An introduction to...

LASERS

And

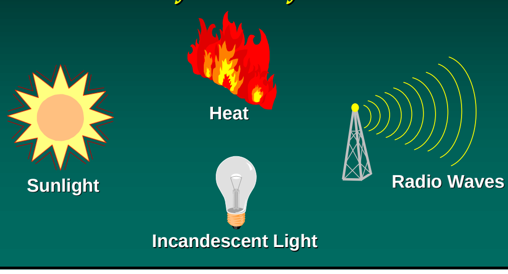
LASER Physics

The word Laser is an acronym…it stands for:

Light
Amplification by
Stimulated
Emission of
Radiation

What makes Laser light special?

Laser light is non-ionizing like these forms of radiation:

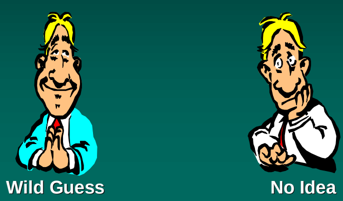


Not this Kind of Radiation!

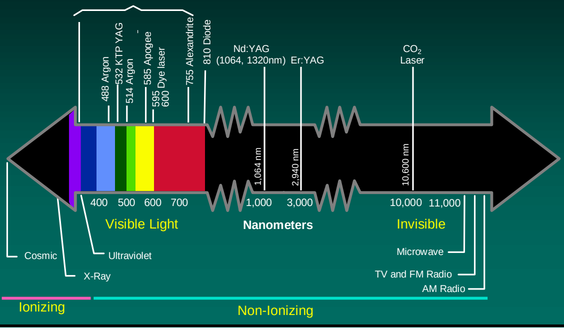
Nuclear radiation , along with gamma rays and x-rays are *ionizing* forms of radiation, meaning the exposure to them can cause cell mutation and/or death.

Lasers are a form of Electromagnetic Radiation

What are some other forms of electromagnetic radiation?



Electromagnetic Spectrum

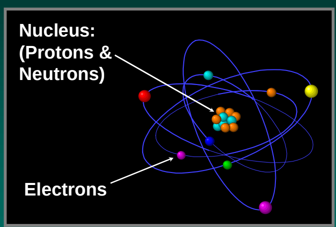


We all remember the basic structure of atoms don't we?

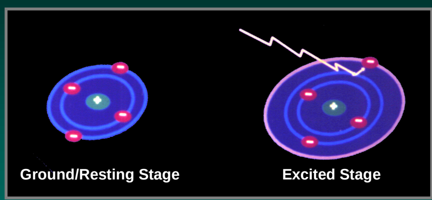
Lets go back to basic physics...

Max Plank: -

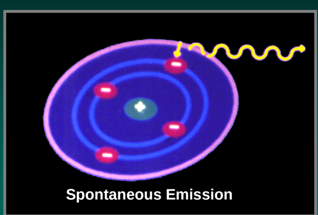
Atoms of any substance are made up of:



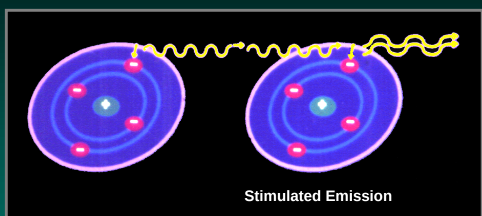
Albert Einstein



Einstein



Photon

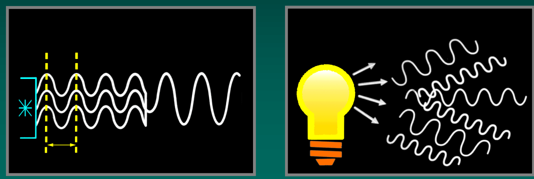


Special case of "Population Inversion" means that more photons are emitted than enter and so, light is "*amplified*"

Laser light has three properties that make it different from ordinary light...

1st Laser Light is Coherent

Coherent Light | *Incoherent Light*

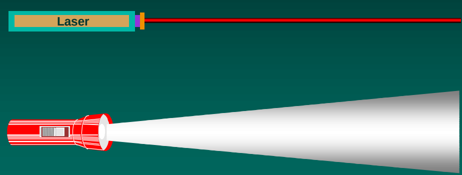


2nd Laser Light is Monochromatic

Regular “White” Light

Laser Light

3rd Laser Light is Collimated



There are Four Basic Components to Every Laser

- Lasing Medium
- Optical Cavity
- Power Source
- Delivery System

Lasing Medium

or the substance that actually produces the laser beam

This could be a GAS such as the CO_2 or Argon laser

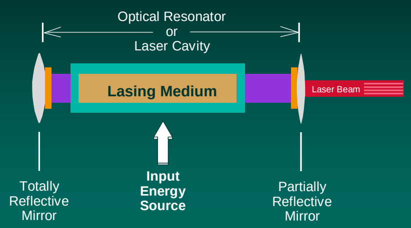
or

a SOLID such as the ND:YAG or Alexandrite laser

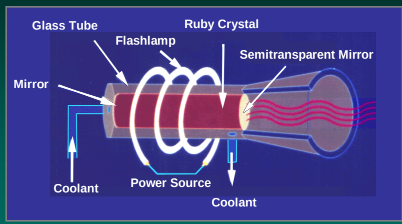
or

a LIQUID such as the Tunable Dye laser

Laser Diagram

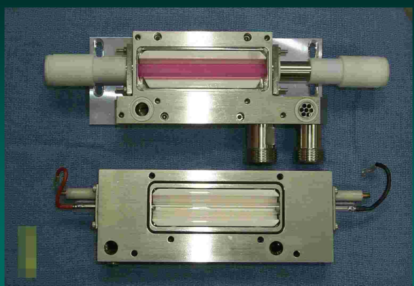


Ruby Laser

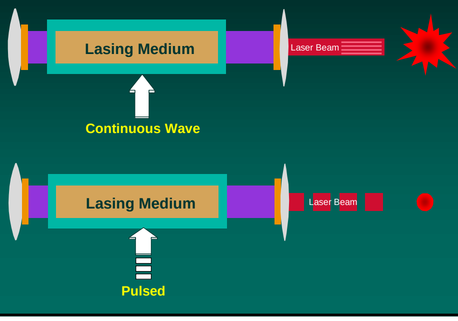


First working laser was by Maiman in 1960

Ruby Laser



Two Types of Lasers



Power Source

what is used to excite, or stimulate the lasing medium to produce the laser beam

Power sources include:

- Electricity
- Flash lamps
- Other lasers

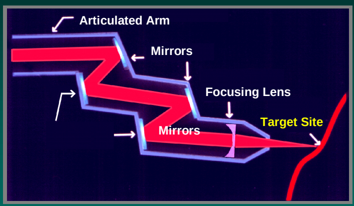
Delivery Systems

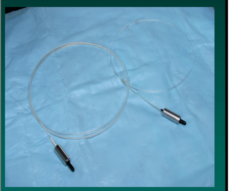
what is used to modify or alter the laser beam and get it to the patient, so it can do it's work for us

Delivery systems include:

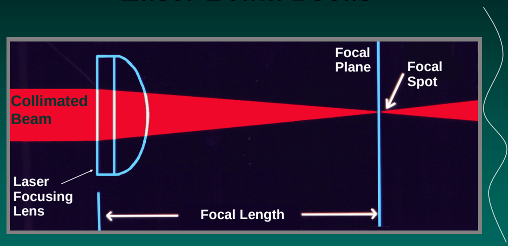
- Articulated arms
- Optical fibers
- Micromanipulators
- Focusing handpieces
- Lenses

Laser Beam Delivery System





Laser Beam Focus



Skin surface

Energy In vs. Energy out.

- What is the average efficiency of a laser?
- Is it: -
  - 5%
  - 10%
  - 50%
  - 100%
  - 150%

Does a LASER truly "Amplify" light?

So…

Now that we have this "special light", and we've delivered it to the tissue, what does it do?

Let's look at tissue effects...

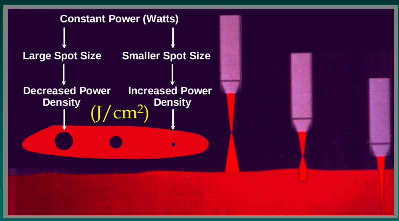
Laser Effect on Tissue

Reflection Scattering Transmission Absorption

LASER : Tissue Interactions

- Photoablation
  - Heats so intensely, tissue is ablated CO_2 Er:YAG
- Photothermal
  - Light is transformed to heat
- Photoacoustic
  - Pulse is so fast, shock wave is created "Q" Switch
- Photochemical
  - Light energy energises photosensitiser
    - ALA, PPIX PDT

Laser Spot Size vs. Power Density



Intensity

- Laser energy is normally described in units of : -
  - Watts
  - Joules
    - J/cm^2 for surface treatments
    - J/cm for lineal treatments

1 Joule = 1 Watt x 1 Second

Selective Photothermolysis

- Anderson and Parrish (Science:1983;220:524-7)
  - Use LASER wavelength that is absorbed by Chromophore of interest.
  - Selectively heat target Chromophore.
  - Leave LASER on only long enough to heat the target.

Absorption by Chromophores

Note that scale is Logarithmic!

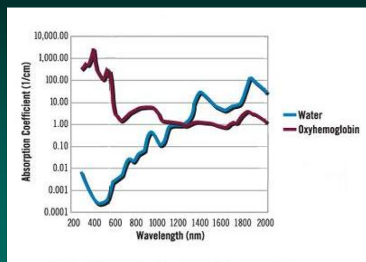
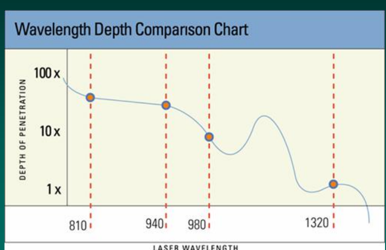
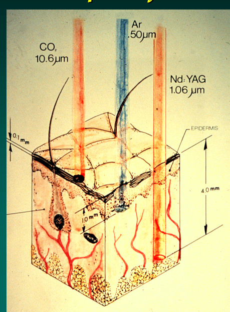


Figure 1: Absorption pattern of water and oxyhemoglobin

Penetration Depth

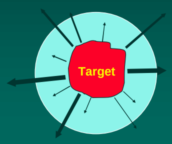


Penetration Depth of Various Lasers



Pulse Length

- Thermal Relaxation Time (TRT)
  - Defined as the time it takes for a target structure to dissipate 50% of the energy absorbed into the surrounding tissue.
- Longer pulses for larger structures



$T_r = (d \times 4k)^2$ approx

TRT

Vessel Size (μm)	TRT (msec)
30	0.86
40	1.54
50	2.40
100	9.60
150	21.6
200	38.4
250	60.0
300	86.2

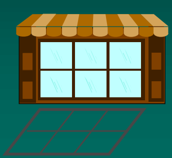
TRT

- Pulse length should be approximately equal to the TRT of the target
- Too long and cannot heat target
- Too short can have “interesting” consequences

Laser Safety

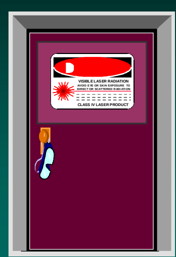
Window Protection

All windows in a laser treatment room should be protected from beam transmission.



Laser Signs

All doors to a laser treatment room are to be closed and have a laser specific danger sign along with a pair of laser eyewear.

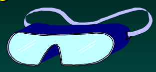


Hazards

Lasers Are Classified in Four Broad Groups:

Class I	No known biological hazard
Class II	Chronic viewing hazard only
Class III	Direct viewing hazard
Class IV	Direct and reflected hazard

Eye Protection



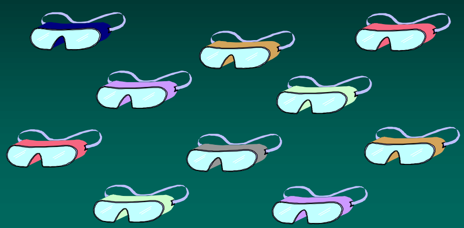
AORN Recommended Practice II

"Eyes of patients and health care workers should be protected from laser beams."

Interpretive Statement I

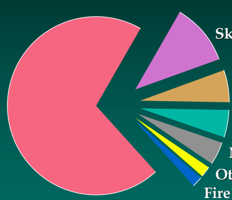
"Laser-safe eye protection with appropriate *wavelength* and *optical density* should be worn by all health care workers and all patients and labeled to protect against improper use."

Eyewear for Different Wavelengths



Laser Accident Summary

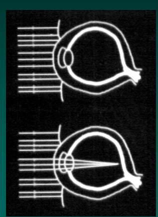
Breakdown of 172 Events



Occular Hazards

- Er:YAG 2940nm or CO_2 10,600nm
  - Corneal / Sclerol damage due to water absorption
- 400-1400nm Visible and Near-infrared
  - Retinal damage
  - Laser retinal burns can be painless
  - Appropriate eye protection required

Laser Eye Penetration



Patient Eye Protection

Choices:
- Laser Eye Wear
- Moist Sponges
- Wet Towel

ANSI Standards for Eye Safety

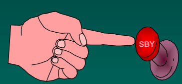
- Class III — Helium-Neon
  - Dangerous only if viewed directly
- Class IV — Argon, YAG, CO_2, Diode
  - Dangerous to view
  - Scattered radiation
  - Goggles mandatory

Fire Hazard

Be on the Lookout for Flammable or Combustable:

- Anesthetics
- Prep Solutions
- Drying Agents
- Ointments
- Plastics
- Resins
- Hair

A Laser should always be in "standby" mode unless an operator is ready to use it.



"standby please"

"laser is in standby"

Electrical Safety

- High Voltage Electricity
- Accidental Discharge Can be Fatal
- Electrical Charges Retained For a Long Time

Laser safety considerations should be no more stressing or intimidating than safety considerations for any piece of O.R. equipment.

Electrosurgical Unit	Laser
Bovie pad	Laser sign
Implants	Doors closed
Touching metal	Windows covered
Fire	Eye protection
Shock	Basin of water
Healthy tissue	Standby mode
Pre solution "pooling"	Fire

Nursing Education

- General Staff
  - Initial in-service on equipment
  - Periodic updates
- Laser Specialists
  - In-depth training in laser technology

Treatment Room

- Safety Equipment
  - Fire extinguisher
  - Emergency cart
- Miscellaneous Equipment
  - Dressings, ointments, ice packs
  - 0.5% Tetracaine eye drops, eye shields
  - Mirror, scissors, tape
  - Local anesthesia equipment

Plume Issues

- Plume Greater with Er:YAG than CO_2
- Need Excellent Smoke Evacuation
- Wall Suction Inadequate
- Use of Laser Protective Masks (0.1µ)
  - To decrease inhalation of particulate matter
- Pumped Air to Clear Handpiece

Controlling Plume Hazard

Thermal destruction of tissue creates smoke byproduct.

Plume can contain toxic gases and vapors such as benzene, hydrogen cyanide and formaldehyde, bioaerosols, dead and live cellular materials including blood fragments and viruses.

Controlling Plume Hazard

- At high concentrations, the smoke causes ocular and upper respiratory tract irritation in health care personnel and creates visual problems for the surgeon. The smoke has unpleasant odors and has been shown to have mutagenic potential.
- DHHS (NIOSH) Publication # 96-128
- (National Institute for Occupational Health and Safety)

Controlling Plume Hazard

- General room ventilation is not sufficient enough to capture contaminants.
- Smoke evacuators should have high efficiency in airborne particle reduction.
- HEPA filter or equivalent is recommended for trapping particulates.
- Generally, the use of smoke evacuators are more effective than room suction systems to control plume

Controlling Plume Hazard

- Evaluation of a Smoke Evacuator System used for Laser Surgery Lasers in Surgery and Medicine. : 276-281 (1989)

- NIOSH Health Hazard Evaluation and Technical Assistance Reports, HETA 85-126-1932 (1988) and HETA 88-101-2008 (1990)