BASIC PRINCIPLES OF MEDICAL LASERS

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Introduction

LASER

Light **A**mplification by **S**timulated **E**mission of **R**adiation.

- An optical source that emits photons in a coherent beam.
- In analogy with optical lasers, a device which produces any particles or electromagnetic radiations in a coherent state is called “Laser”, e.g., Atom Laser.
- In most cases “laser” refers to a source of coherent photons i.e., light or other electromagnetic radiations. It is not limited to photons in the visible spectrum. There are x-ray lasers, infrared lasers, UV lasers etc.

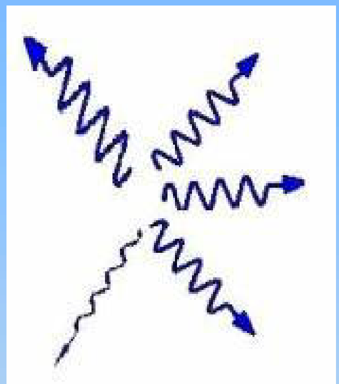
Properties of Laser Light

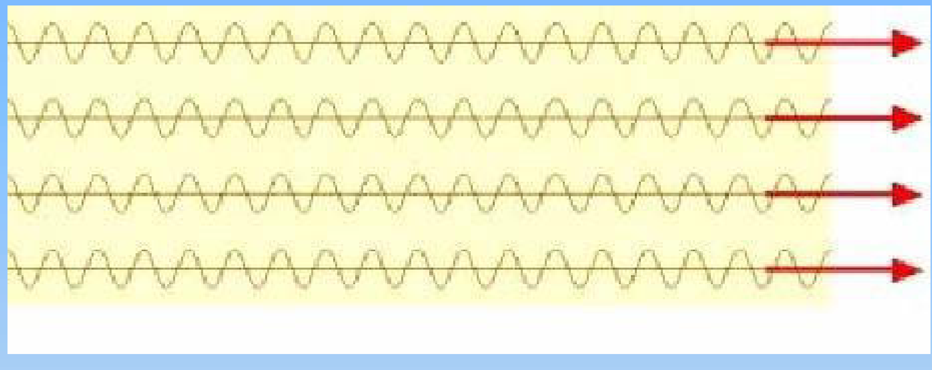
- The light emitted from a laser is ***monochromatic***, that is, it is of one color/wavelength. In contrast, ordinary white light is a combination of many colors (or wavelengths) of light.

- Lasers emit light that is highly ***directional***, that is, laser light is emitted as a relatively narrow beam in a specific direction. Ordinary light, such as from a light bulb, is emitted in many directions away from the source.

- The light from a laser is said to be ***coherent***, which means that the wavelengths of the laser light are in phase in space and time. Ordinary light can be a mixture of many wavelengths.

Ordinary Light vs. Laser Light





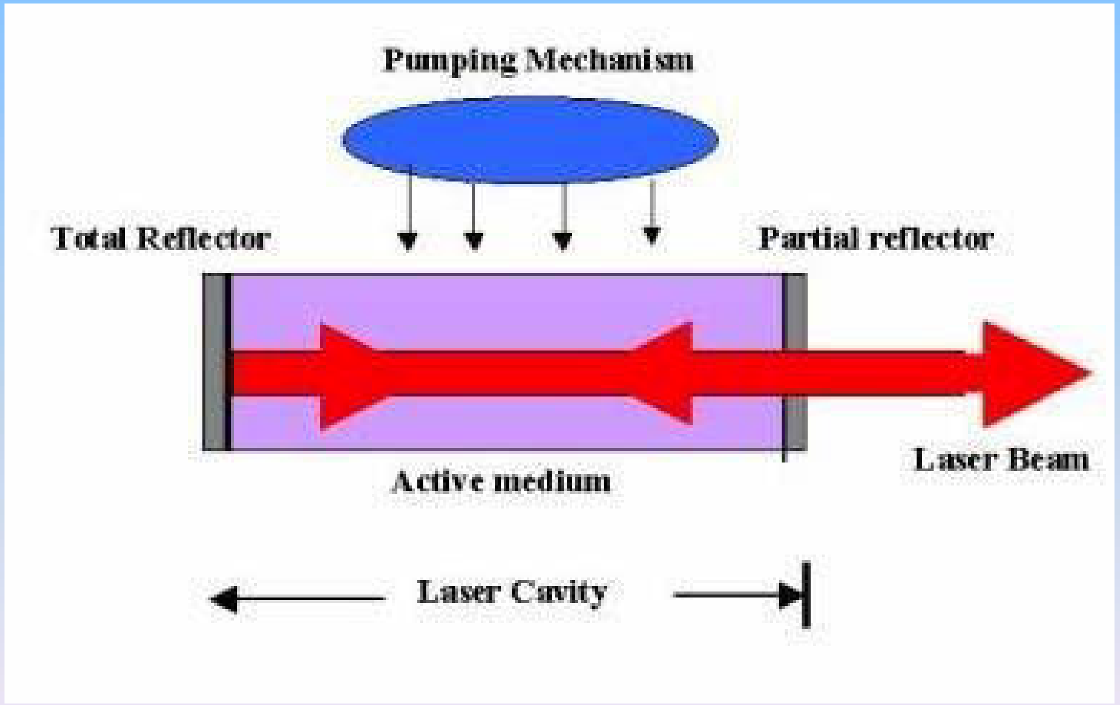
Laser Light

Ordinary Light

Basic Components of Laser 1

Laser system consists of three important parts.

1. Active medium or laser medium
2. An energy source (referred to as the pump or pump source)
3. An optical resonator consisting of a mirror or system of mirrors



Basic Components of Laser 2

Active Medium

Major determining factor of the wavelength of operation and other properties of laser.

- Hundreds of different gain media in which laser operation has been achieved.
- The gain medium may be solid crystals such as ruby or Nd:YAG, liquid dyes, gases like CO_2 or Helium/Neon, and semiconductors such as GaAs.

Pumping Mechanism

- The pump source is the part that provides energy to produce a population inversion.
- Pump sources include electrical discharges, flash lamps, arc lamps, light from another laser, chemical reactions and even explosive devices.
- The type of pump source used principally depends on the gain medium.

Optical Resonator

Its simplest form is two parallel mirrors placed around the gain medium.

- Light from the medium produced by the spontaneous emission is reflected by the mirrors back into the medium where it may be amplified by stimulated emission.
- One of the mirrors reflects essentially 100% of the laser light while the other reflects less than 100% of the laser light and transmits the remainder.

Basic Principles of Light Emission and Absorption 1

In 1916, Einstein considered various transition rates between atomic states (say, 1 and 2) involving light of intensity, *I*.

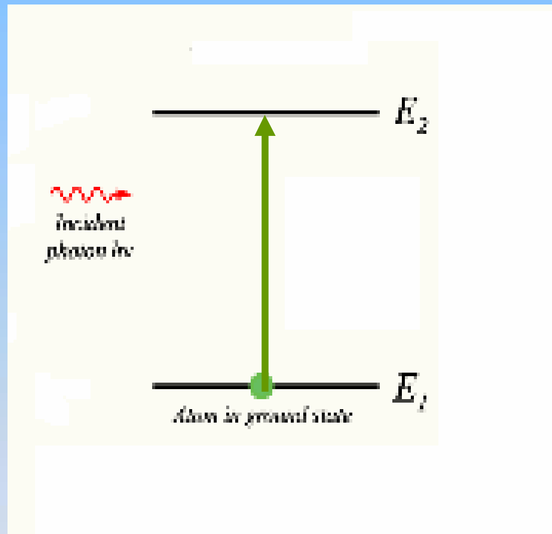
- **<u>Absorption:</u>**

  Absorption is the process by which the energy of the photon is taken up by another entity, e.g., by an atom whose valence electrons make transition between two electronic energy levels. The photon is destroyed in the process.

  Rate of Stimulated Absorption = $B N_1 I$

  B Einstein's Coefficient for Stimulated Absorption

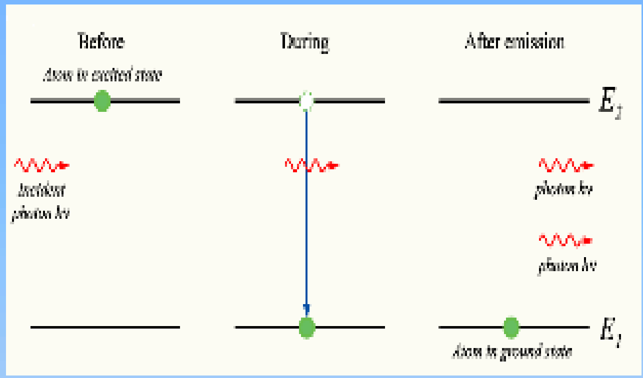
  N_1 Population in the Ground State



Basic Principles of Light Emission and Absorption 2

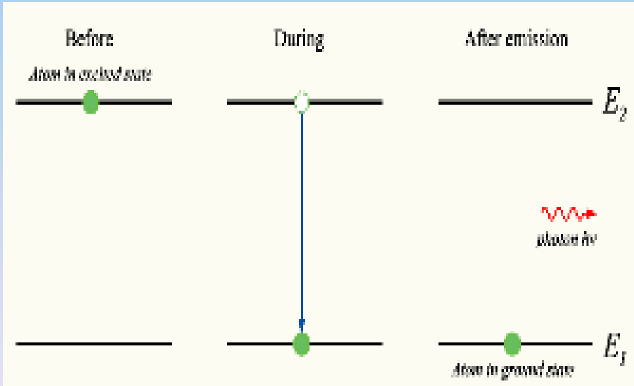
- **Stimulated Emission:**
  A process by which, when perturbed by a photon, matter may lose energy resulting in the creation of another identical photon.

  Rate of stimulated emission = $B N_2 I$
  B Einstein's Coefficient for Stimulated Emission
  N_2 Population in the Excited State

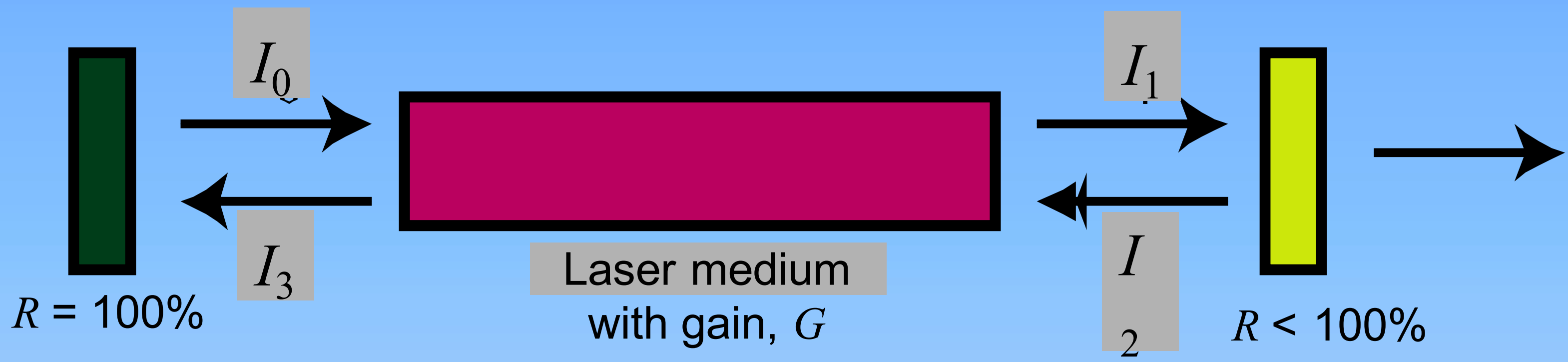


- **Spontaneous Emission:**
  A process by which an atom, molecule in an excited state drops to a lower energy level.

  Rate of spontaneous emission = $A N_2$
  A Einstein's Coefficient for Spontaneous Emission



Threshold Condition



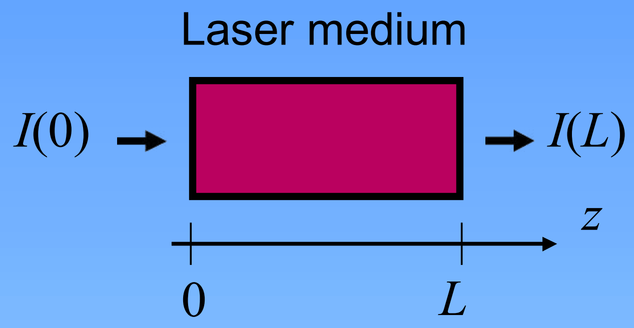
A laser action will be achieved if the beam increases in intensity during a round trip: that is, if $I_3 \geq I_0$

Usually, additional **losses** in intensity occur, such as absorption, scattering, and reflections. In general, the laser will lase if, in a round trip:

Gain > Loss

This is called achieving **Threshold**.

Laser Gain



Neglecting spontaneous emission:

$$\frac{dI}{dt} = c\frac{dI}{dz} \propto BN_2 I - BN_1 I$$ [Stimulated emission minus absorption]

$$\propto B\left[N_2 - N_1\right] I$$

$$I(z) = I(0)\exp\left\{\sigma\left[N_2 - N_1\right]z\right\}$$

Proportionality constant is the **absorption/gain cross-section, σ**

There can be exponential gain or loss in intensity. Normally, $N_2 < N_1$, and there is loss (absorption). But if $N_2 > N_1$, there's gain, and we define the gain, G:

$$G \equiv \exp\left\{\sigma\left[N_2 - N_1\right]L\right\}$$

If $N_2 > N_1$: $\quad g \equiv \left[N_2 - N_1\right]\sigma$

If $N_2 < N_1$: $\quad \alpha \equiv \left[N_1 - N_2\right]\sigma$

Population Inversion

In order to achieve $G > 1$, that is, stimulated emission must exceed absorption:

$$B N_2 I > B N_1 I$$

Equivalently,

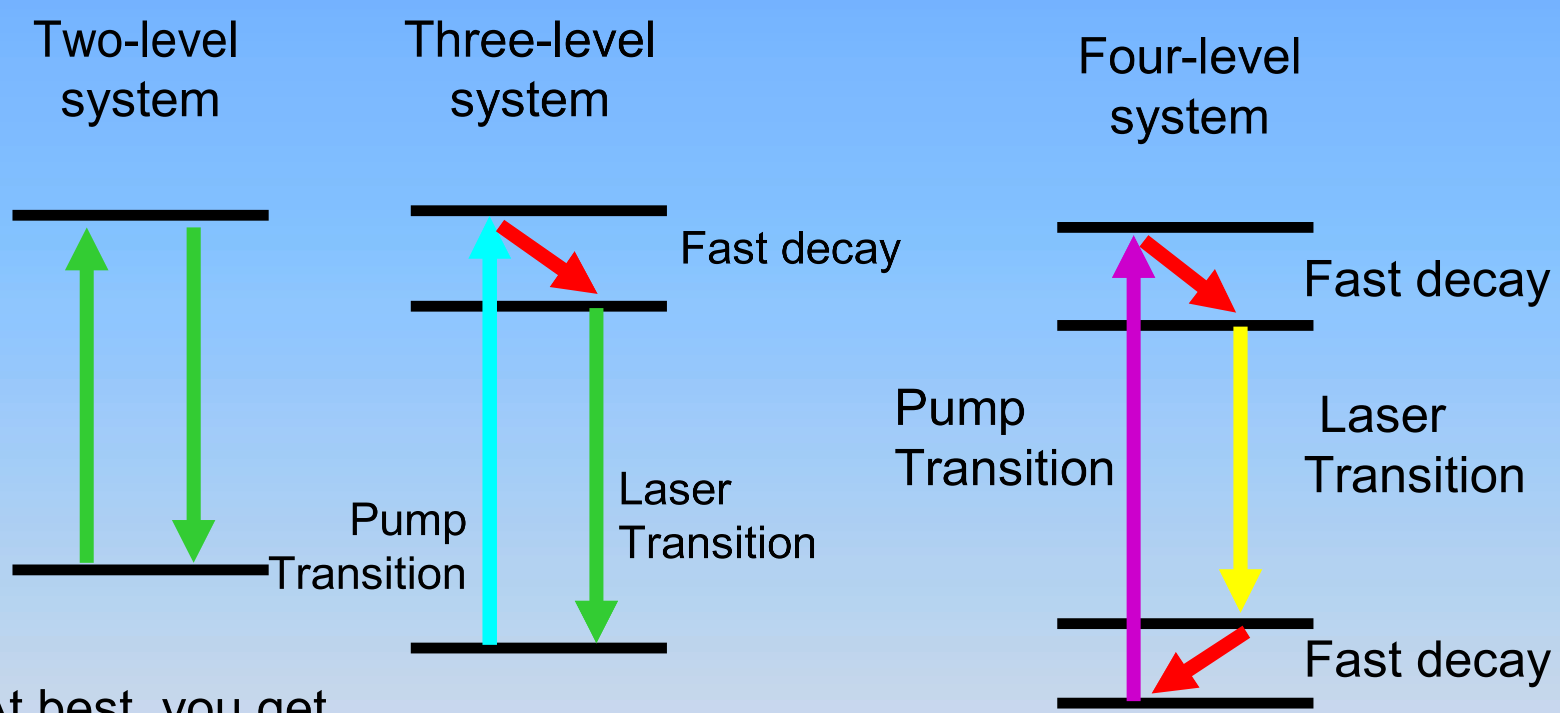
$$N_2 > N_1$$

This condition is called ***population inversion***. It does not occur naturally. It is inherently a non-equilibrium state.

In order to achieve inversion, we must pump the laser medium in some way and choose our medium correctly.

Population inversion is the necessary condition for laser action.

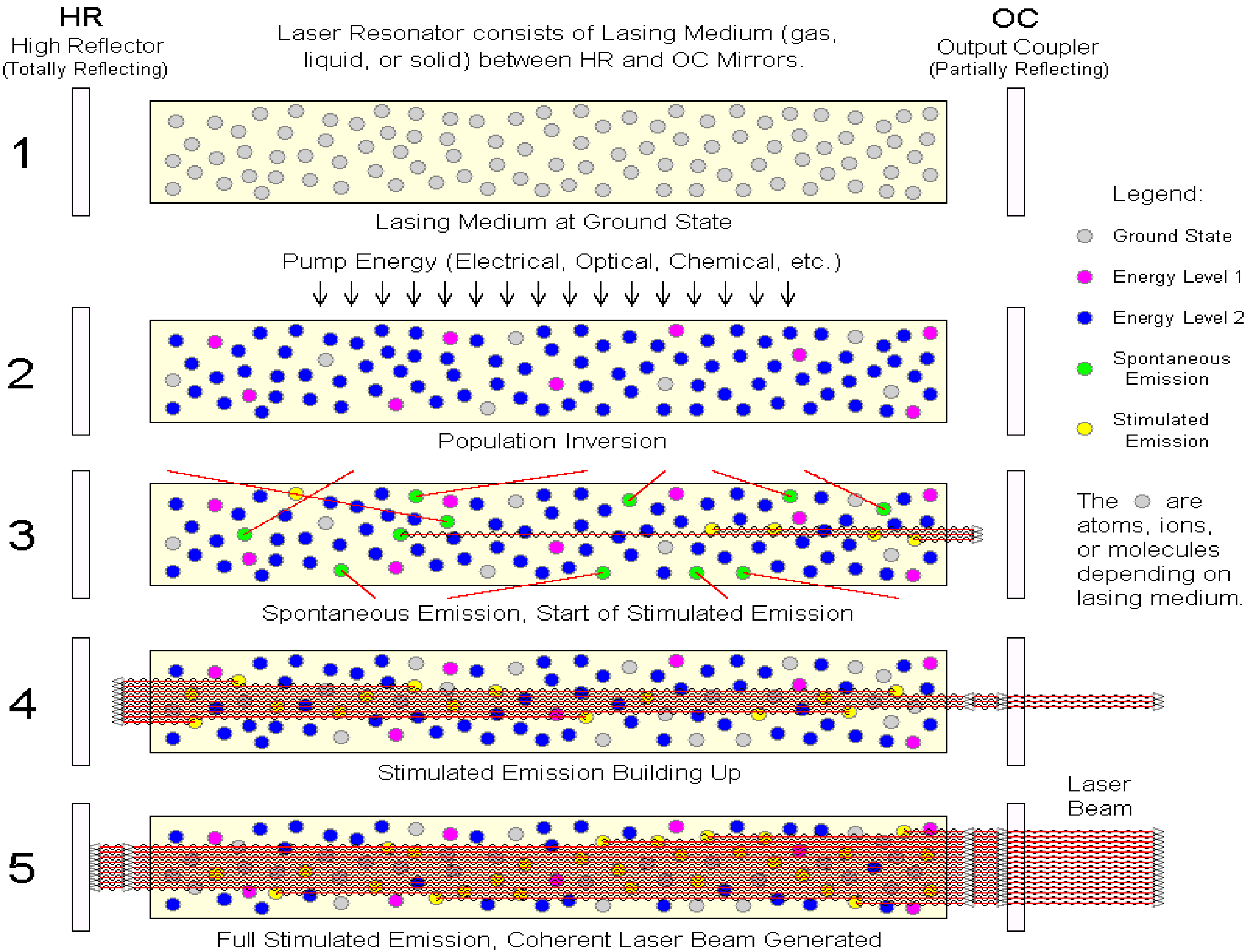
Two-, Three-, and Four-Level Systems



At best, you get equal populations. No lasing.

If you hit it hard, you get lasing.

Lasing is easy!



Basic Laser Operation

Laser Beam Properties

- Many lasers operating on fundamental Transverse mode, or TEM_{00} mode of the laser resonator, emit beams with a Gaussian profile.
- For a Gaussian beam, the complex electric field amplitude, measured in volts per meter, at a distance *r* from its centre, and a distance *z* from its waist, is given by

$$E(r,z) = E_0 \frac{w_0}{w(z)} \exp\left(\frac{-r^2}{w^2(z)}\right) \exp\left(-ikz - ik\frac{r^2}{2R(z)} + i\zeta(z)\right) ,$$

where *w(z)* Beam width or spot size

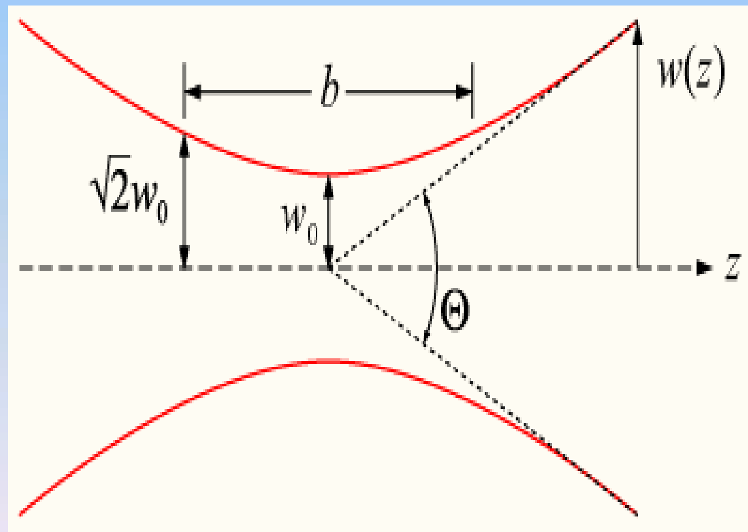
R(z) Radius of Curvature

ζ(z) Longitudinal Phase delay

If beam is not a pure Gaussian shape, the transveres modes of the beam

may be analyzed as a superposition of Hermite-Gaussian or

Laguerre-Gaussian beams.



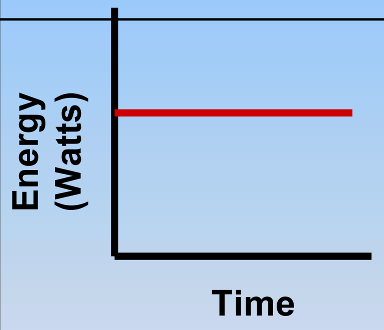
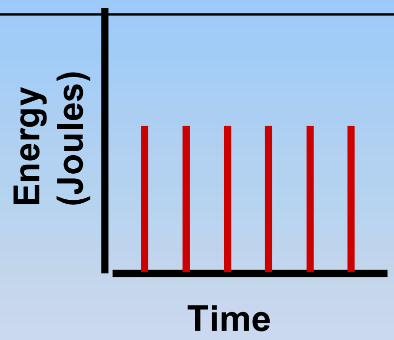
Laser Beam Output 1

- Characteristics that affect laser performance are the **power output** and **mode of emission** - continuous wave, pulsed, Q-switched or Mode –locked lasers.
- **CW laser**- emits a continuous beam of light as long as medium is excited.
- **Pulsed laser**- emit light only in pulses- from femtoseconds to second
- **Q-switched laser**-pulses from micro to nanosecond are produced
- **Mode-Locked laser** –pulses from pico (10^{-12}s) - to femtoseconds (10^{-15}s) are produced

Laser Beam Output 2

Lasers operated in ***Continuous Wave*** (**CW**) or ***Pulsed*** modes.

CW lasers-energy is continuously ***pumped*** - producing a continuous laser output. ***Pulsed lasers* -** the pump energy is applied in pulses- usually with a flash lamp

Continuous Output	Pulsed Output
	

Laser: Q-switching

- Q-switching is a way of obtaining ***short*** - from a few nano -seconds to few tens of nano - seconds – ***powerful -*** from a few megawatts to few tens of megawatts- pulses of laser.
- Q – quality factor of laser resonator.
- High Q – Low losses
- Low Q - High losses
- The term Q-switching refers to an abrupt switching of the cavity Q from low value to a high value.

Laser: Q-switching

- Methods of Q-switching: There are many ways to Q-switch a laser
- **Active Q-switching**

1. Mechanical devices- shutters, chopper wheel or spinning mirror.
2. Electro-optic device: Pockel cells and kerr cells.
3. Acousto-optic device

- **Passive Q-switching**

1. Q-switch is a saturable absorber.

Laser: Mode-Locking

- **Mode-locking** - technique that allowed the generation of ultra short optical pulse in the range of femtosecond.

Principle of Mode-Locking

- Mode-locking- achieved by locking together the phases of all oscillating axial laser modes - having slightly different frequencies.
- Interference between these modes causes the laser light to be produced as a train of pulses.

Laser: Mode-Locking

Methods of Mode-Locking

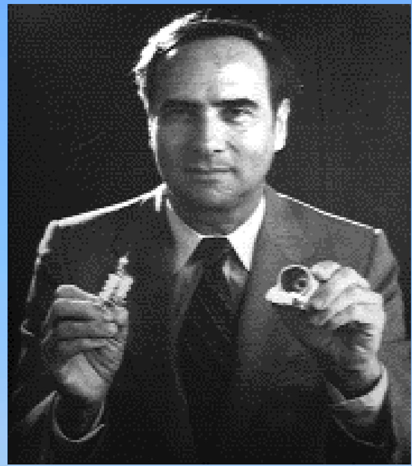
- A modulation of the electromagnetic field is induced by-fast modulating crystals- Active Mode-locking or saturable absorbers- Passive Mode-Locking.
- Mode-Locking- fundamentally multimode phenomenon

Physical Properties of Laser

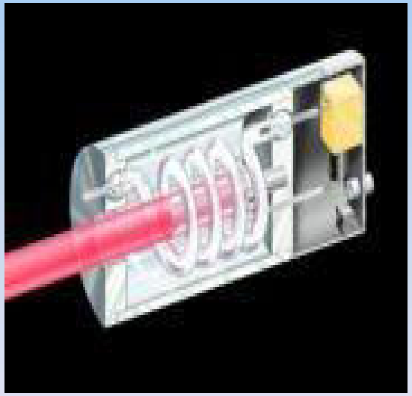
1. Energy- the amount of work accomplished – measured in joules
2. Power- Rate of energy expenditure – measured in joules per second or Watts (1J/s =1 W)
3. Irradiance- power density- the power of the laser per unit area.
4. Fluence - energy density- amount of energy delivered per unit area - irradiance multiplied by the exposure time (j/cm^2)- more important in determining laser effect on tissues than total energy delivered.

Types of Laser

Lasers are usually classified in terms of their active (lasing) medium. Major types are:



- **Solid-state lasers**
- **Semiconductor Lasers**
- **Dye Lasers**
- **Gas Lasers**



Types of Lasers 2

- **Solid-state lasers** have lasing material distributed in a solid material (such as ruby or neodymium:yttrium-aluminum garnet "YAG"). Flash lamps are the most common power source. The Nd:YAG laser emits infrared light at 1.064 nm.
- **Semiconductor lasers** sometimes called diode lasers, are pn junctions. Current is the pump source. Applications: laser printers or CD players.
- **Dye lasers** use complex organic dyes, such as rhodamine 6G, in liquid solution or suspension as lasing media. They are tunable over a broad range of wavelengths.
- **Gas lasers** are pumped by current. Helium-Neon lases in the visible and IR. Argon lases in the visible and UV. CO_2 lasers emit light in the far-infrared (10.6 micro m), and are used for cutting hard materials.

Applications of Laser

- Laser considered to be "a solution in search of a problem“ in 1958. Now Laser has many applications

- **Scientific Applications.**
- **Commercial Applications.**
- **Medical Applications**.

- The properties like Coherence, mono-chromaticity, and ability to reach extremely high powers, allow for these specialized applications.

Scientific Applications

In science Lasers are used in many ways including

- A wide variety of interferometric techniques
- Raman spectroscopy
- Laser induced breakdown spectroscopy.
- Atmospheric remote sensing
- Investigating nonlinear optics phenomena

Commercial Applications

- Cutting, welding, marking,
- Rangefinder / surveying,
- LIDAR / pollution monitoring,
- CD/DVD player,
- Laser printing,
- Laser engraving of printing plates,
- Laser pointers, holography, laser light displays
- Photolithography,
- Optical communications.

Medical Applications

- Cosmetic surgery:
- Dentistry:
- Dermatology:
- Eye surgery:
- Cardiology:
- Neurology:
- Urology:
- Optical Imaging:

MEDICAL LASER

Principle of Medical Lasers 1

Laser applications in medicine and surgery have been evolved with time – many medical laser systems available - but all use the principal of selective photothermolysis

Selective Photothermolysis:

Getting the right amount of the right wavelength of laser energy to the right tissue to damage or destroy only that tissue, and nothing else.

Thermal relaxation time: The time tissue takes for 50% of laser energy to be thermally conducted to the surrounding tissues

Principle of Medical Lasers 2

THE RIGHT WAVELENGTH

- Most medical laser devices deliver only one wavelength of laser light - the laser surgeon must choose the right wavelength for the specific tissue involved.
- Some lasers can be "frequency doubled“- can deliver two wavelengths of laser light.
- A very few lasers are tune-able over a narrow range of wavelengths.

Principle of Medical Lasers 3

THE RIGHT AMOUNT OF LASER ENERGY:

- All medical lasers allow the laser surgeon to adjust the power setting and duration of the laser pulse.
- As a general rule- the length of the laser pulse is as important as the wavelength or the power setting -in determining its medical use.
- Lasers can operated in ***continuous wave* (CW) or *pulsed*** mode.
- ***CW lasers*** emit a steady beam- If steady beam is held on tissue longer than the ***thermal relaxation time***, excessive heat will be conducted into normal tissue- delay healing and increase scarring.
- ***Pulsed* lasers** emit light in individual pulses-long-pulses (thousandths of a second) or short-pulse (millionths of a second).
- Some lasers can be used in different *modes, CW and Pulsed by using techniques like* Q-Switching and Mode-locking.

Principle of Medical Lasers 4

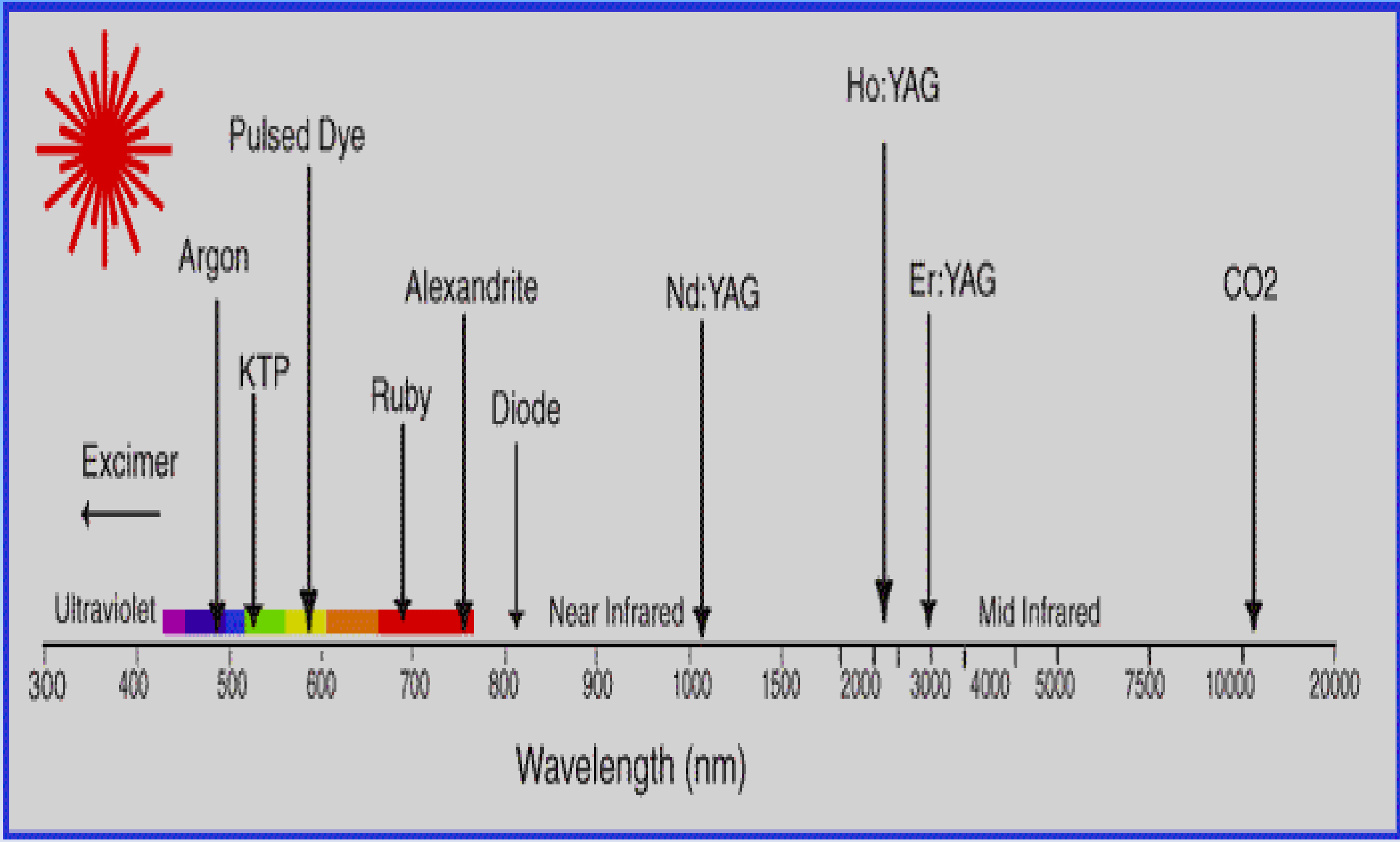
GETTING THE LASER ENERGY THERE

- A "***delivery device***" – needed to get the laser energy to the tissue.
- It includes special fiber-optic cables with hand pieces, or articulated arms*.*
- **Slit lamps**- for use on the eye.
- **Operating microscopes**- for use in the ear and throat.
- **Insulated fibers-**for use with endoscopes in gastrointestinal and bronchial surgery.
- **Scanners-** to scan the laser beam in a preset pattern and limit the time a CW laser beam dwells on the target tissue.

Types of Medical Lasers

- **Medical lasers are one small subset of a larger group of lasers.**
- **Medical Lasers are not magic-they are only tools, and one should always select the right tool for the right job!**

- **CO2 Laser:**
- **Argon Laser:**
- **YAG Lasers:**
- **Ruby Laser:**
- **Alexandrite Laser:**
- **Pulsed Dye Laser:**
- **Copper Vapor Laser:**
- **Diode Lasers:**
- **Excimer Lasers:**


Pulsed Dye
Ho:YAG
Argon
Alexandrite
Nd:YAG
Er:YAG
CO2
KTP
Ruby
Diode
Excimer
Ultraviolet
Near Infrared
Mid Infrared
300
400
500
600
700
800
900
1000
1500
2000
3000
4000
5000
7500
10000
20000
Wavelength (nm)

CO2 LASER

- **CO2 Laser-** the "Surgical Laser“-resembles traditional surgery .
- It usually is coupled with a visible helium-neon beam for guidance.
- Strongly absorbed by water- constitutes over 80% of soft tissue.
- The **CO2 laser** emits continuous wave (CW) or pulsed far infrared light at 10,600 (nm) - focused into a thin beam - used to cut like a scalpel, or defocused to vaporize, ablate, or shave soft tissue.
- The CO2 Laser also operated in pulsed mode or used with scanning devices to precisely control the depth and area of ablation.

USED IN:

- Removal of benign skin lesion, such as moles, warts, keratoses
- As a "laser scalpel" in patients or body areas prone to bleeding
- "No-Touch" removal of tumors, especially of the brain and spinal cord.
- Laser surgery for snoring
- Shaving, resurfacing scars and skin irregularities
- Cosmetic Laser Resurfacing for Wrinkles

ARGON-ION LASER

- **Argon Laser:** One of the first lasers to be used clinically
- The **Argon** (or argon-ion) **laser** is a continuous wave (CW) gas laser that emits blue-green light at 488 and 514 nm.
- **Argon laser** light is strongly absorbed by hemoglobin and melanin.
- Its beam may be mechanically pulsed.
- Delivery is through a fiber optic cable to a hand piece, slit lamp, or operating microscope.

USES INCLUDE:

- Retinal and inner ear surgery
- Treatment of thick or nodular port wine birthmarks
- Facial spider veins
- Small dark moles
- Cherry hemangioma – small red bumps on nose or trunk

YAG: LASERS

- **YAG Lasers: YAG** lasers use a **Y**ttrium-**A**luminum-**G**arnet crystal rod as the lasing medium.
- The **YAG** is used commonly because of its efficiency, optical quality, and high thermal conductivity, which permits high rates of repetition.
- Dispersed in the **YAG** rod are atoms of rare earth elements- such as neodymium (**Nd**)- Erbium (**Er**) or Holmium (**Ho**), which are responsible for the different properties of each laser.
- All **YAG** lasers may be operated in continuous,/pulsed, or Q-Switched mode.
- Continuous and pulsed delivery is through fiber optic cables, either bare-fiber or through hand piece or scanners.
- The Q-Switched delivery- because of the very high power- is through an articulated arm.

Nd:YAG LASER

Nd:YAG Laser:

- The Nd:YAG emits a near-infrared invisible light at 1064nm or 1320nm.
- The 1064 nm wavelength allows for a relatively deep penetration- 10 mm because this frequency is outside the absorption peaks of both hemoglobin and water.
- It may be delivered in CW or "long pulsed" (millisecond) mode through a fiber to a sapphire tip to cut tissue - or because of its deep penetration- used directly to coagulate tissue.
- It is suitable for lithotripsy when Q-switched.
- The Q-Switched Nd:YAG is effective for black tattoo ink - and has been used with fair results for hair removal.
- Millisecond-range Nd:YAG laser light is very effective for long-term hair removal.

KTP LASER

- **KTP Laser:**
- Nd:YAG laser light at 1064 nm is passed through a potassium-titanyl-phosphate (**KTP**) crystal- the wavelength is halved to 532 nm.
- It penetrates less than Nd:YAG because of its shorter wavelength and its absorption by hemoglobin.
- A brilliant green light used in CW mode to cut tissue- in pulsed mode for vascular lesions including facial and leg veins- and in Q-Switched mode for red/orange tattoo pigment.
- Delivery is through an insulated fiber, fiber hand piece, scanner, or microscope for CW/pulsed mode, and articulating arm for Q-Switched mode.
- Currently, less expensive, more reliable green light lasers such as the KTP and other Frequency doubled Nd:YAG are used for most vascular lesions.

Er:YAG LASER

- **Er:YAG Laser:**
- Referred as the "Erbium" laser.
- It emits a mid-infrared beam at 2940 nm- coincides with the absorption peak for water.
- Its principal use is to ablate tissue for cosmetic laser resurfacing for wrinkles.
- The **Erbium** laser has been advantages of reduced redness, decreased side effects and rapid healing compared to the pulsed or scanned CO2 laser.
- But it has limited penetration into tissue, which limits the results compared to the more versatile CO2 laser.
- It has also been used as a dental drill substitute to prepare cavities for filling.

Ho:YAG LASER

- **Ho:YAG Laser:**
- Relatively new to the medical/dental fields.
- The **Ho:YAG** laser emits a mid-infrared beam at 2070 nm.
- It superheats water- which absorbs light energy at this wavelength - creates a vaporization bubble at the tip of a low–water density quartz or silica fiber used for delivery- vapor bubble expands rapidly and destabilizes the molecules it contacts. This is ideal for lithotripsy of all stone types.
- It's principal use is to precisely ablate bone and cartilage - with many applications in orthopedics for arthroscopy - urology for lithotripsy (removal of kidney stones) - ENT for endoscopic sinus surgery and spine surgery for endoscopic disc removal.

RUBY LASER

- **Ruby Laser:**
- The **Ruby laser** emits red light with a wavelength of 694 nm.
- The lasing medium is a synthetic ruby crystal of aluminum oxide and chromium atoms- excited by flash lamp.
- is highly absorbed by melanin
- Early ruby laser systems were used for retinal surgery- but weren't suitable for dermatologic work until the development of Q-Switching technology in the mid 1980's.
- **Ruby laser** light is strongly absorbed by blue and black pigment, and by melanin in skin and hair.
- Modern ruby laser systems are available in Q-Switched mode, with an articulating arm, "free running" (millisecond range) mode with a fiber optic cable delivery, or as dual mode lasers.

CURRENT USES:

- Treatment of tattoos (Q-Switched mode)
- Treatment of pigmented lesions including freckles, liver spots (Q-Switched mode)
- Laser Hair Removal (free-running mode)

ALEXANDRITE LASER

- **Alexandrite Laser:**
- The **Alexandrite Laser** contains a rod of synthetic chrysoberyl- a gemstone discovered in Russia in 1830.
- It emits a deep red light at 755 nm, and has properties similar to the ruby laser.
- It's slightly longer wavelength permits slightly deeper penetration into skin- with slightly less absorption by melanin.
- Prinicipal uses include laser hair removal in millisecond-range pulsed mode, and tattoo removal in Q-Switched mode.

PULSED DYE LASER

- **Pulsed Dye Laser:**
- It emits the yellow light at 577-585 nm- coincides with the peak absorption of hemoglobin in blood.
- It has a lasing medium of rhodamine dye- excited by flashlamp-, emitting a pulse in the range of 450 microseconds - just less than the thermal relaxation time - of minute blood vessels.
- Developed in the late 1980's, the **Pulsed Dye Laser is** preferred for the treatment of vascular lesions- including spider veins- strawberry birthmarks and port wine stains.
- Better than the Argon Laser because of decreased heat damage and decreased chance of scarring.
- In the pulsed mode, this laser is used for lithotripsy and ablation of vascular lesions.
- However, the PDL's short pulse and high absorption ruptures the targeted blood vessels, causing unsightly purpura (black and blue marks) which can last up to 2 weeks.
- Laser treatment of thick, red scars

COPPER VAPOR LASER

- **Copper Vapor Laser:**
- Vaporized copper bromide is the lasing medium in the **Copper Vapor Laser (CVL) -** which emits yellow light at 577 nm and green light at 511 nm, delivered through a fiber optic cable.
- Unlike the PDL, there is no purpura (appearance of red or purple discolorations on the skin- caused by bleeding underneath) because of the longer pulse duration.
- However, a long warm up time and short laser cavity life make the CVL a less popular choice than the PDL for vascular lesions.

DIODE LASER

- **Diode Lasers:**
- Are smaller- more efficient, and potentially cheaper than most other lasers now in use.
- Their wavelength can be tuned by adding various elements (e.g., aluminum, indium).
- An 805-nm laser is produced using AlGaAs, and a 1000-nm beam is produced from the active compound InGaAs.
- Clinically **used Diode lasers** -emit near-infrared light in the 800-900 nm range.
- Currently their principal application is in millisecond-range pulsed mode for laser hair removal, and for periodontal surgery.
- Other applications include treatment of leg and facial veins.

EXCIMER LASER

- **Excimer Lasers:**
- Noble gas: Halide, or **Excimer Lasers,** emit invisible ultraviolet (UV) light that triggers a photochemical reaction on the target tissue.
- This very short wavelength is capable of high resolution and microscopic surgery.
- The most common medical application is the Argon: Fluorine (Ar:F) laser at 193 nm, used for PRK and LASIK (Laser in-situ Keratomilieusis) vision correction.
- The laser beam is delivered through an operating microscope integrated with the laser housing and operating table.
- Excimer laser radiation shows great promise for cardiac revascularization and lithotripsy, but is currently limited by the lack of durable UV-capable fiber optic delivery devices.

Laser :Medical Applications

- **Cosmetic surgery:** removing tattoos, scars, stretch marks, wrinkles, birthmarks, and hairs.
- **Dentistry:** caries removal, tooth whitening, and oral surgery.
- **Dermatology:** Treatment of acne and skin cancer by PDT
- **Eye surgery:** Cataract and Glaucoma surgery
  - LASIK (laser vision correction)

  LASIK- acronym for **L**aser-**A**ssisted in **Si**tu **K**eratomileusis (Keratomileusis- method of reshaping the cornea surface to change its optical power).
  - LASEK (laser-assisted sub-epithelial keratectomy)
  - PRK (photorefractive keratectomy)

  LASEK and PRK - laser eye surgery- intended to correct a person's vision, reducing dependency on glasses or contact lenses.

Laser :Medical Applications 2

- **Cardiology:** Angioplasty, vessel recanalization
- **Neurology:** To cut, ,vaporize and coagulate tissue with out mechanical contacts
- **Urology:** lithotripsy (removal of kidney stones)
- **Laser scalpel:** gynecology, urology, laparoscopy
- **Optical Imaging:** field of online monitoring and diagnostics

Laser: Surgery and Diagnostics 1

- **Advances in lasers and fiber optics-make them suited to travel- in the human body where no hand or scalpel has gone before- used in techniques like endoscopy, laparoscopy and hysteroscopy.**

- **Endoscopy**- the introduction of a flexible- fiberoptic scope into a body cavity - equipped with a tiny video monitoring device that allows- to diagnose or treat a condition.

Laser: Surgery and Diagnostics 2

Types of Endoscopy

- **Arthroscopy-** examination of joints for diagnosis and treatment
- **Bronchoscopy -** examination of the trachea and lung's bronchial trees to reveal bronchitis, carcinoma, tumors, tuberculosis, infection, inflammation
- **Colonoscopy-** examination of the inside of the colon and large intestine to detect tumors, ulceration, inflammation, and removal of foreign bodies.
- **Cystoscopy -** examination of the bladder, urethra, urinary tract and prostate (men) with insertion of the endoscope through the urethra.
- **Hysteroscopy-** is a procedure that allows to look inside your uterus in order to diagnose and treat- done using a hysteroscope - thin lighted tube-hysteroscopy can be either diagnostic or operative
- **laparoscopy-** procedure that allows to look directly at the contents of a patient's abdomen or pelvis.

Laser: Surgery and Diagnostic 3

- **Laparoscopic Surgery** – minimal invasive- modern surgical technique – operations are done with small incisions (0.5-1.5 cm).

- **Laparoscope**- a telescopic rod lens system-connected to a video camera- attached to a fiber optic cable system connected to a 'cold' light source (halogen or xenon - to illuminate the operative field- inserted through a 5 mm or 10 mm canola to view the operative field.
- The abdomen is usually insufflated with **carbon dioxide gas** to create a working and viewing space- CO2 is common to the human body- removed by the respiratory system if it absorbs through tissue.
- The CO2 is non-flammable - important due to the fact that electrosurgical devices are commonly used in laparoscopic procedures

Difference between Endoscopy and Laparoscopy:

Endoscopy - involves viewing the interior of organs and systems
Laparoscopy- allows to view the outside of internal organs.

Laser Hazards 1

- **Properties of laser that make it unique " Hazardous":**

- The single wavelength of laser emission – selective interaction with human tissue- depending on wavelength.
- The ability to generate pulsed emission- ultra short duration- causing harm over short time-scales
- The directionality- resulting in localized but high power densities- even large distances from source.
- The very high brightness- can create extremely high power density levels- focused by a suitable lens – as inside the eye.

Laser Hazards 2

- The laser- give rise to exposure levels considerably greater than-not possible from other source- at the surface of the body- and internally to the retina at the back of eye
- These effects are due to high concentration of optical radiation produced by the lasers- rather than the total magnitude of the emitted power- 0.01mW laser is hazardous to the eye – whereas a 60 Watt bulb is not.
- The concentration of optical radiation- exposure received at the surface of body on which a laser beam was incident- measured in terms of either the energy density –called **radiant exposure** or in power density-called **irradiance**.
- **Radiant exposure – joules per square meter**
- **Irradiance –watts per square meter**

Laser Hazards 3

The basic hazards from laser can be categorized as

- **Laser Radiation Hazards**

  Eye Hazards- such as retinal or cornea burns.

  Skin Hazards- such as burns.
- **Chemical Hazards-** Some materials used in lasers – excimer, dye and chemical –may be hazardous and/ or contain toxic substances.
- **Electrical Hazards-** Lethal electrical hazards may be present in all lasers –particularly in high-power laser systems

Secondary Hazards

- Excessive noise from very high energy lasers
- Explosions from faulty optical pumps
- Fire hazards.

Laser Radiation Hazards

- Exposure of the body to laser radiation at all wavelengths can cause injury- from serious burns to the skin – to the outer layer of the eyes (e.g. cornea).
- Serious damage to the interior tissues of the eyes- to sensitive retinal layer- with permanent visual loss.
- The most common cause of laser-induced tissue damage is thermal in nature- where the tissue proteins are denatured due to the temperature rise following absorption of laser energy.

Post LASIK Hemorrhage

SAFETY STANDARDS

- **Safety standards for lasers generally cover two aspects.**

1. They can specify the requirements placed on those who manufacture laser products.
2. They can define the safety measures that should be adopted by those who use laser equipment.

- In some countries laser safety standards are compulsory – others advisory.
- Main laser safety standards are:
- **IEC- International Electro -technical Commission**

  This is the international standard on laser safety- equipment classification- requirements and user's guide.
- **ANSI – American National Standards Institute**

  This is the US standard applicable to laser users- American National Standards foe the safe use of laser.
- **IRPA –International Radiation Protection Association**

  Define guidelines on human exposure to laser radiation.

Laser Safety

- A system of hazards classification for lasers was first introduced by ANSI in 1973- to allocate every laser into several hazard classes- depending on its potential for harm.

- All Lasers- laser products (complete units containing lasers) and laser systems (installations or machinery into which laser is incorporated) are allocated into one of four broad laser categories,

- Classified by wavelength and maximum output power into four classes- to categorize lasers according to their ability to produce damage in exposed people.
- Classification and labeling- responsibility of the manufacturer or supplier of the equipment.

Laser Safety Classification 1

- **Class 1: Safe –** Lasers inherently safe under any condition- because of the very low output or because of its engineering design – totally enclosed- prevents exposure to the radiation.
- **Class 2: Potential eye hazard-safe for accidental momentary viewing –**Lasers emitting low power visible radiations (400-700nm)- not inherently safe- eye protection is afforded by *natural aversion response (or Blink reflex of the eye to bright light t=0,25s)* to bright light. The emission limit for CW class 2 lasers is 1mW.

Laser Safety Classification 2

- **Class 3A: Safe for accidental viewing with unaided eye**- Lasers emitting visible or invisible radiation for which direct viewing with optical magnifying instruments may be hazardous. Accidental viewing eith unaided eye (spectacles or contact lens) and subject to natural aversion response for visible lasers is not hazardous. The emission limit for CW class 3A lasers is 5mW.
- **Class 3B: Safe for viewing diffuse reflections only-** Lasers emitting visible or invisible radiation for which direct viewing with unaided eye can be hazardous. The maximum CW limit for 3B is 0.5 W.
- **Class 4 - unsafe –**Lasers (visible or invisible) that are cabable of producing hazardous diffuse reflections in addaition to the hazards of direct viewing. In addition to permanent eye damage even viewing diffuse reflections. Class 4 lasers are also able to cut or burn skin.

Laser Pointers are not Toys

- The potential for hazards with Laser Pointers is limited to unprotected eyes by direct beam (intrabeam viewing).
- No skin hazards usually exists.
- Laser pointers are categorizes Class- IIIA devices by ANSI.

References

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Thank You