less Cataract Surgery

Technology is identical to the LASER used in Lasik

- Near infrared femtosecond laser with a wavelength of approximately 1053 nm
- It thus also belongs to the category of ultrafast lasers or ultrashort pulse lasers.

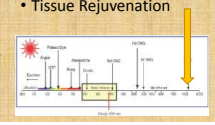
- The laser creates the micro-incisions in the cornea, the circular incision into the lens capsule (capsulotomy) and carries out segmentation of the lens, creating perfect, precise incisions
- The surgeon is able to 'design' the surgery using a sophisticated computer, tailoring the operation to the exact patient needs, with an image-guided laser



CO2 Laser

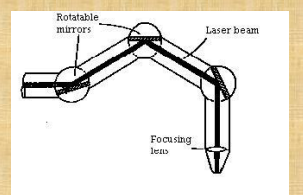
- Invisible wavelength
- Can be pulsed or continuous
- 10,600 wavelength
- Remains focused for long distances
- Uses an aiming beam
- Absorbed by water
- Seals the vessels
- Can now be used through a fiber

- ENT with Microscope
- Neurosurgery
- Spine Surgery
- Dermatology
- Plastic Surgery –Laser Resurfacing
- Heart Procedures
- Tissue Rejuvenation



CO2 Laser

- Articulated Arm



CO2 Laser

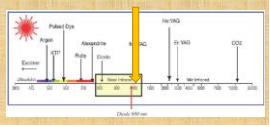
- Invisible wavelength – need a visible aiming beam to see where the laser energy is focused
- Need to test laser prior to the procedure to make sure the aiming beam and the invisible CO2 beam are in alignment and spot size is accurate

- What is wrong with this picture??

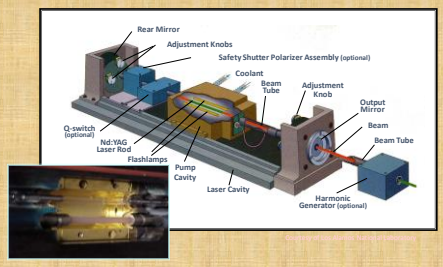
ND YAG

- Neodymium Doped Yttrium Aluminum Garnet – Solid Medium
- 1064 nm
- Invisible wavelength – Need aiming beam
- Almost always delivered by a fiber

- Laser Assisted Hair Removal
- Removal of spider veins
- Tumor de-bulking and ablation
- Laser Prostate Surgery



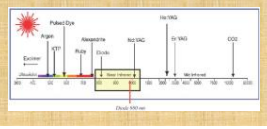
NEODYMIUM YAG LASER

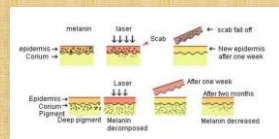


Q Switched Nd: YAG

- High Peak Power
- Nanosecond pulses
- Shatters Pigment into particles, either bounce out of skin or get absorbed

- Pigmented Lesions
- Tattoo removal (best for black/blue pigments)
- Wrinkles and Acne scars
- Hair reduction

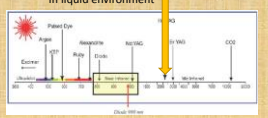




Holmium YAG

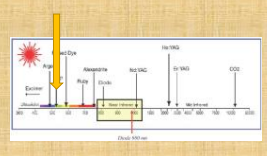
- Rare Earth Element, Doped in a YAG crystal
- 2150 nm
- Delivered in pulses
- Superheats water, creating a vaporizing bubble at the tip of the fiber
- Bubble expands rapidly and destabilizes the molecules it contacts
- Very shallow absorption rate when used in liquid environment

- Urology- Lithotripsy for urinary and bladder stones
- Arthroscopy



KTP

- Laser Beam goes through second medium, which halves the Nd-YAG laser wavelength
- Green Laser

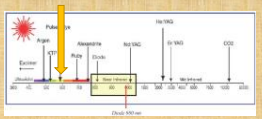


- Pan Retinal photocoagulation for diabetic retinopathy
- UPPP and Tonsillectomy
- Oral Soft tissue surgery

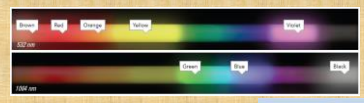
Pulsed Dye

- Can adjust wavelength - tunable

- Dermatology
  - Port wine stains
  - Scars
  - Tattoo Removal
- Urology
  - Kidney stones



Pulsed Dye

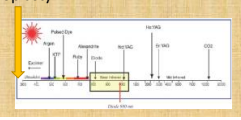


Multiple wavelengths can treat a wide range of tattoo ink colors

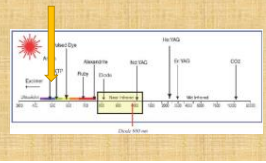
Excimer

- Multiple Wavelengths 157-351 nm
- Gas Laser Medium. Eximer is shortened form of Excited Dimer
- Disrupts molecular bonds of the surface tissue through ablation rather than burning
- Can remove exceptionally fine layers of surface material without affecting other tissue

- LASIK
- Photocoagulation to treat wet form age related macular degeneration (AMD)
- Dermatology
- Angioplasty



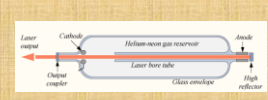
Argon

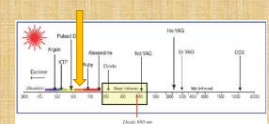


- Argon-Plasma Coagulation – cauterizes blood vessels of the airway and lung
- Can kill the cancer cells without touching the tumor- important for bleeding tumors

Helium Neon

- Also called HeNe beam
- Best known is red – 633 nm
- Used as an aiming beam with non-visible wavelengths
- Can cause eye damage if viewed with the naked eye for a period of time





Other Applications

- Photodynamic Therapy
  - Injection of Photosensitizing agent to make cells more sensitive to light
  - Subjected to Laser light, which vaporizes the tumor cells
  - Patient may be sensitive to bright light for several weeks post-op
- Dentistry
- Veterinarian Medicine
- Cold Laser Therapy
- Fat Removal – Laser Liposuction (650 nm Diode laser)

Publications by Karen Andersen

- How to Stay Laser Safety Compliant
  - Outpatient Surgery Magazine - November 2000 I, No.11
  - http://www.outpatientsurgery.net/surgical-facility-administration/personal-safety/how-to-stay-laser-safety-compliant--11-00
- Laser Technology – A Surgical Tool of the Past, Present and Future
  - AORN November 2003- Volume 78, Issue 5, Pages 794-802, 805-807
- Safe Use of Lasers in the Operating Room- What Perioperative Nurses Should Know
  - AORN January 2004, Volume 79, Issue 1, Pages 171-172,174,176-183, 185-188

Resources

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