

LASER APPLICATIONS TO MEDICINE AND BIOLOGY



Dr. wafaa mansor



FIRST OFF WHAT DOES LASER STAND FOR?

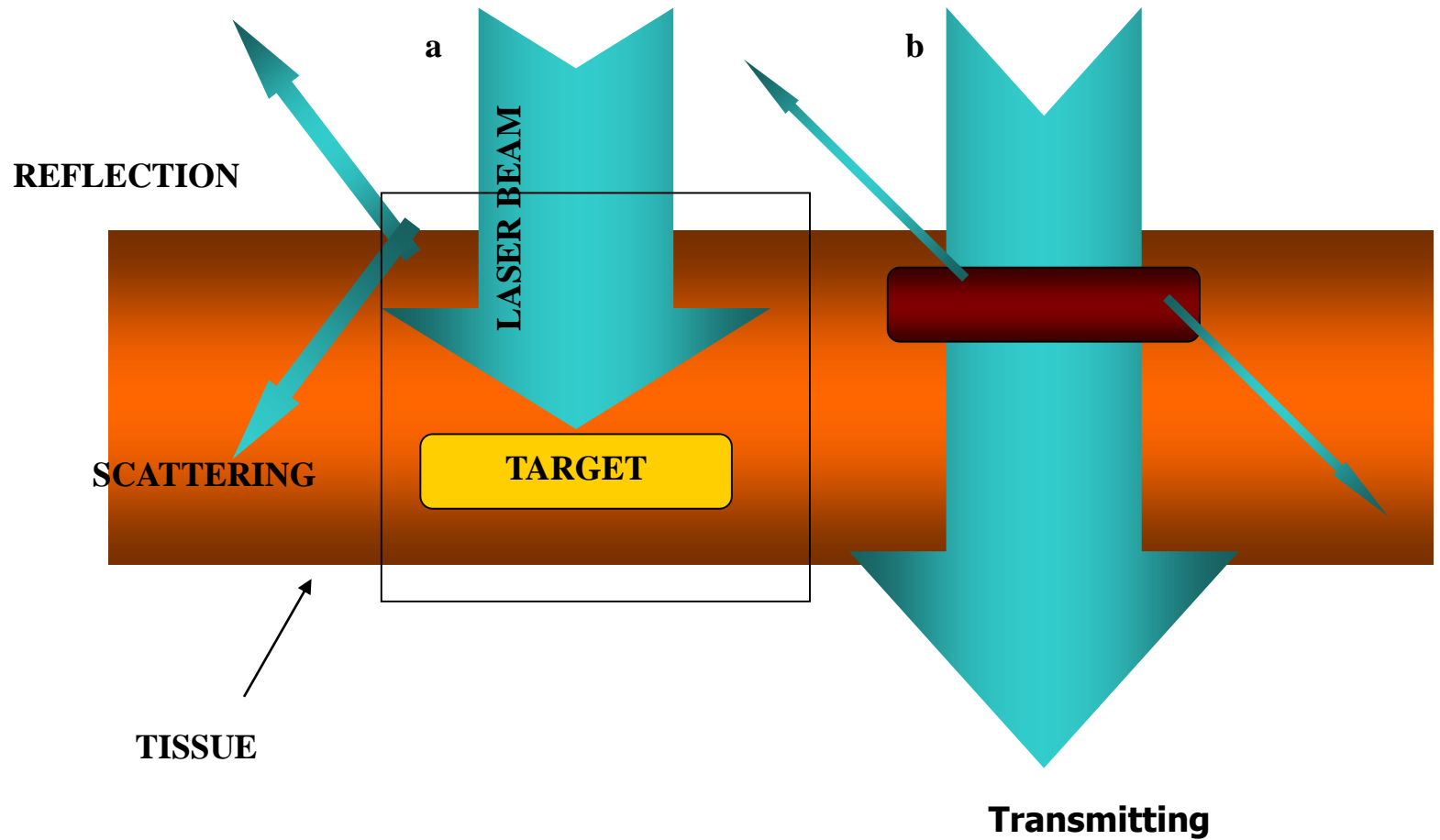
- **LIGHT**
- **AMPLIFICATION BY**
- **STIMULATED**
- **EMISSION OF**
- **RADIATION**

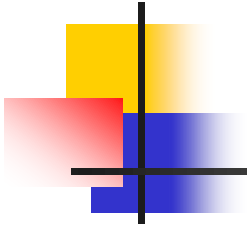


Basic Concepts:

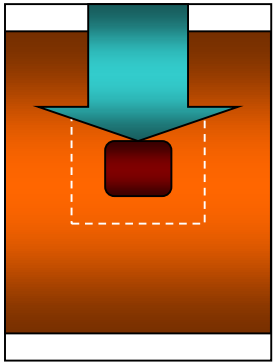
- ***Laser*** is a **narrow beam** of light of a single wavelength (**monochromatic**) in which each wave is in phase (**coherent**) with other near it.
- ***Laser apparatus*** is a device that produce an intense concentrated, and highly parallel beam of coherent light.

Laser Tissue Interaction:





c



HEAT

d

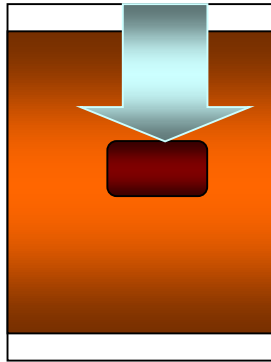
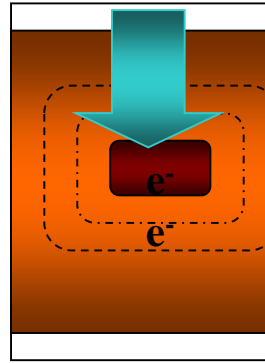


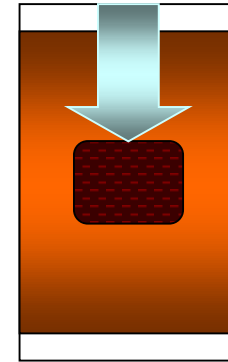
PHOTO-DISSOCIATION
(Break molecular bond)

e



SHOCK WAVE
(Breaks mineralized deposits)

f



FLUORESCENCE
For diagnostic

g

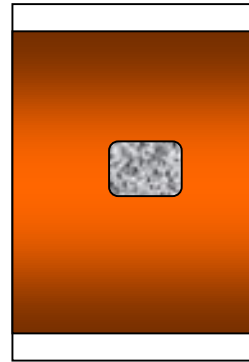
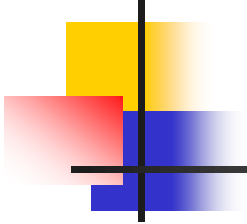


PHOTO-CHEMISTRY
Destroy the target



TREATMENT & DIAGNOSTIC BY LASER

- **PHOTOCOAGULATION OF THE RETINA**
- Heating a blood vessel to a point where the blood coagulate and block the vessel.
- Photocoagulation can be done by:
 - 1- Xenon lamp
 - 2- Laser



Photocoagulation

Xenon lamp:

Spot size 750 μ m

High energy deposited in the eye:
20-50 times greater than deposited
treatment by laser beam

Longer exposure (1 sec)
than laser, so local anesthesia
must be used

Laser

Spot size 50 μ m
low energy deposited in the eye

Short exposure (μ s to ms)
So local anesthesia are not needed



Laser Treatment & Diagnostics

- Treatment cover everything from the ablation of tissue using high power lasers to photochemical reaction obtained with a weak laser.
- Diagnostics cover the recording of fluorescence after excitation at a suitable wavelength and measuring optical parameters.



Diagnostic Laser System

Several factors have to be considered in designing a diagnostic laser system:

- 1- A suitable excitation wavelength.
- 2- Knowledge about fluorescence properties of different chromophores in tissue is needed.
- 3- Origin of the fluorescence spectra must be identified.
- 4- Tumor seeking drugs (e.g. hematoporphyrin) is used to enhance the optical demarcation of malignant tumors.

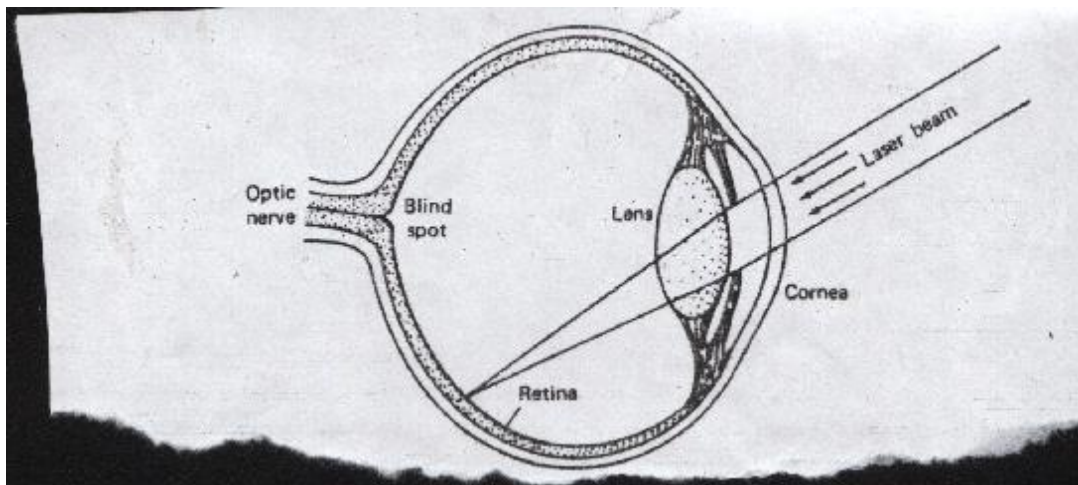


Surgical Application of Laser

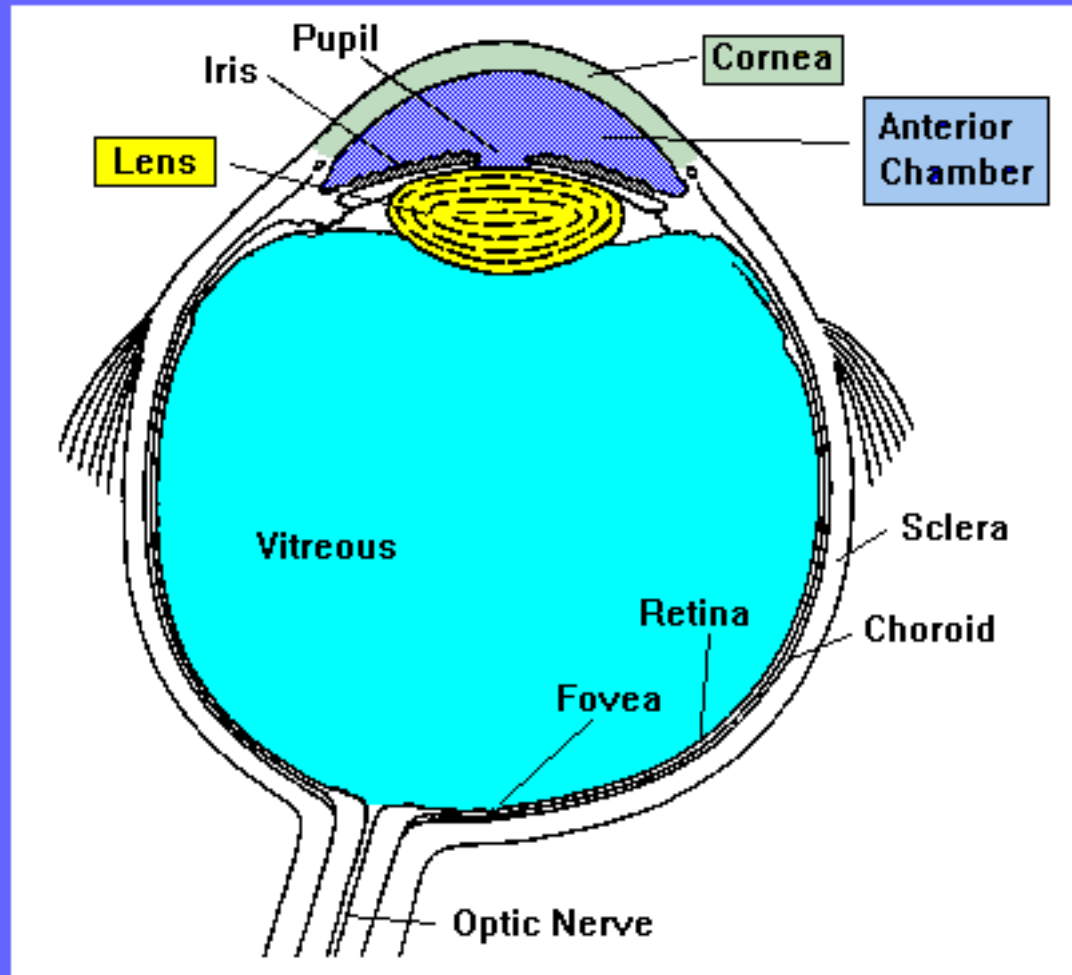
- Tissue heating (Skin rejuvenation & tissue welding)
- Coagulation
- Vaporization
- Fragmentation of tattoo pigment
- Cold cutting
- Photoacoustic (lithotripsy)
- Photodissociation (non-thermal ablation of the cornea in ophthalmology).

Retina Treatment

- The dark brown melanin pigment of the retina absorb the green beam of the argon laser.
- The argon laser can destroy specific regions of the retina without harming the other area of the eye, which absorb different wavelength of light.



Laser Eye Surgery



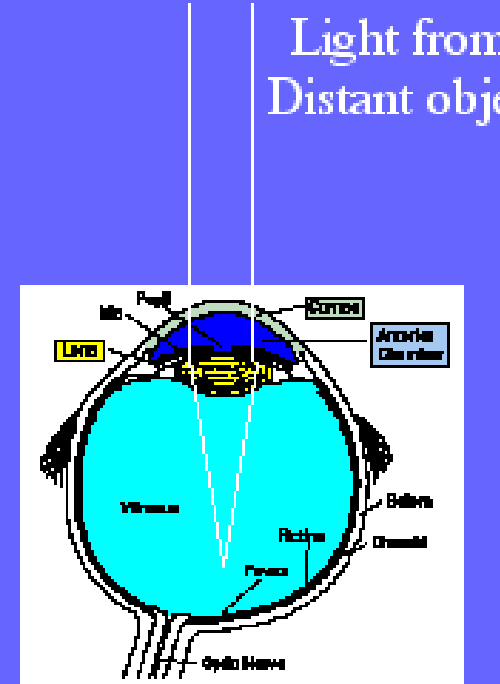
PRK

(photorefractive keratectomy)

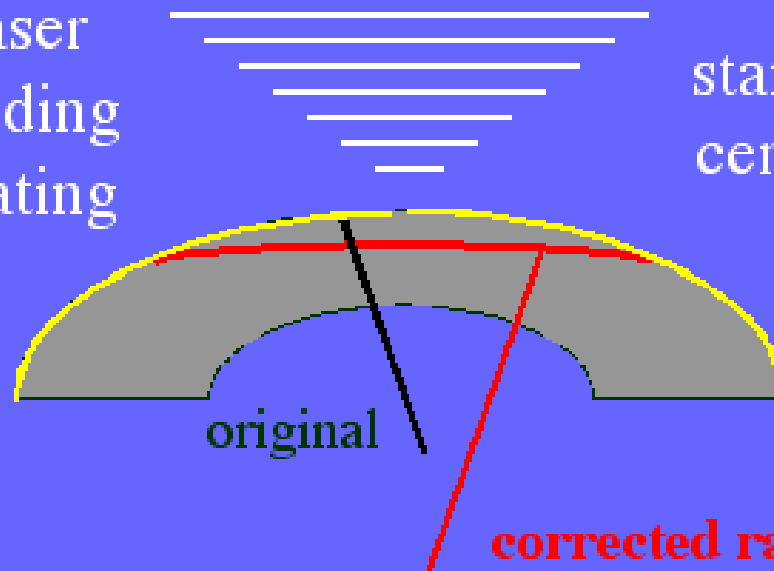
Myopia: Lens focal length is TOO SHORT

$$P = \frac{1}{f} = (n-1) \left(\frac{1}{R_1} \right)$$

R_1 TOO small -- NEED to flatten the cornea



UV 193 nm excimer laser
Exceeds molecular binding
Ablates cornea/ no heating



stair-step pulses (10 Hz)
center is more ablated

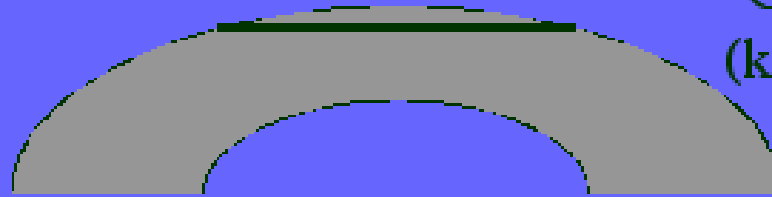
Bowman's membrane
removed - regenerates
after a few days
(occasional haze)

corrected radius of curvature

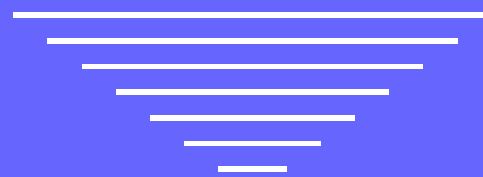
LASIK

(laser-assisted in situ keratomileusis)

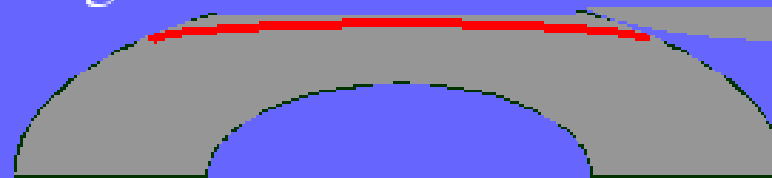
Corneal flap cut
(knife or IR laser)



UV 193 nm excimer laser
Exceeds molecular binding
Ablates cornea/ no heating



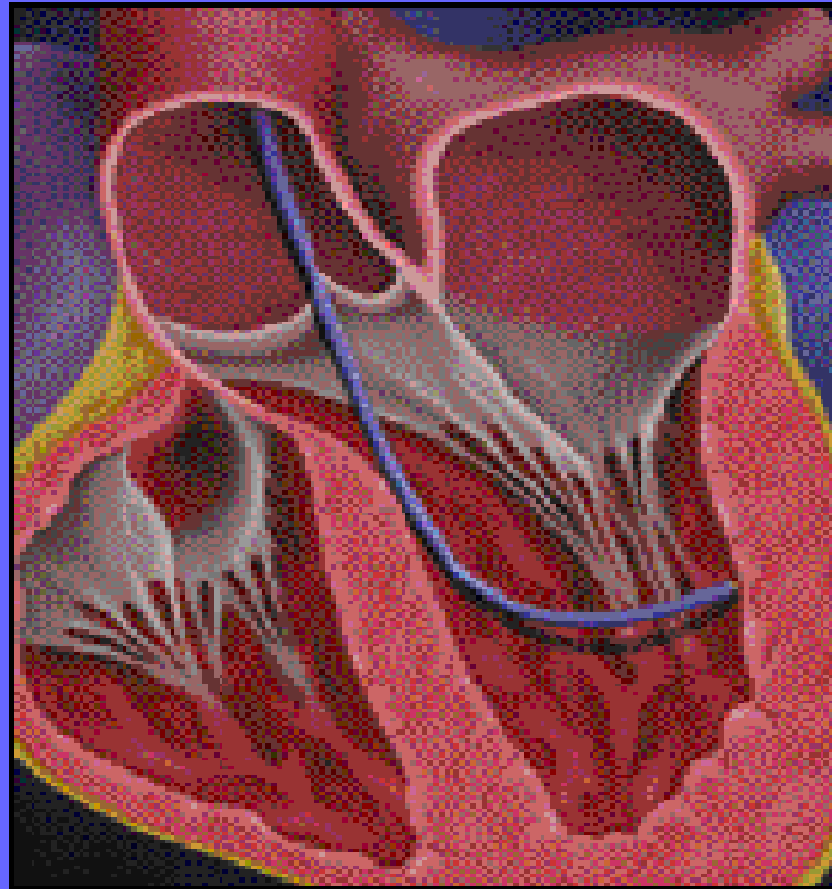
stair-step pulses (10 Hz)
center is more ablated



original

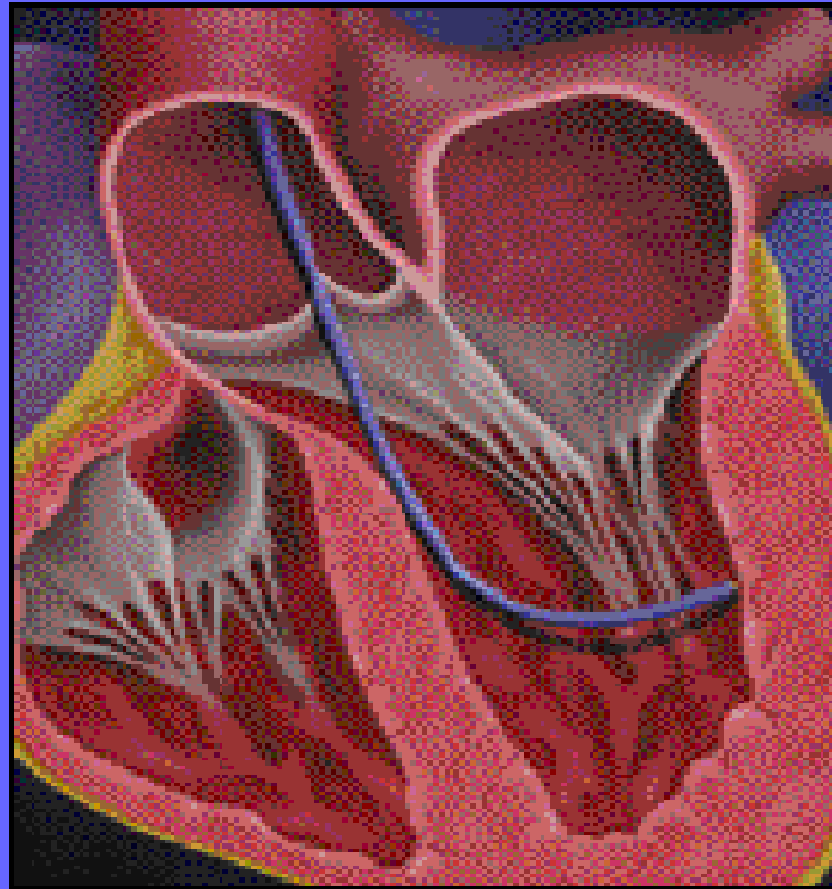
corrected radius of curvature

Laser Surgery: Revascularization



For end-stage coronary artery disease and angina pectoris
alternative to coronary bypass surgery and angioplasty:
Burn channels in the myocardial wall with Ho:YAG laser ($2.1 \mu\text{m}$)
Transmitted via optical fiber into the left ventricle
percutaneous transluminal myocardial revascularization

Laser Surgery: Revascularization

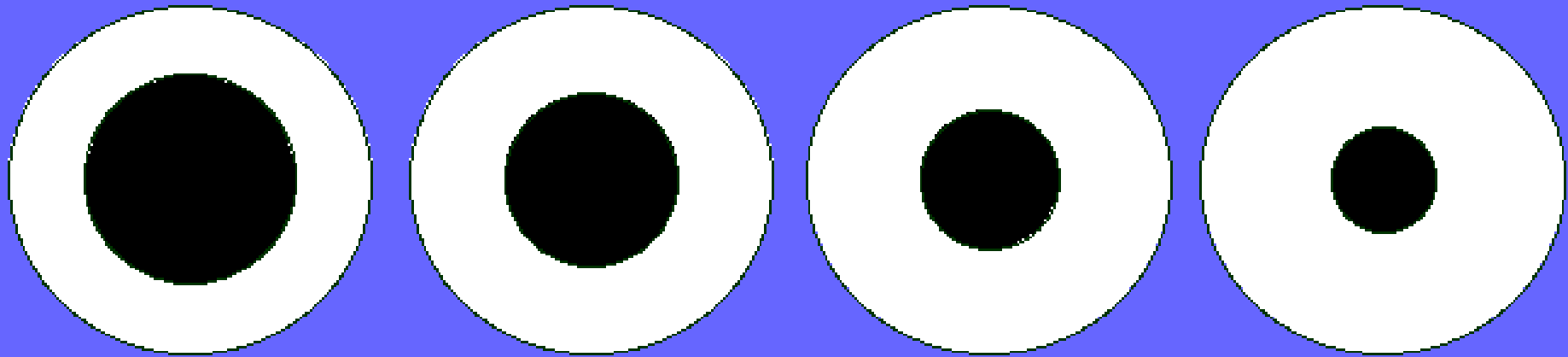


“Certainly a placebo effect cannot be ruled out. Otherwise Desperate patients are offered new hope connected with the Somewhat magical word ‘laser’” - Dr. Bernward Lauer

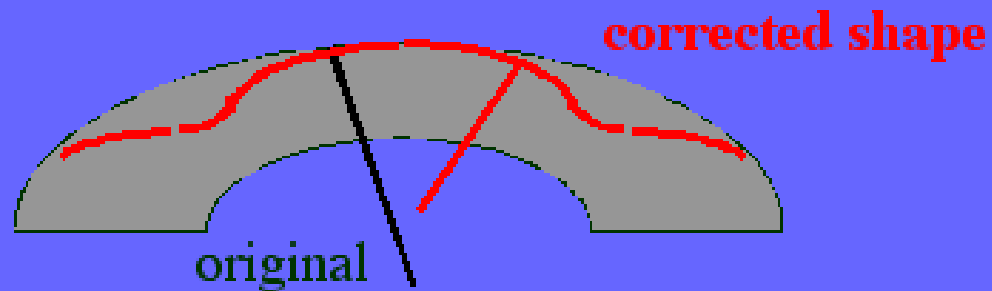
Laser Eye Surgery: Hyperopia

Lens focal length is TOO LONG

$$P = \frac{1}{f} = (n-1) \left(\frac{1}{R_1} \right)$$



LESS ablation in the center

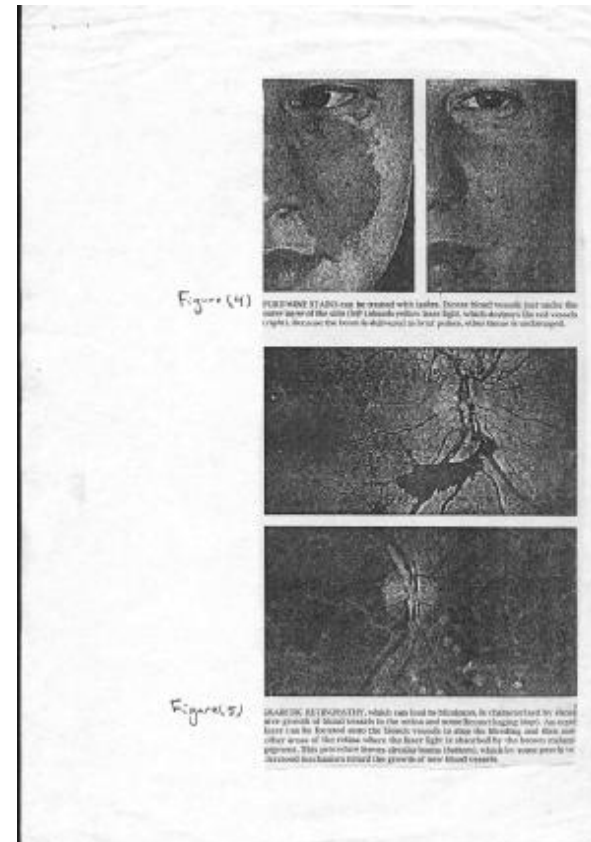


Other therapeutic laser applications

- Dermatology
 - Hair removal (700-1000 nm)
 - Skin resurfacing (3-10 μm)
 - Vascular and pigment conditions (532-600 nm)
- Ophthalmology
 - Detached retina repair
 - Retinal cancer
- Stroke clot blasting (via fiber optic)

Red birthmarks (Port wine stains)

- Red birthmarks also absorb the argon laser, which could be blue or green depending on its wavelength.
- The absorbed light destroys hundreds of the extra blood vessels that beneath the skin's outer layer and discolor it.





Disadvantages

- The heat generated by the beam can sometimes **spread** to parts of the skin other than the abnormal blood vessels and cause scarring or loss of pigments.
- R. Rox Anderson and A. Jhon (1983) (Harvard University) suggested that **short exposure** less than 1 ms – to intense light would destroy the absorption site but produce little or no damage to adjacent tissue.



Advantage of wide damage

- Wide damage caused by the longer slower heating of tissue can be turned advantage.
- Removing of a damaged portion of the liver cause extensive bleeding.
- The long exposure to a continuous wave laser reduces bleeding because heat spreads to the capillaries nearby.
- A CO₂ laser with a wavelength 10.6 microns may be used because it is absorbed by the compound most common to tissue: Water



Intraocular Nd: YAG Laser

Damage Mechanisms of intraocular Nd:YAG Laser Surgery (Single laser pulse):

- Plasma formation and expansion
- Emission of acoustic transient
- Cavitations with jet formation

Pulsed lasers can also remove tissue



- Er-YAG Laser (Erbium Yttrium-Aluminum Garnet) which has a wavelength of 2.9 micron and pulse duration of 200 us, can cleanly ablate calcified bone.
- Xenon chloride excimer laser (0.308 microns and pulse duration of 10 ns) can vaporize bone with little or no associated thermal damage.

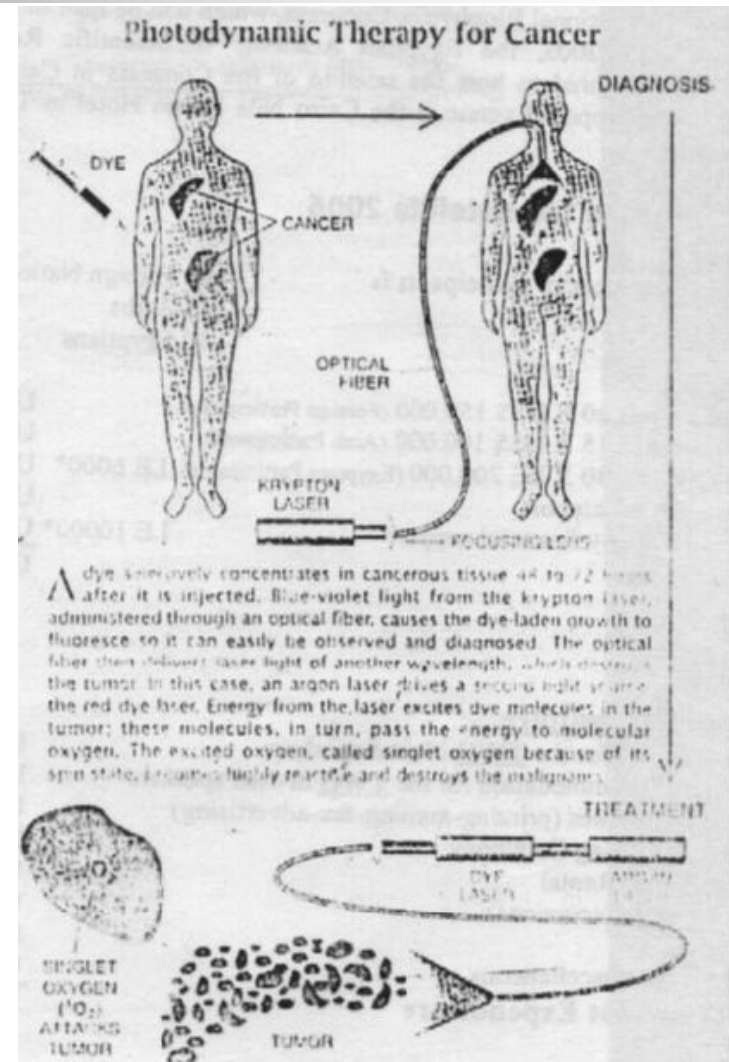


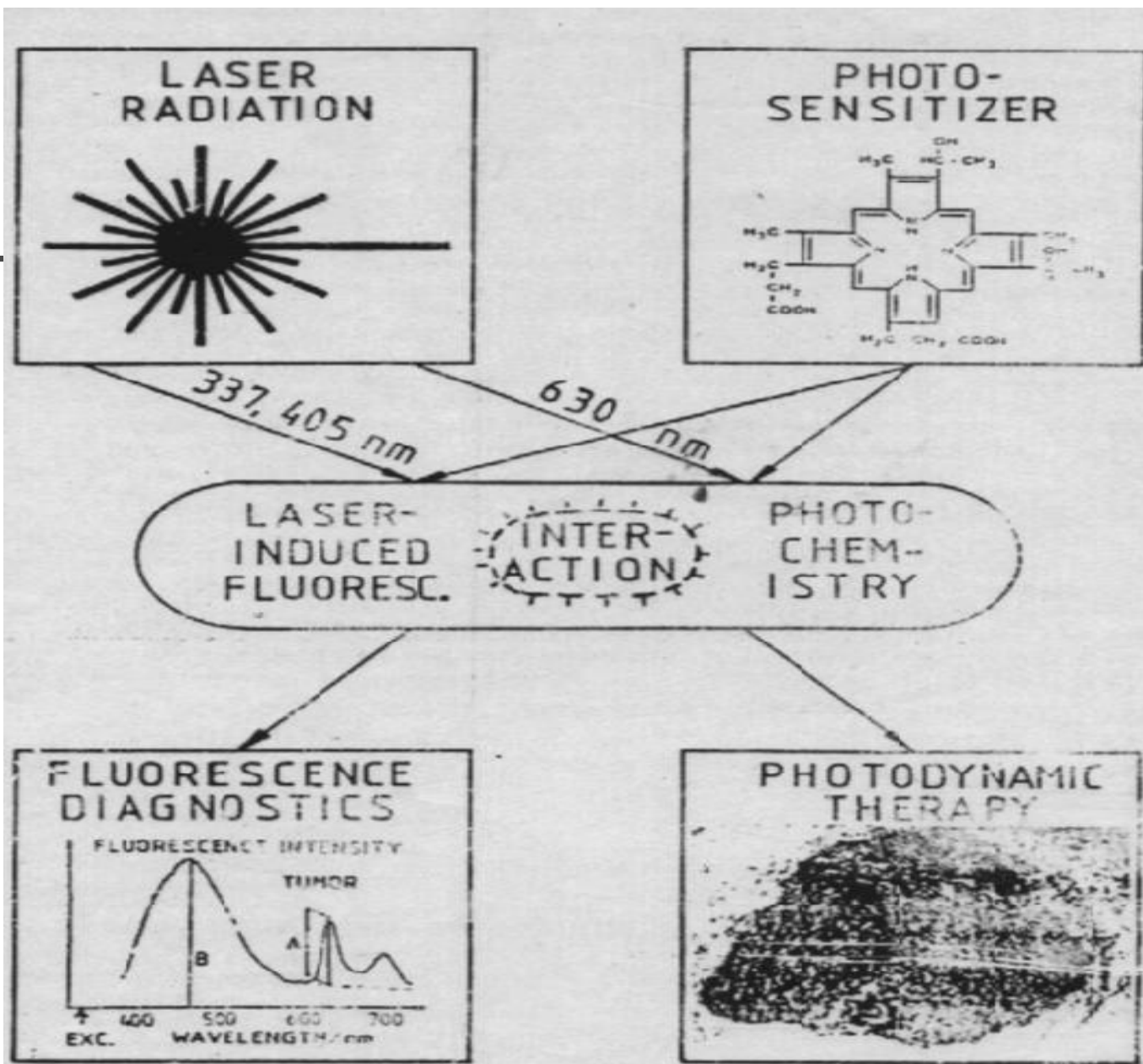
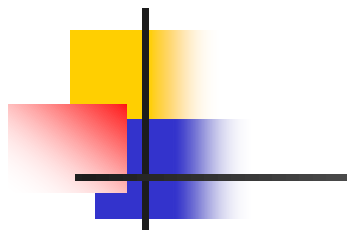
Laser and Fiber Optics

- Coupling lasers with other technologies such as fiber optics, one can achieve non-thermal, as well as thermal, results in previously inaccessible parts of the body.

Photodynamic Therapy of Cancer

- A dye selectively concentrates in cancerous tissue 48 to 72 hours after it is injected.
- Blue-violet light from krypton laser, administered through an optical fiber, causing dye to fluorescence, so it can easily be observed and diagnosed.
- The optical fiber then drives laser light of another wave length, which destroys the tumor.







Laser Angioplasty

- The removal of plaque in obstructed vessel by laser, administered through a fiber optics.
- Fluorescence characterization of the vessel wall could be performed via the same fiber as that used for the delivery of high-power pulses for plaque removal.

Malignant Tumor and Atherosclerotic Plaque Diagnosis Using Laser-Induced Fluorescence

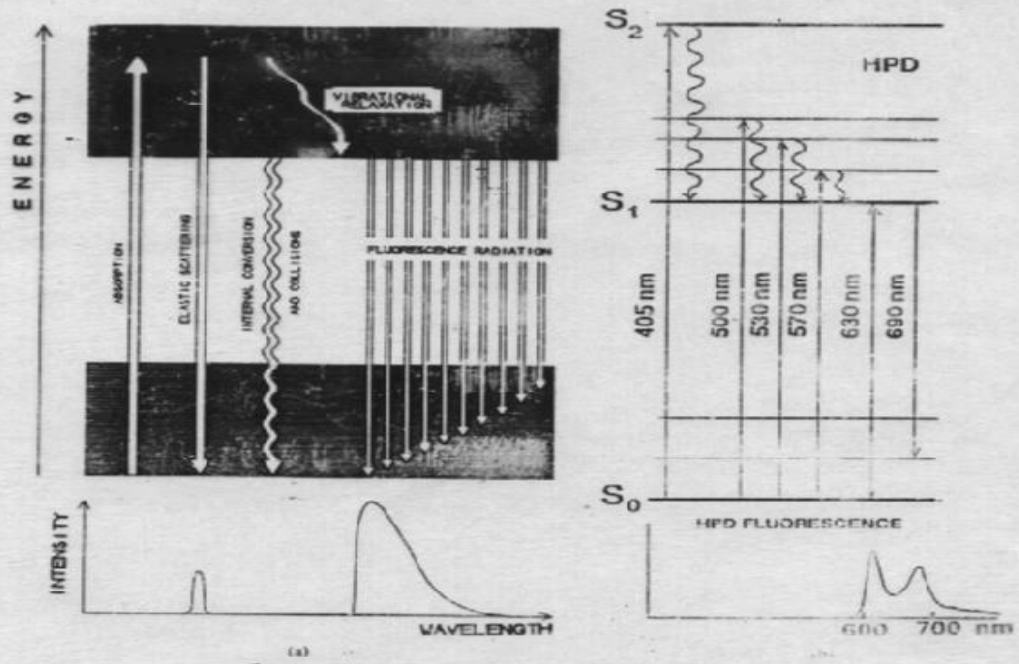
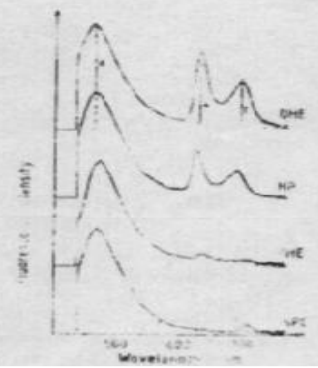
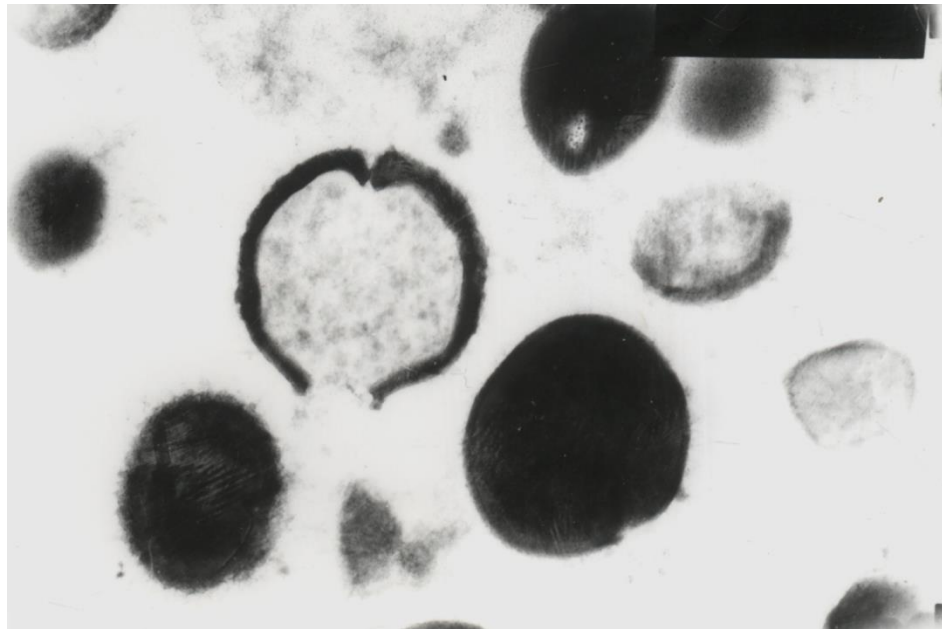


Fig. 7. (a) Schematic diagram of the LIF process in large molecules. (b) Schematic energy-level diagram and fluorescence for hematoporphyrin molecules.



Ultrastructural changes of *Staph. aureus* by laser irradiation:





There are many benefits of laser dentistry. They include:

- Faster healing.
- Reduced risk of infection
- Decreased Sensitivity.
- Less time in the dental chair.
- Less bleeding.
- Less post-treatment discomfort



laser Doppler velocimeter

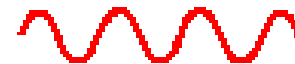
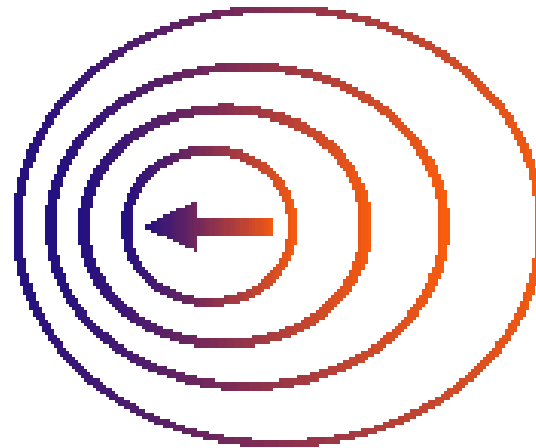
- The **laser Doppler velocimeter** sends a monochromatic laser beam toward the target and collects the reflected radiation.
- According to the Doppler effect, the change in wavelength of the reflected radiation is a function of the targeted object's relative velocity.
- Thus, the velocity of the object can be obtained by measuring the change in wavelength of the reflected laser light, which is done by forming an interference fringe pattern.



Typical Laser Doppler Velocity meter (Velocimeter)

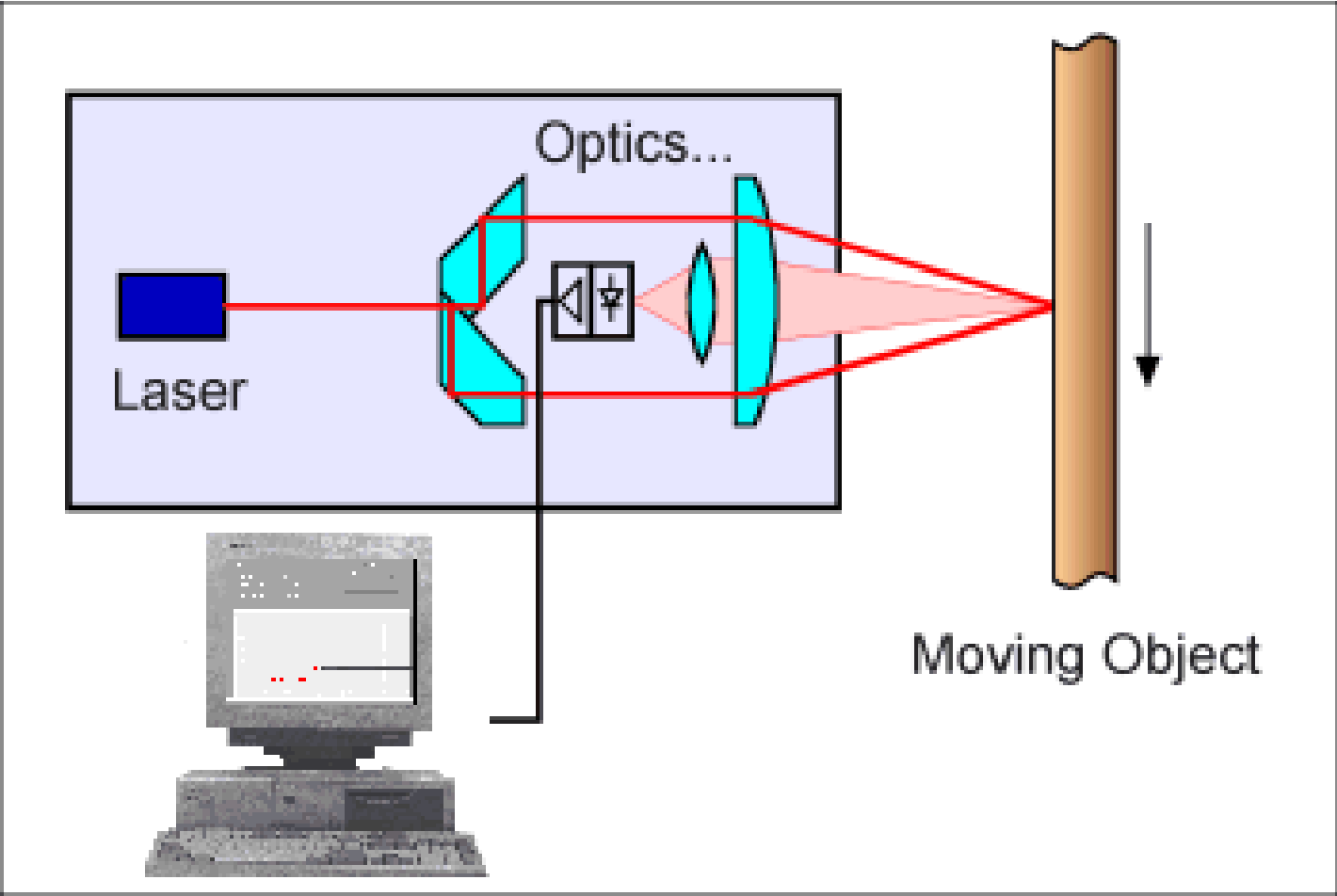
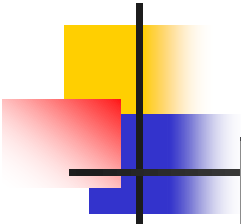
- A laser power source is the essential part
- a Helium-Neon (He-Ne) or Argon ion laser with a power of 10 mW to 20 W is used.
- Lasers have many advantages over other radiation/wave sources, including excellent frequency stability, small beam diameter (high coherence), and highly-focused energy.

Doppler Effect

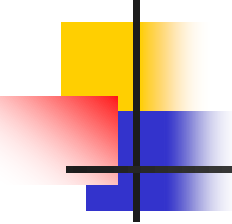


Source moving TOWARD observer
Wavelength decreasing,
Frequency increasing,
Observer experiencing BLUE shift.

Source moving AWAY from observer
Wavelength increasing,
Frequency decreasing,
Observer experiencing RED shift.



Comparison Between the Single - Beam and Cross-Beam Systems



- single-beam system,
 - employs a focused laser beam which is scattered from particles.
 - A portion of the scattered light is sampled and mixed with a portion of the unscattered laser beam and collected by an optical - p h o t o m u l t i p l i e r system
 - The two l i g h t beams heterodyne to yield the difference frequency between the two light beams.



Thank you
