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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – I - FIBRE OPTICS & LASER FOR BIOMEDICAL APPLICATIONS – SBMA7003

I. Introduction

1.1 Principles of Light Propagation through a fibre material

Introduction

- Optical fibre is a dielectric wave guide
- Operates at optical frequencies
- Cylindrical

in form

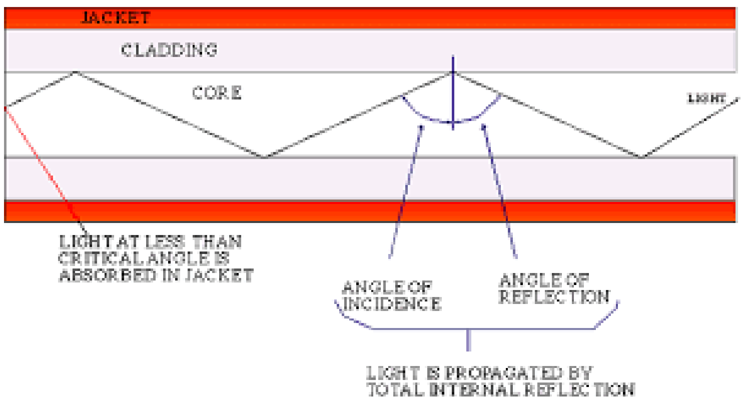
Functions

- Confines electromagnetic energy which is in the form of light within it's surfaces
- Guides the light in a direction parallel to its axis

Total internal reflection

- When light rays incident on the interface between two medium having different refractive indices at an angle greater than the critical angle the light gets totally reflected internally within the medium which has higher refractive index.

- n_1 refractive index of first medium
- n_2 refractive index of second medium
- Θ_1 inclination angle



Ray optics

- The law governing the nature of light is called law of optics or Ray theory.
- Speed of light varies in different medium
- Speed of light in free space is $3*10^8$ m/sec or

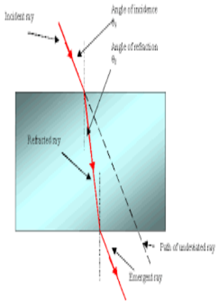
$186*10^3$ miles/sec

1. Reflection

- When a light rays is incident on the reflective surface at an incident angle Θ from the imaginary perpendicular normal the ray will get reflected at some angle Θ from normal which is equal to the angle of incidence.

2. Refraction

- Occurs when light pass from one medium to other medium with different densities
- The direction of light changes at the interface of two medium
- Example: air and water□straight straw appears bent when a portion is immersed in water

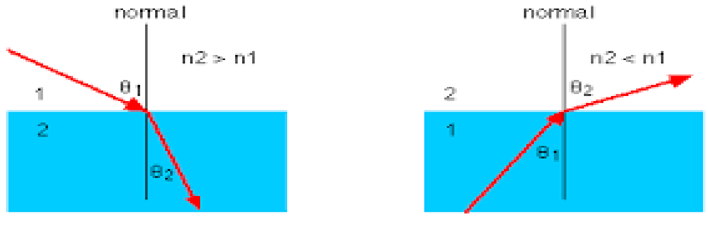


3. Refractive index

- It is the amount of bending of light at the junction of materials with different densities.
- It is expressed as ratio of velocity of light in free space to the velocity of light in the dielectric material.
- Refractive index
- n=Speed of light in air/speed of light in medium • n=c/v
- n of air=1
- n of water=1.3
- n of glass=1.5

4. Snell's law

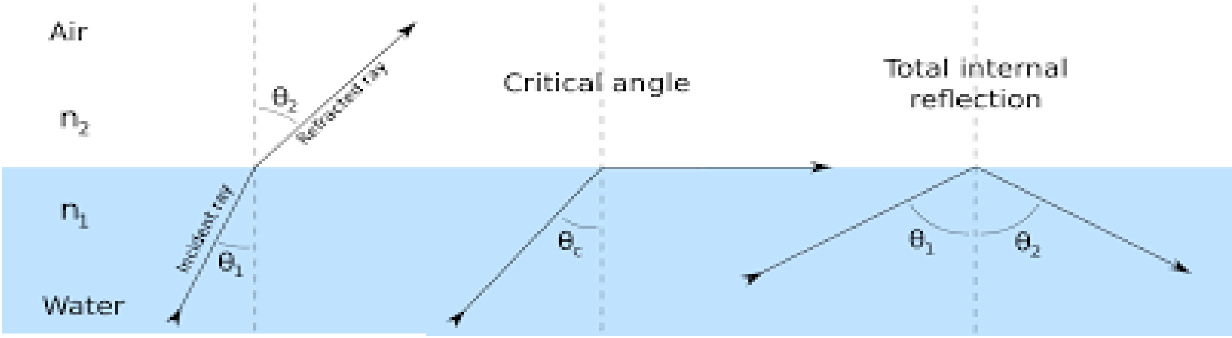
- It explains the reaction of light when it comes across the interface of two medium with different refractive index.
- It states that the ratio of sines of the incident angle and the ration of refractive index are same
- Angle of incidence is indirectly proportional to refractive index.
- When n1<n2—refracted wave will be towards the normal
- When n2<n2—refracted wave will be away from the normal



Snell's law : $n_1 \sin\theta_1 = n_2 \sin\theta_2$ or, equivalently, $\sin\theta_1 / \sin\theta_2 = v_1 / v_2$

5. Critical angle

- When the incident angle is increased gradually the refractive angle also increases. At a certain point refractive angle becomes 90 degree to the normal.
- The light travels along the interface.
- The angle of incidence at which the refractive angle becomes 90 degree is called the critical angle.



Snell's Law:

$n_2 . \sin \theta_c = n_1 . \sin 90^0$

$\sin \theta_c = \frac{n_1}{n_2}$ $\qquad \theta_c = \sin^{-1}\left(\frac{n_1}{n_2}\right)$

6. Total internal reflection

- When the incident angle is increased beyond the critical angle the light gets totally internally reflected
- It does not pass through the interface
- This phenomenon helps the propagation of light within the fibre cable medium
- Total internal reflection can be observed only in materials in which the speed of light is less when compared to the speed of light in air.

Condition to achieve total internal reflection

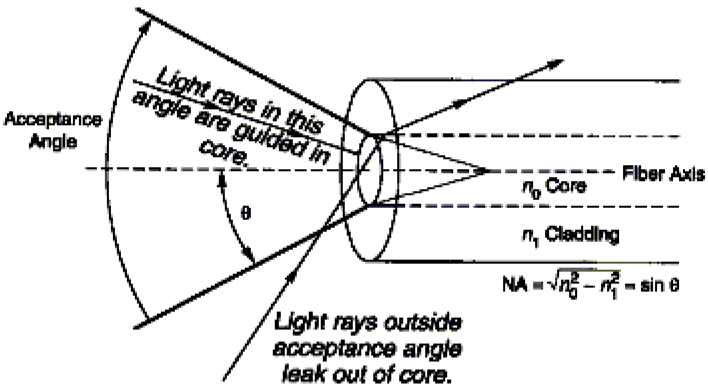
- Light incident on the dielectric medium should travel from lower refractive index to higher refractive index.
- The angle of incidence should not increase more than the critical angle.

1.2 Transmission of light in a perfect optical fibre

- The light rays gets reflected at the interface of core and cladding.
- If fibre is not proper then refraction will take place which would lead to loss of light
- Rays are called meridional rays since they travel along the axis of the fibre

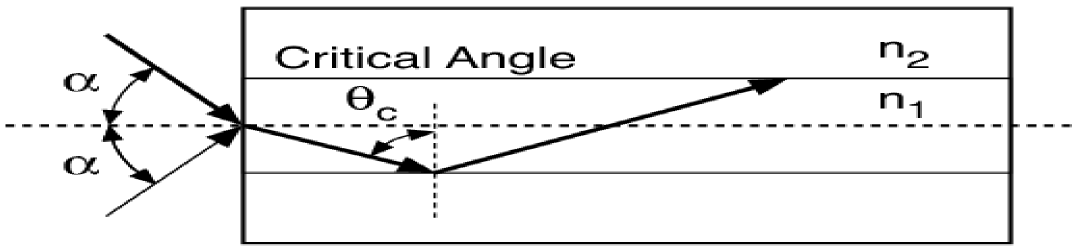
Acceptance angle (Θ_a)

- When launching into the optical fibre the acceptance angle is the maximum angle to the axis at which light may enter to get total internal reflection and hence propagate through the fibre
- If the incident light enters at an angle greater than Θa it gets refracted at the core cladding interface and gets lost due to radiation.
- Hence the light rays should be incident within the Acceptance cone.



Numeric Aperture

- Measure of amount of light rays that can be accepted by the fibre
- It gives the relationship between the acceptance angle and the refractive indices of core, cladding and air.



$$NA = \sin\alpha = \sqrt{n_1^2 - n_2^2}$$

Full Acceptance Angle = 2α

Mode

- Propagation of light along a wave guide can be described in terms of a set of guided electromagnetic waves called the modes of wave guide
- Guided modes are called bound or trapped modes of the wave guide.

II. Typed of fibre and their properties

- Communication based classification

1. Step index fibre
   - Ø Single mode
   - Ø Multi mode
2. Graded index fibre
   - Ø Multi mode

Step index fibre

Step index single mode fibre

- Cylindrical wave guide core with central inner core
- Inner core has uniform refractive index n_1
- Cladding has lesser refractive index n and decreases step wise
- Difference between core and cladding is very less
- Core diameter is very small it has low attenuation and high band width
- It has low numerical aperture
- Used in long distance communication
- $n_2 = n_1(1-\Delta)$, where Δ is the relative refractive index

Step index fibre

Step index multimode fibre

- Cylindrical wave guide core with central inner core
- Inner core has uniform refractive index n_1
- Difference between core and cladding is more
- Core diameter is more and it has large attenuation
- Used in short distance communication

Graded index multimode

- Refractive index of the core varies parabolically such that the refractive index is maximum and at the core axis and minimum at the core cladding interface
- It has a smaller diameter fibre than step index multi mode fibre
- It has large bandwidth and low attenuation
- r- radial distance from fibre axis

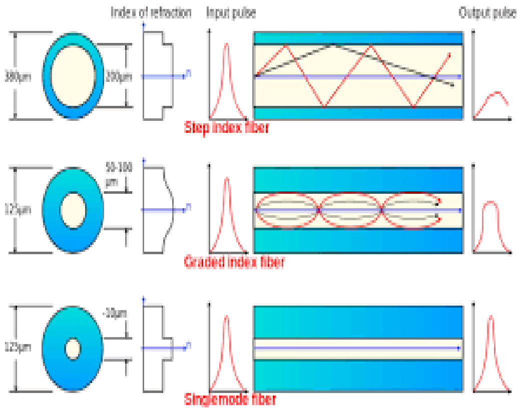
- a-core radius
- n1-refractive index of core, n2 refractive index of cladding
- where α is the refractive index profile
- For parabolic type graded index fibre α=2
    - When α=∞, then $n(r)= n_1$
    - Numerical Aperture

III. Typed of fibre depending on material composition

- Communication based classification

1. Step index fibre
   - ➢ Single mode
   - ➢ Multi mode
2. Graded index fibre

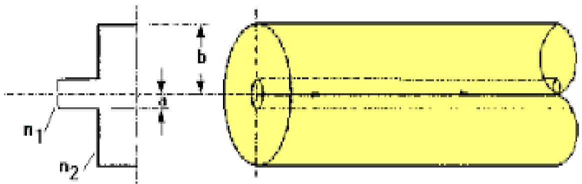
   Multi mode



Step index fibre

Step index single mode fibre

- Cylindrical wave guide core with central inner core
- Inner core has uniform refractive index n_1
- Cladding has lesser refractive index n_2 and decreases step wise
- Difference between core and cladding is very less
- Core diameter is very small it has low attenuation and high band width
- It has low numerical aperture
- Used in long distance communication
- $n_2 = n_1(1-\Delta)$, where Δ is the relative refractive index

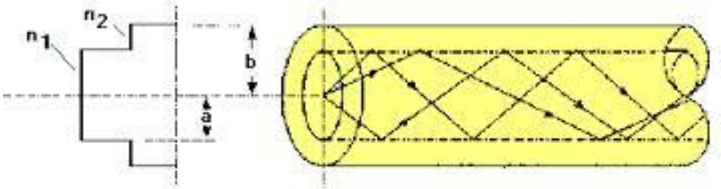


SINGLE MODE STEP-INDEX FIBER

Step index fibre

Step index multimode fibre

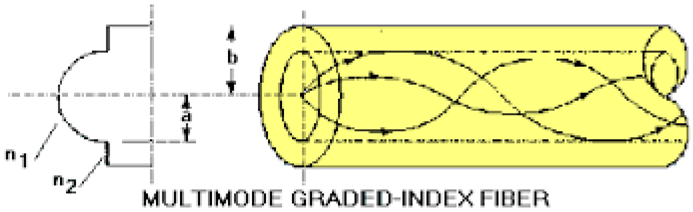
- Cylindrical wave guide core with central inner core
- Inner core has uniform refractive index n_1
- Difference between core and cladding is more
- Core diameter is more and it has large attenuation
- Used in short distance communication



MULTIMODE STEP-INDEX FIBER

Graded index multimode

- Refractive index of the core varies parabolically such that the refractive index is maximum and at the core axis and minimum at the core cladding interface
- It has a smaller diameter fibre than step index multi mode fibre
- It has large bandwidth and low attenuation
- r- radial distance from fibre axis
- a-core radius
- n1-refractive index of core, n2 refractive index of cladding



MULTIMODE GRADED-INDEX FIBER

$$n(r) = n_1\left[1 - 2\Delta\left(\frac{r}{a}\right)^{\alpha}\right]^{\frac{1}{2}} \; for\; 0 \le r \le a$$

$$n(r) = n_1[1 - 2\Delta]^{\frac{1}{2}} \qquad for\;\; r \ge a$$

$$\propto = \frac{n_1^2 - n_2^2}{2n_1^2}$$

- where α is the refractive index profile
- For parabolic type graded index fibre α=2
- When α=∞, then n(r)= n_1
- Numerical Aperture

$$NA = [n(r)^2 - n_2^2]^{\frac{1}{2}}$$

$$= NA(0)\sqrt{1 - (\frac{r}{a})^{\alpha}}$$

$$= 0 \; for\; all\; r > a$$

Parameter	Step Index	Graded Index
Refractive Index of core	Uniform throughout and abrupt change at the core cladding boundary	Made to vary parabolically. Maximum refractive index at the core and minimum refractive index at the boundary
Diameter	Core-50 to 200 µm in multimode 10 µm in single mode	About 50 µm
Band width	50 MHz Km for multimode More than 1000 MHz Km for single mode	200 to 600 MHz Km
Attenuation	More in multimode and less in single mode	Less
Numerical Aperture	• More in multimode and less in single mode • Remains same	• Less • Changes continuously with distance from the axis
Signal Distortion	• No distortion in single mode • More in multimode since higher angled rays arrive late when compared to lower angled rays. Hence signals are broadened and distortion occurs.	It is very less because of self focusing effect. Rays travel at different speed. Higher speed at outer part and lesser speed at the centre. Hence they arrive at the same time in helical path

Single Mode	Multimode
Only a single ray or mode can propagate through a fibre	Allows large number of paths of mode
Smaller diameter at the core(10 µm) and the difference between refractive index of core and cladding is very small	Core diameter and relative refractive index diameter difference is large
No dispersion, i.e. no degradation while travelling through the fibre	Even though there is self focusing effect the signal degradation due to multimode dispersion and material dispersion is present

	Since the information transmission capacity in optical fibre is inversely proportional to dispersion. Hence it is suitable for long distance communication	Due to large dispersion and attenuation, multimode fibres are less suitable for long distance communication. They are used in LAN
	Launching light into the fibre and joining two fibres are very difficult	Easy
	Fabrication is difficult	Less difficult
	Very costly	Less Costly

Typed of fibre losses depending on material composition

Material used in optical fibre communication must be able to guide the light efficiently with

- Low scattering
- Low absorption
- Low dispersion

Materials that satisfy these conditions are

- Glass
- Plastic

1. Glass fibre

- Silica SiO_2 glass fibre exhibits ultra low loss property
- Used in long distance communication
- Acts as transmission windows at the wave length of 1.3 μm and 1.55 μm
- Multicomponent glass fibres are also available but have higher loss.
  - Sodium borosilicate glass
  - Soda lime silicate glass

Used in endoscopes

2. Plastic clad Silica Fibre(PCS fibre)

- Core is made of silica and cladding is made of Silicone resin
- Teflon is used as buffer coating material
- Has a high Numerical Aperture since the difference in the refractive index of core and cladding is large

3. Plastic Fibre

- Low cost fibre
- Multi mode step index fibre
- Has high Numerical Aperture and High toughness
- Higher attenuation than glass
- Example 1
  - Core- Polystyrene (n=1.6) ; Cladding- Methylmethacrylate (n=1.49)
  - Core- Methylmethacrylate (n=1.49); cladding its co polymer(n=1.40)

Dopants

- Materials added with SiO_2 (core) to produce a similar material having slightly different refractive index for cladding
- Some cases doped silica acts as core and pure silica acts as cladding
- Different preferred compositions of fibre materials are

- SiO_2 –refractive index is 1.46 at 850nm.
  - When added to TiO_2, Al_2O_3,GeO_2 and P_2O_5 the refractive index increases
  - When added with B_2O_3 or fluorine refractive index decreaces

Core	Cladding
SiO_2	B_2O_3-SiO_2
GeO_2-SiO_2	SiO_2
P_2O_5-Sio_2	SiO_2
GeO_2-B_2O_3-SiO_2	B_2O_3-SiO_2

IV Losses

Absorption Losses

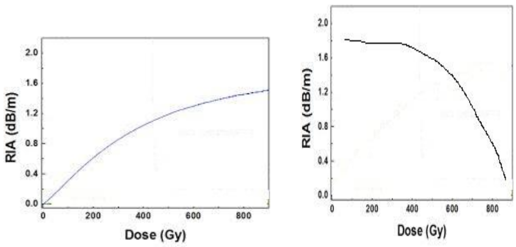
- Absorption losses is caused by 3 different mechanism

1. Absorption by atomic defects in the composition of glass
2. Extrinsic absorption by impurity atom in glass
3. Intrinsic absorption by basic constituent atoms of the fibre material

Atomic defect

- It is the defect of imperfection in the atomic structure of the fibre material.
- Ex: missing molecules, high density clusters of atom groups or oxygen defects in the glass structure
- It is negligible when compared to intrinsic and impurity absorption effects
- It is significant if exposed to ionization radiation in nuclear reactor environment and medical radiation therapy etc

- Basic response of a fibre to ionization radiation is an increase in attenuation centers that absorb optical energy.
- The loss increases as radiation increases.
- It gets relaxed when the radiation is withdrawn.



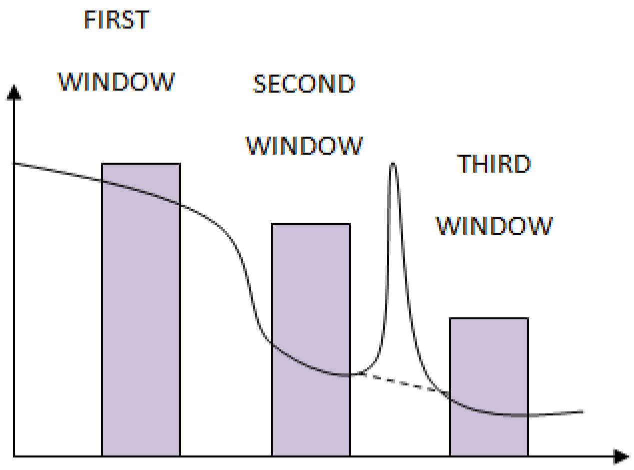
Extrinsic Absorption

- It is also called as impurity loss
- It results predominantly from transition metal ions such as Iron, Cobalt Copper and water.

- Transition metal impurity present in the starting material used for direct melt fibres range between 1 to 10 ppb and its loss is from 1 to 10 dB/Km
- It occurs due to electronic transition between energy levels associated with incomplete filled inner sub shell ions
- The presence of OH ions in fibre results from oxyhydrogen flame used for hyrdrolysis reaction of SiCl4, PoCl3 and GeCl4
- For attenuation to be less than 20dB/Km, water impurity concentration should be less than 10 ppb.

By reducing OH content to 1 ppb single mode fibre which is commercially available has an attenuation of 0.5dB/Km in 1100nm window and 0.3 db/Km in 1550 nm window

- An efficient complete elimination of water molecules from the fibre will result in dashed line.
- This is for all fibre made of lucent technologies.



Intrinsic Absorption

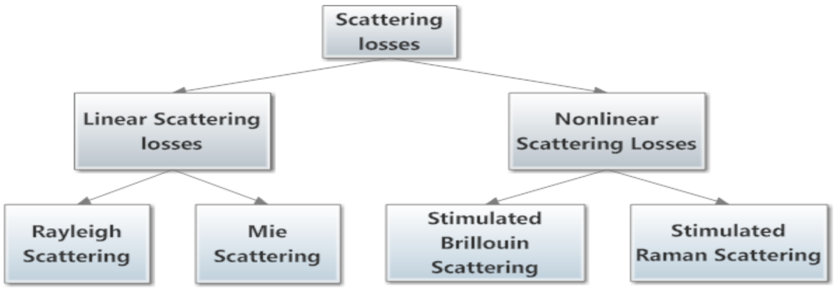
- This is associated with basic fibre material. It is the chief factor that defines transparency window of a material over a specified spectral region.
- It occurs when the material is perfect with no impurity, variations in density, homogeneities in material etc.
- This happens due to electronic absorption bands in the UV region and from atomic vibration bands in near IR region.
- It occurs in amorphous glass material. Absorption occurs when a photon interacts with the valence electron and gets excited to higher level.
- The UV edge of electron absorption bands of amorphous and crystalline materials follow the given relationship called as Urbach's rule.

$$\alpha_{uv} = Ce^{E/E_o}$$

C, E_0-empirical constants, E-photon energy.

Scattering losses

- Mostly found in multimode fibres due to its large diameter and huge compositional variance
- Scattering losses are of two types



Linear Scattering

- It transfers the optical power linearly from one propagating mode to a another mode.
- It may cause attenuation of operating mode power by means of transferring power by means of transferring power to leaky or radiation mode which will not continue to propagate within the core of fibre but is radiated from the fibre.
- High scattering loss in multimode fibres due to high dopant, concentration, concentration of greater fluctuations.

Rayleigh Scattering

- It is the dominant mechanism in UV region. Its extends upto infrared region.
- Rayleigh scattering is inversely proportional to the fourth power of wavelength.
- It occurs due microscopic homogeneities present in the fibre material
- The inhomogeneties ma arise the density fluctuations, refractive index fluctuations and compositional variations
- For SiO2 fibre the Rayleigh scattering density is given by

$$\alpha_{scat} = \frac{8\pi^3}{3\lambda^4} n^8 p^2 \beta_c K T_f m^{-1}$$

Where n is refractive index for silica, p is the photo elastic coefficient for silica,βc is isothermal compressibility, k is constant, λ is wavelength, Tf is annealing temperature.

- The transmission los due to Rayleigh scattering is given by

$$\propto = exp(-\alpha_{scat} . L)$$

- There will be no change in frequency hence it is also call
- Where L is the Length of the fibre
- By operating on higher wavelength this loss can be reduced Elastic scattering loss

Question Bank

1. Explain in detail about the various features of Ray theory.
2. Derive the expression for Numerical Aperture of the FIBRE.
3. What are skew rays? Derive the expression for numerical aperture for skew rays.
4. Discuss in detail about the materials used in the manufacturing of optical FIBRE.
5. What are the different types of FIBREs used in communication? Explain each type with neat diagrams.
6. List the differences between step index FIBRE and graded index FIBRE.
7. Discuss in detail about ray optic theory.
8. Explain in detail about absorption losses and its types.
9. Explain in detail about linear scattering loss and non linear scattering losses.
10. Elaborate on losses caused due to dispersion in the optical FIBRE.

References

1. G.Keiser, Optical Fiber Communication, McGraw Hill, 1995.
2. M.Arumugam, Optical Fiber Communication and Sensors, Anuradha Agencies, 2002.
3. Monte Ross, Laser Applications, McGraw Hill, 1971.

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OPTICAL SOURCES, DETECTORS, FIBRE COUPLERS & CONNECTORS

I Introduction

- Emission of light in the form of a photon can take place either spontaneously or can be stimulated by the presence of another photon of the right energy level.
- External energy must be provided to boost the electron from its low energy state to a higher energy state for spontaneous or stimulated emission to occur
- The energy can come the following sources: Heat (Incandescent light),
  Electrical Discharge (D2 , Hg, Na lamps),
  Electrical Current (LED, LD),
  Bioluminescence (Fire fly- luciferase enzyme)

II Optical sources

- Applications of optical fibre are in the area of medical, automotive,
  analytical equipments, communications and industry.
- Types of Optical Source
  Tungsten, Deuterium, Mercury, Hollow Cathode Lamp Optical
- Source specifically suited to FO systems are:

1. Light Emitting Diode (SLED, ELED, SLD)
2. Laser Diode (DFB, DBR)

Optical Source Requirement for Performance of optical fibre are

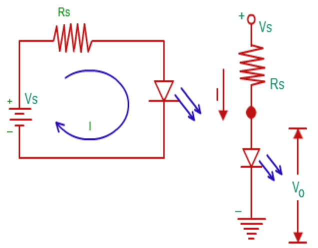
- Physical dimensions to suit the optical fibre
- Narrow radiation pattern (spectral width)
- Linearity (output light power proportional to driving current)
- Ability to be directly modulated by varying driving current
- Fast response time
- Adequate output power into the fibre
- Narrow spectral width (or line width)
- Stability and efficiency
- Driving circuit issues
  Reliability and cost

Difference between LED AND LASER

LED	LASER
It is of low cost	It is very expensive
It has low output optical power	It has high output optical power
Poor power launching efficiency	Very efficient in power launching
Large spectral widths (70- 100 nm)	Low spectral widths (2-3 nm)
Useful for short distance communication	Useful for long distance high speed communication
It is useful for intensity modulation only because of incoherent output light	Due to coherent and switching nature of optical output, it can be subjected to ASK, FSK, PSK.
Not Useful in nonlinear optics	Useful in nonlinear optics

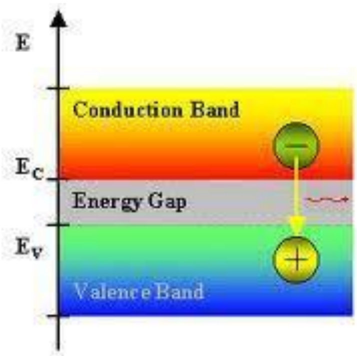
III Basics of LED

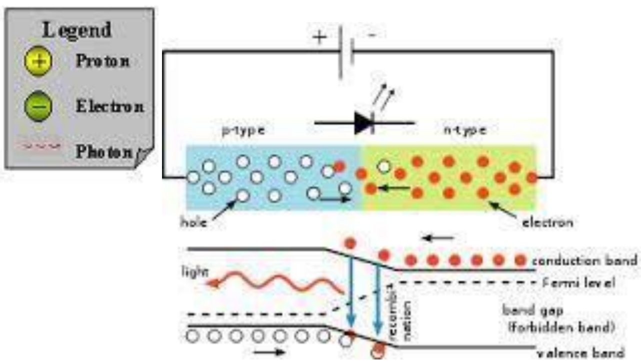
- A light-emitting diode is a semiconductor device that emits visible light when an electric current passes through it.
- In most LEDs light emitted is monochromatic, occurring at a single wavelength.
- The output from an LED can range from red (at a wavelength of approximately 700 nanometers) to blue-violet (about 400 nanometers). Some LEDs emit infrared (IR) energy (830 nanometers or longer); such a device is known as an *infrared- emitting diode* (IRED).



Basic construction of LED

- The holes are present in the valance band and the free electrons are in the conduction band.
- When a p-n junction is forward biased, the electron from n-type semiconductor material cross the p-n junction and combine with the holes in the p-type semiconductor material. Thus with respect to the holes, the free electrons are at higher energy level.
- When a free electron recombines with hole, the energy level changes from higher value to the lower value and it falls from the conduction band to the valance band.
- There is an energy release due to the electron travel.
- In LED the energy release in the form of photons which emit the light energy. This process is called electroluminescence.





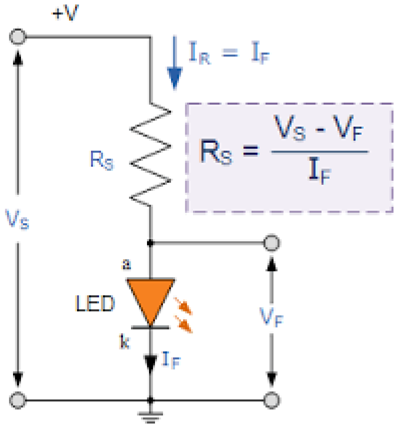
- The colour and wavelength of the emitted light can be controlled by doping with various impurities.
- The LED use mixtures of Gallium (Ga), Arsenic (As) and Phosphorous (P). The colour of the LED decided by the wavelength depends on forbidden energy gap. Hence different mixtures give the different colours.
- Red LED or Green LED : The mixture of Gallium phosphide (GaP) will produce the Red or Green colour light.
- Yellow LED or Red LED: The mixture of Gallium, Arsenide and Phosphide (GaAsP) will produce the yellow and red colour light.
- Infrared light emitting diode or Invisible LED: The mixture of Gallium arsenide (GaAS) will produce infrared light.

- Consider the LED which is connected to the supply voltage through a current limiting resistor. The current through the LED is given by the relation

$$\therefore I_F = \frac{V_S - V_F}{R_S}$$

Where,
V_S = supply voltage
V_F= voltage drop across LED R_S = Current limiting resistor.

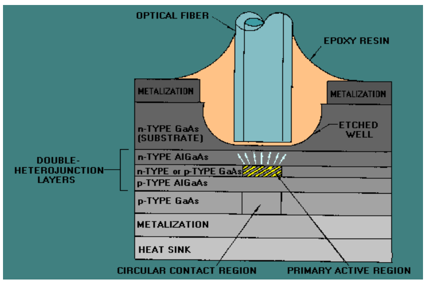
- The value of the current limiting is given by



IV Types of LED in optical fibre communication

Surface-Emitting LED

- The surface-emitting LED is also known as the Burrus LED in honor of C. A. Burrus, its developer.
- In SLEDs, the size of the primary active region is limited to a small circular area of 20µm to 50 µm in diameter. The active region is the portion of the LED where photons are emitted. The primary active region is below the surface of the semiconductor substrate perpendicular to the axis of the fibre.
- A well is etched into the substrate to allow direct coupling of the emitted light to the optical fibre. The etched well allows the optical fibre to come into close contact with the emitting surface.
- The epoxy resin that binds the optical fibre to the SLED reduces the refractive index mismatch, increasing coupling efficiency.



Edge-Emitting LED

- The demand for optical sources for longer distance, higher bandwidth systems operating at longer wavelengths led to the development of edge-emitting LEDs.
- The primary active region of the ELED is a narrow stripe, which lies below the surface of the semiconductor substrate. The semiconductor substrate is cut or polished so that the stripe runs between the front and back of the device.
- The polished or cut surfaces at each end of the stripe are called facets
- In an ELED the rear facet is highly reflective and the front facet is antireflection-coated. The rear facet reflects the light propagating toward the rear end-face back toward the front facet. By coating the front facet with antireflection material, the front facet reduces optical feedback and allows light emission.

- ELEDs emit light only through the front facet. ELEDs emit light in a narrow emission angle allowing for better source-to-fibre coupling.
- They couple more power into small NA fibres than SLEDs. ELEDs can couple enough power into single mode fibres for some applications.
- ELEDs emit power over a narrower spectral range than SLEDs. However, ELEDs typically are more sensitive to temperature fluctuations than SLEDs.

V A SUPERLUMINESCENT LIGHT EMITTING DIODE (SLD)

- A **superluminescent diode** (SLD) is an edge-emitting semiconductor light source based on superluminescence. It combines the high power and brightness of laser diodes with the low coherence of conventional light-emitting diodes. Its emission band is 5–100 nm wide.
- It is similar to a laser diode, based on an electrically driven pn-junction that, when biased in forward direction, becomes optically active and generates amplified spontaneous emission over a wide range of wavelengths.
- The peak wavelength and the intensity of the SLD depend on the active material composition and on the injection current level.
- SLDs are designed to have high single pass amplification for the spontaneous emission generated along the waveguide but, unlike laser diodes, insufficient feedback to achieve lasing action. This is obtained very successfully through the joint action of a tilted waveguide and anti-reflection coated (ARC) facets.
- When an electrical forward voltage is applied an injection current across the active region of the SLD is generated. Like most semiconductor devices, a SLD consists of a positive (p-doped) section and a negative (n-doped) section.
- Electric current will flow from the p-section to the n-section and across the active region that is sandwiched in between the p- and n-section. During this process, light is generated through spontaneous and random recombination of
  positive (holes) and negative (electrons) electrical carriers and then amplified when travelling along the waveguide of a SLD.
- The pn-junction of the semiconductor material of a SLED is designed in such a way that electrons and holes feature a multitude of possible states (energy bands) with different energies. Therefore, the recombination of electron and holes generates light with a broad range of optical frequencies, i.e. broadband light

Advantages of LED

- Very low voltage and current are enough to drive the LED.
- Voltage range required is 1 to 2 volts.
- Current range is 5 to 20 milliamperes.
- Total power output will be less than 150 milliwatts.
- The response time is very less, about 10 ns.
- The device does not need any heating and warm up time.
- Miniature in size and hence light weight.
- Have a rugged construction and hence can withstand shock and vibrations.
- An LED has a life span of more than 20 years. Disadvantages of LED
- A mild excess in voltage or current can damage the device.
- The device has wider bandwidth compared to the laser.
  - The temperature depends on the radiant output power and wavelength.

VI LASER diodes

- A Laser Diode is similar to an LED in many respects but in produces a narrow beam of high intensity.

- The radiation produced by the laser diode is of a single wavelength so that, if it is passed through glass panels it will not split into different wavelengths.

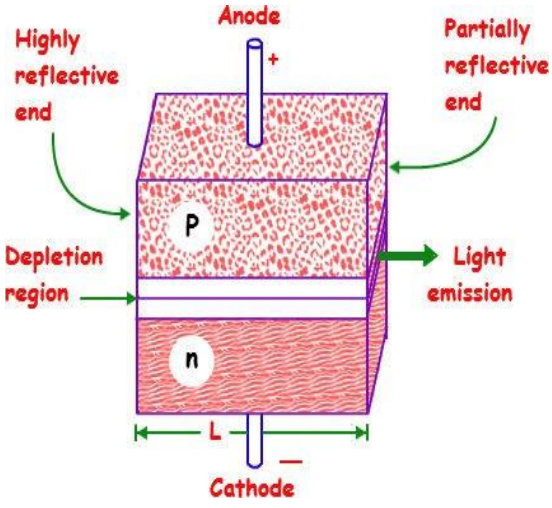
- The acronym laser means light amplification by stimulated emission of radiation. The light which is coming out from a laser diode can be characterized as follows:
- **Monochromatic:** It consists of a single color and not a mixture of colors. The spectral width of the radiated light is very narrow.
- **Well directed:** It radiates a narrow, well directed beam that can be

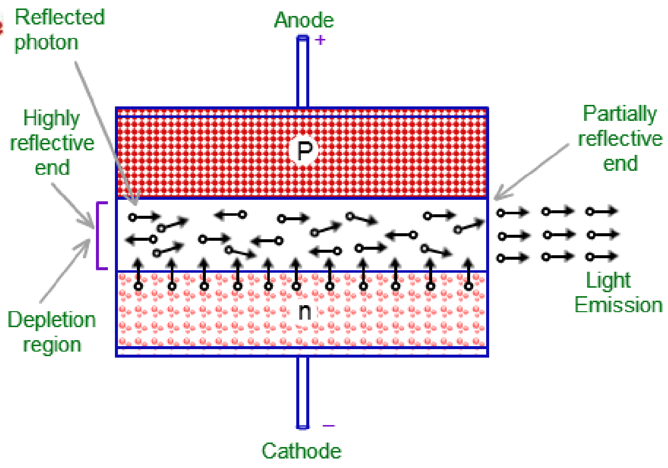
easily launched into an optical fibre. Highly intense and power efficient.

- **Coherent:** Coherent light means that a light with single wavelength. Since the light emitted by the LED has wide band of wavelength, it is an incoherent light whereas laser light is a coherent light.

Construction of LASER diode

- The p-n junction formed in a Laser diode by two doped gallium arsenide layers. It has got two flat ends structure which is parallel with one end mirrored and one partially reflective. Wavelength of the light to be emitted is precisely related to the length of the junction.



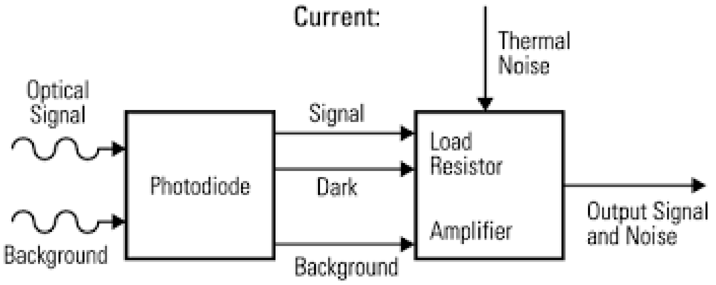


Operation of laser diode

- When a p-n junction is forward biased by an external voltage source, the electrons move through the junction and recombines as in an ordinary diode. When electrons recombine with holes, photons are released. These photons strikes atoms, causing more photon to be released. As the forward bias current is increased, more electrons enter the depletion region and cause more photon to be emitted.
- Eventually some of the photons that are randomly drifting within the depletion region strike the reflected surface perpendicularly, so that they are reflected back along their original path. The reflected photons are then again reflected back from the other end of the junction. This movement of photons from one end to the another end continues for many times. During this movement of photons strike more atoms and release additional photons due to avalanche effect. This process of reflection and generation of increasing number of photons results a very intense beam of laser light.
- Each photons produced in the above explained emission process is identical to the other photons in energy level, phase relation and frequency. Thus emission process gives a intense beam of laser with single wavelength. To produce a beam of laser light it is necessary to have a current through the laser diode above certain threshold level. The current below threshold level forces diode to behave as LED, emitting incoherent light.
- GalnAsP – This is a diode made up of Ga,ln,As and P. which emits laser light having wavelength 1300nm. It find applications in fibre optical communications

Photo detectors

- Photo detectors for optical communication should have sufficiently fast response and must provide a measurable output for a small amount of light.
- Must be easily reproducible and economical.



VII PIN photo diode

- The PIN photodiode is a semiconductor device region that is sandwiched between a p-type and an that consists of an intrinsic (lightly doped) n-type layer.
- When this device is reverse-biased, it exhibits an almost infinite internal impedance (Le., like an open circuit), with an output current that is proportional to the input optical power.
- The input-output relationship defines a responsivity R and a

  quantum efficiency η

$$R = \frac{\text{output current } I}{\text{input optical power } P} \text{ (amperes/watts)}$$

$$\eta = \frac{\text{number of output electrons}}{\text{number of input photons.}}$$

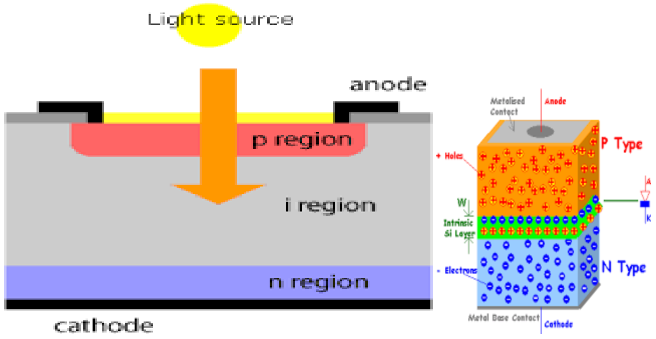
- Rand η are related through the relationship

$$R = \frac{e\eta}{h\nu}$$

where e is the electron charge, η is the efficiency, h is Planck's constant, and v is the light frequency .

- When a photon creates an electron-hole pair, the device produces a current pulse with duration and shape that depends on the response time of the device. The RC time constant determines the frequency response of the PIN device.
- The capacitance of the reverse-biased PIN photodiode is a limiting factor to its response (and switching speed). As the switching speed increases to very high frequencies, parasitic inductance becomes significant and causes "shot noise," which is estimated as $2e(I_s+I_{dark})$ where I_si s the signal current and I_{dark} the current that flows at the absence of signal, or dark current.

Construction of PIN diode



VIII The avalanche photodiode

- Possesses a similar structure to that of the PIN or PN photodiode.

  The structure is optimized for avalanche operation.

- It operates under a high reverse bias condition to enable avalanche multiplication of the holes and electrons created by the initial hole electron pairs created by the photon / light impact.

- these electrons collide with other electrons in the semiconductor material, they cause a fraction of them to become part of the photocurrent. This process is known as **avalanche multiplication**.

- Avalanche multiplication continues to occur until

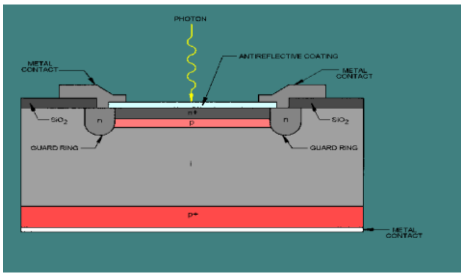
  the electrons move out of the active area of the APD.

- During this multiplication process, shot noise is multiplied as well,

  and is estimated

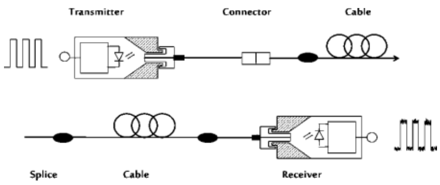
- The avalanche action enables the gain of the diode to be increased many times, providing a much greater level of sensitivity.

Construction of APD



- The response time of an APD and its output circuitry depends on the same factors as PIN photodiodes. The only additional factor affecting the response time of an APD is the additional time required to complete the process of avalanche multiplication.

Fibre Couplers and Connectors



- Optical communication requires both joints and termination of the transmission medium.
- Joints and connections are dependent upon the link length
- Fibre to fibre connection has to be done with low loss and minimum distortion.

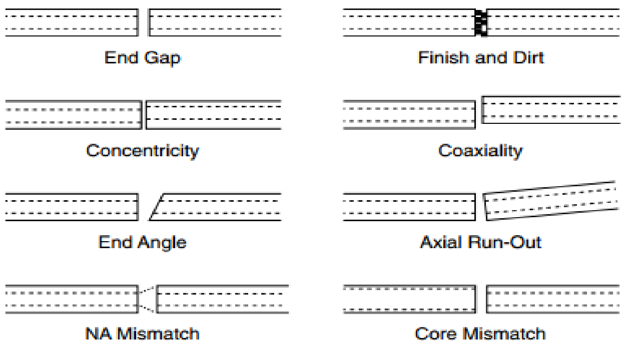
There are many reasons for fibre joints, they are

1. Fibres with limited length must be joined.

2. Fibre may also be joined to distribution cables and splitters.

3. At both transmit and receive termination points, fibres must be joined to that source and detector

Cable cuts and their subsequent restoration.



VIII Types of connectors

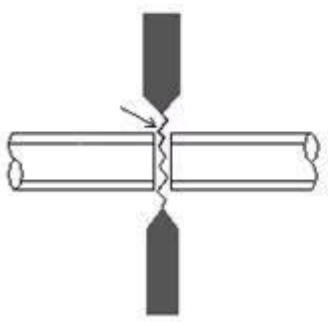
1. Resilient ferrule 2. Rigid ferrule 3. Grooved plate hybrids 4. Expanded beam 5. Rotary

Splicing

- Splices normally are a permanent joint between two fibres.
- The two basic categories of splices are fusion and mechanical.
- Splices give a lesser return loss, lower attenuation, and greater physical strength than connectors.
- Splices are usually less expensive per splice than connectors, require less labor, constitute a smaller joint for inclusion into splice closures, offer a better hermetic seal, and allow either individual or mass splicing.

Fusion splicing

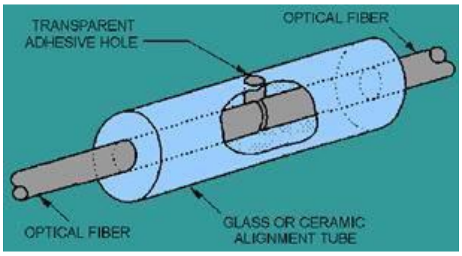
- Fusion splicing works on the principle of an electric arc ionizing the space between the prepared fibres to eliminate air and to heat the fibres to proper temperature (2,000°F).
- The fibre is then fed in as a semiliquid and melds into its mate. The previously removed plastic coating is replaced with a plastic sleeve or other protective device.
- The perfect fusion splice results in a single fibre rather than two fibres having been joined.
- The disadvantage in fusion splicing is that it most generally must be performed in a controlled environment, that is, a splicing van or trailer, and should not be done in open spaces because of dust and other contamination.



Mechanical Splicing

- Mechanical splicing, on the other hand, is quick and easy for restoration, its major use, and is also used for new construction, especially with multimode fibre.

- It does not require a controlled environment other than common sense dust control.
- The strength of a mechanical splice is better than most connectors; however, fusion remains the strongest method of splicing. Back reflection and loss vary from one type of splice to another.
- Mechanical splices are best suited for multimode fibre applications. Some mechanical splices have been introduced for single mode fibres, but they usually have a higher insertion loss



Fibre optic couplers

- It can either be passive or active devices.
- **Passive** fibre optic couplers are said to be passive as no power is required for operation. They are simple fibre optic components that are used to redirect light waves. Passive couplers either use micro-lenses, graded- refractive-index (GRIN) rods and beam splitters, optical mixers, or splice and fuse the core of the optical fibres together.
- **Active** fibre optic couplers require an external power source. They receive input signal(s), and then use a combination of fibre optic detectors, optical-to-electrical converters, and light sources to transmit fibre optic signals.

IX Types of Fibre Optic Couplers

- Types of fibre optic couplers include splitters, combiners, X-

couplers, trees, and stars, which all include single window, dual window, or wideband transmissions.

- **Fibre optic splitters** take an optical signal and supply two outputs. They

can further be described as either Y-couplers or T-couplers.

- **Y-couplers** have equal power distribution, meaning that the two output signal each receive half of the transmitted power.
- **T-couplers** have an uneven power distribution. The signal outputs still carrier the same signal, however the power of one output is greater than the second output.

Fibre optic combiners receive two signals and provide a single output. The output signal is typically comprised of multiple wavelengths, due to the amount of interference that occurs when attempting to combine two signals that share the same wavelength.

X-couplers carry out the function of a splitter and combiner in one package. They are a 2x2 coupler that combines the power of two signals and then divides the signal between two outputs.

Star couplers have M inputs and N outputs (MxN). They are used to distribute the power from all of the inputs to all outputs.

Tee couplers either have 1 input and M outputs (1xM) or N

inputs and 1 output (Nx1).

1. List the types of LEDs used in optical fiber applications. With neat diagram explain the working and construction of each type of LED.
2. Write about the various types photo detectors with neat diagrams.
3. Discuss in detail about the methods used for splicing.
4. What is the use of connectors in optical fibers? Explain its types with neat diagram.
5. Write notes on
   a. Couplers
   b. Reason for fiber joints
   c. Types of fiber joints.

References

1. G.Keiser, Optical Fiber Communication, McGraw Hill, 1995.
2. M.Arumugam, Optical Fiber Communication and Sensors, Anuradha Agencies, 2002.
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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – III - FIBRE OPTICS & LASER FOR BIOMEDICAL APPLICATIONS – SBMA7003

OPTICAL SOURCES, DETECTORS, FIBRE COUPLERS & CONNECTORS

Laser Characteristics

Single frequency operation

- A *single-frequency laser* (sometimes called a *single-wavelength laser*) is a laser which operates on a single resonator mode, so that it emits quasi- monochromatic radiation with a very small linewidth and low phase noise.
- mode distribution noise is eliminated, single-frequency lasers also have the potential to have very low intensity noise. In nearly all cases, the excited mode is a Gaussian mode, so that the output is diffraction limited.
- The *mode suppression ratio* (MSR) is then defined as the power of the lasing mode divided by that in the next strongest mode. It can be optimized by making the laser resonator more frequency-selective.
- Single-frequency lasers can be very sensitive to optical feedback. Even if less than a millionth of the output power is sent back to the laser, this may in some cases cause strongly increased phase noise and intensity noise or even chaotic multimode operation. Therefore, single-frequency lasers have to be carefully protected against any back-reflections, often using one or two Faraday isolators.
- important types of single-frequency lasers, which differ very much in terms of
  output power, linewidth, wavelength, complexity and price

Types of Single frequency LASER

- low-power *laser diodes*
- distributed feedback lasers (DFB lasers) or distributed Bragg reflector lasers (DBR lasers)
- unidirectional ring laser
- distributed feedback lasers
- *Diode-pumped solid-state bulk lasers*
- vertical cavity surface-emitting lasers
- *helium–neon laser*

Applications

- Typical applications of single-frequency lasers occur in the areas of optical metrology (e.g. with fibre-optic sensors) and interferometry, optical data storage, high-resolution spectroscopy (e.g. LIDAR), and optical fibre communications. In some cases such as spectroscopy, the narrow spectral width of the output is directly important. In other cases, such as optical data storage, a low intensity noise is required, thus the absence of any mode beating noise.

- Single-frequency sources are also attractive because they can be used for driving resonant enhancement cavities, e.g. for nonlinear frequency conversion, and for coherent beam combining. The latter technique is currently used to develop laser systems with very high output powers and good beam quality.

Coherence of laser

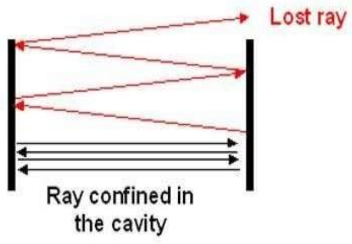
- The coherent light produced by a laser differs from ordinary light in that it is made up of waves all of the same wavelength and all in phase (i.e., in step with each other); ordinary light contains many different wavelengths and phase relations. Both the laser and the maser find theoretical basis for their operation in the quantum theory. Electromagnetic radiation (e.g., light or microwaves) is emitted or absorbed by the atoms or molecules of a substance only at certain characteristic frequencies. According to the quantum theory, the electromagnetic energy is transmitted in discrete amounts (i.e., in units or packets) called quanta. A quantum of electromagnetic energy is called a photon. The energy carried by each photon is proportional to its frequency.

- An atom or molecule of a substance usually does not emit energy; it is then said to be in a low-energy or ground state. When an atom or molecule in the ground state absorbs a photon, it is raised to a higher energy state, and is said to be excited. The substance spontaneously returns to a lower energy state by emitting a photon with a frequency proportional to the energy difference between the excited state and the lower state. In the simplest case, the substance will return directly to the ground state, emitting a single photon with the same frequency as the absorbed photon.
- In a laser or maser, the atoms or molecules are excited so that more of them are at higher energy levels than are at lower energy levels, a condition known as an inverted population. The process of adding energy to produce an inverted population is called pumping. Once the atoms or molecules are in this excited state, they readily emit radiation. If a photon whose frequency corresponds to the energy difference between the excited state and the ground state strikes an excited atom, the atom is stimulated to emit a second photon of the same frequency, in phase with and in the same direction as the bombarding photon.
- The bombarding photon and the emitted photon may then each strike other excited atoms, stimulating further emissions of photons, all of the same frequency and all in phase. This produces a sudden burst of coherent radiation as all the atoms discharge in a rapid chain reaction.
- Often the laser is constructed so that the emitted light is reflected between opposite ends of a resonant cavity; an intense, highly focused light beam passes out through one end, which is only partially reflecting. If the atoms are pumped back to an excited state as soon as they are discharged, a steady beam of coherent light is produced.

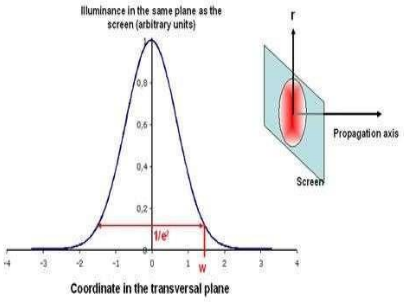
Spatial distribution

Spatial characteristics of the emitted laser beam

- The cavity acts as a spatial filter by selecting only those light rays beams close to its central axis: the others are lost due to their distance from the axis and the size of the mirrors

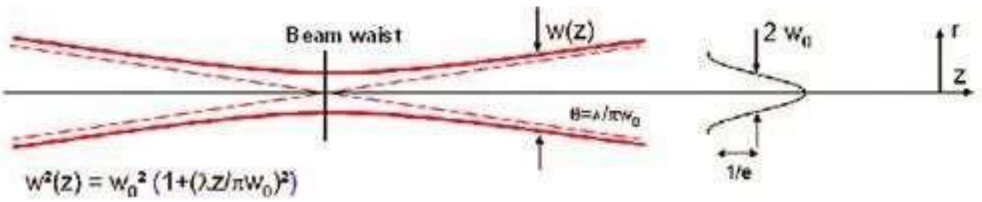


- A laser operating in a steady state produces a light wave whose spatial structure does not change despite numerous round trips inside the cavity. In this case, the laser cavity must contain a light wave able to propagate in the cavity and remain constant after each round trip. This is known as a "Gaussian" wave whose light distribution is Gaussian in shape in the plane perpendicular to the axis of propagation. Physically, a Gaussian wave concentrates the light along the axis of the cavity. A Gaussian wave emitted through space is like a narrow beam of light and is called a Gaussian beam. By placing a small piece of cardboard or a detector perpendicular to the propagation axis of the wave (at the laser output) it is possible to measure the irradiance (the number of photons incident on a surface per unit area). Graphically, this irradiance will follow a Gaussian curve.



- A certain spatial extension of the light wave can also be defined: the radius of the beam is equal to the distance between the optical axis and the spot where the irradiance is divided by 1/e2 in relation to the maximum irradiance of the wave.
- A Gaussian wave propagates in a slightly different way from that described by classic geometrical optics. It has a minimum w0 at one place along the beam axis, known as the beam waist . Far from the waist, the beam diverges "in a straight line" at an angle of divergence θ.

$\theta = \lambda \; / (\pi \times w_0)$



Appearance of the light beam according to its position (z is the propagation axis).

- The above formula also proves that if the divergence is high (for example if the beam is focused by a lens) then the radius of the beam at the waist is very small. Generally, it is possible to focus the laser beam at a radius of the same magnitude as the wavelength. This can also be done with an ordinary lamp but the difference is the number of photons that can be delivered per second onto a small area. This is very low for an ordinary lamp but huge for a laser. For example, a 633 nm beam with a power of 1 mW corresponds to a flux of 1015 photons per second and can easily be focused on a micrometre-wide spot . Thus, the power density of a simple helium-neon laser at a focal point is much greater than a sunbeam focused by a lens.
- To summarise, an optical cavity selects a specific beam (a Gaussian beam) from the many photons spontaneously emitted by the "lamp-amplifying medium" and the number of photons carried by this beam is increased considerably, as it travels back and forth, by the process of stimulated emission. This beam can have a very low divergence and can be very precisely focused if the right optical tools are used.

Intensity of Laser emission

- Intensity or irradiance is the power of the laser beam divided by the cross-sectional area of the beam. It is thus typically given in watts per square centimeter (W/cm2). It is a measure of the amount of energy that can be applied to a specific region within a given amount of time.

- one of the two most important parameters in using the laser for materials processing applications such as welding, cutting, heat treating, ablating, and drilling, or for laser surgery.
- The other important parameter is the laser wavelength, since the amount of absorption of all materials, including biological materials, is dependent upon the wavelength of the light. In some instances a deep penetration of the beam is desired, for example in doing processes that must be carried out quickly. In that situation, a laser wavelength in which the material has a relatively low absorption would be selected.
- Other applications might require a shallow penetration in order to control the quality of the edge to be left after the process is completed, such as in some surgical processes or in drilling very small holes.
- a wavelength region of high absorption would be chosen for the laser. A general rule is that absorption is very high for most materials at ultraviolet wavelengths and decreasing at longer wavelengths. However, this does not hold true for all materials or for all wavelengths. Many materials have high absorption peaks at specific wavelengths that could occur anywhere in the spectrum, so one must be careful to obtain the
- absorption versus wavelength curves for the desired material before choosing the specific laser
- In all instances where high beam intensity is desired, the availability of the laser with sufficient intensity at that wavelength must be considered. Not all wavelengths with such intensity are possible. There are, however, lasers such as the CO2 laser in the middle infrared (10.6 μm); the Q-switched Nd:YAG laser in the near infrared (1.06 μm) and frequency-doubled Nd:YAG to the green (530 nm); the copper vapor laser in the green (510 nm) and yellow (578 nm); and the ultraviolet excimer lasers including the XeF laser (351 nm), XeCl laser (308 nm), KrF laser (at 248 nm), ArF laser (193 nm), and F2 laser (157 nm). For various aspects of materials processing, the beam must have an intensity in the range of 108–109 W/cm2.

Polarization of Laser Emission

- Natural sunlight and most forms of artificial illumination transmit light waves whose electric field vectors vibrate equally in all planes perpendicular to the direction of propagation. When their electric field vectors are restricted to a single plane by filtration, however, then the light is polarized with respect to the direction of propagation.

Light Passing Through Crossed Polarizers

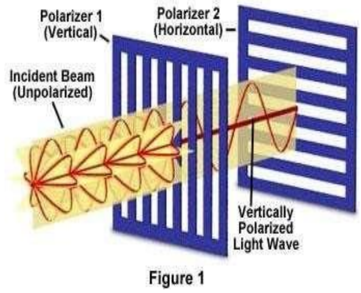
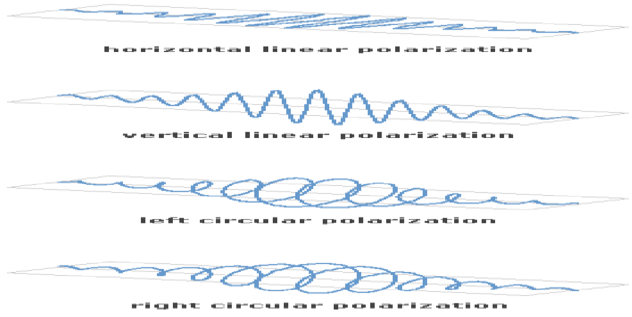


Figure 1

- The basic concept of polarization is illustrated above in Figure 1. In this example, the electric field vectors of the incident light are vibrating perpendicular to the direction of propagation in an equal distribution of all planes before encountering the first polarizer, a filter containing long- chain polymer molecules that are oriented in a single direction. Only the incident light that is vibrating parallel to the polarization direction is allowed to continue propagating unimpeded.
- Therefore, since Polarizer 1 is oriented vertically, it only permits the vertical waves in the incident beam to pass. However, the waves that pass through Polarizer 1 are subsequently blocked by

Polarizer 2 because it is oriented horizontally and absorbs all of the waves that reach it due to their vertical orientation. The act of using two polarizers oriented at right angles with respect to each other is commonly termed **crossed polarization** and is fundamental to the practice of polarized light microscopy.

- cases the output of a laser is polarized. This normally means a linear polarization state, where the electric field oscillates in a certain (stable) direction perpendicular to the propagation direction of the laser beam. There are cases (occurring e.g. with fibre lasers) where a different, e.g. elliptical but also more or less stable polarization state is generated, which can be transformed into a linearly polarized beam, e.g. by using an appropriate combination of waveplates. This is not possible, however, for broadband emission with wavelength-dependent polarization state.



- Under special circumstances, radially polarized beams can be generated, where the polarization direction within the beam profile is radially oriented. Usually, a radially polarized beam is generated from a linearly polarized beam with some optical element, but it is also possible to obtain radially polarized emission directly from a laser. The advantage of this approach, applied in a solid-state bulk laser, is that depolarization loss may be avoided
- Polarized laser emission is important for a range of applications. Some examples are:
- nonlinear frequency conversion, where phase matching in a nonlinear crystal is normally obtained only for one polarization direction
- cases where two laser beams need to be polarization-coupled (→ *polarization beam combining*)
- processing of laser beams in polarization-dependent devices, such as interferometers, semiconductor optical amplifiers, and optical modulators
- However, some lasers (e.g. many fibre lasers) do not generate a polarized output. This does not necessarily mean that the laser output is truly unpolarized, containing equal optical powers in two polarization components at any time, without any correlation of the corresponding amplitudes. The polarization state may simply be unstable, e.g. due to temperature drifts, or randomly switch between different directions. For generating a truly unpolarized laser beam, some kind of polarization-scrambling optical device is usually required.
- The degree of linear polarization is often quantified with the *polarization extinction ratio* (PER), defined as the ratio of optical powers in the two polarization directions, often specified in decibels, and measured by recording the orientation-dependent power transmission of a polarizer. Of course, the extinction ratio of the polarizer itself must be higher than that of the laser beam.

MEASUREMENT OF PULSED LASER ENERGY

- *Energy per pulse:*
  Energy per pulse is determined by dividing the average power by the repetition rate.
  The resultant quantity is the energy, in Joules, contained in EACH laser pulse.

$$E = \frac{P_{Av}}{R_{Rate}}$$

Where: *E = Energy i*$^{n\ Joules}$

Av P = Average power in Watts

Rate R = Repetition rate in pulses per Second.

Peak Power per Pulse:

Peak Power per pulse is determined by dividing the energy per pulse by the pulse duration.

Pk

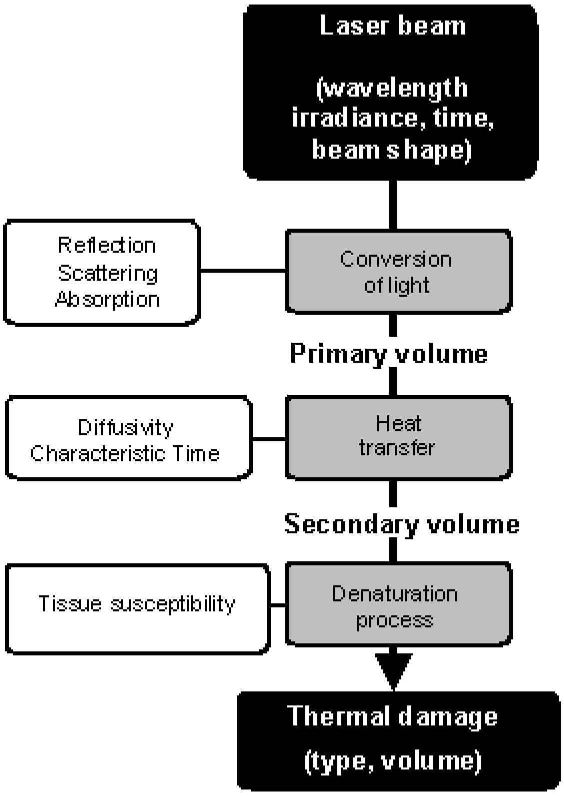
$$P_{pk} = \frac{E}{D_{pulse}}$$ *Where: P = Peak power in Watts*

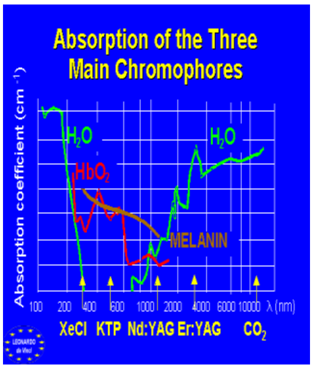
E = Energy per pulse in Joules

pulse D = Pulse duration at the full-width-half-maximum points.

Mechanisms for Polarized or Unpolarized Emission

- Different mechanisms can be responsible for linearly polarized emission of a laser:
- The laser gain may be polarization dependent. This is the case in some anisotropic laser crystals (e.g. Nd:YVO_4 or Nd:YLF), but also in some semiconductor optical amplifiers
- Note that a very small gain or loss difference for the two polarization directions can be sufficient for obtaining a stable linear polarization, provided that there is no significant coupling of polarization modes within the laser resonator
- Note that a very small gain or loss difference for the two polarization directions can be sufficient for obtaining a stable linear polarization, provided that there is no significant coupling of polarization modes within the laser resonator.
- On the other hand, the polarization state of the laser output can be disturbed e.g. by random (and temperature-dependent) birefringence, such as occurs e.g. in optical fibres (if they are not polarization-maintaining or single-polarization fibres) and also in laser crystals or glasses as a result of thermal effects (→ *depolarization loss*). If the laser gain is isotropic, small drifts of the birefringence may lead to large changes of the polarization state, and also a significant variation in the polarization state across the beam profile.





- The thermal effect of lasers on biological tissue is a complex process resulting from three distinct phenomena; conversion of light to heat, transfer of heat and the tissue reaction, which is related to the temperature and the heating time.

  This interaction leads to denaturation or to the destruction of a volume of tissue. The known factors are the parameters of the laser (wavelength, power, time and mode of emission, beam profile and spot size) and the tissue being treated (optical coefficients, thermal parameters and coefficients of the reaction of thermal denaturation).
- a) Creation of the source of heat

  The source of heat results from conversion of laser light to heat. The optical reflection determines what proportion of the beam will effectively penetrate the tissue. Precise knowledge of the tissue reflectivity is important because it can reach high levels (30 to 50% of an argon beam is reflected by the skin). However, for wavelengths longer than the visible range, reflectivity tends to be considerably lower
- b) Mechanisms of heat transfer
- The transfer of heat through tissues will tend to enlarge the volume of this source of "primary" heat. This transfer is essentially produced by the mechanism of conduction; the influence of blood circulation (transport by convection) is negligible. Conduction may be considered to be like a transfer of energy by interaction with tissue particles. This transfer occurs randomly between the more and the less energetic particles and results in a "secondary" heated volume which is bigger than the "primary" source which is based only on the conversion of light to heat. It is this "secondary" heated volume which should be considered when studying the denaturation of tissue.
- c) Mechanism of tissue denaturation

  Denaturation of tissue is the final result of thermal action on tissue. Knowledge of the kinetics of this transformation is necessary to describe the process of denaturation. These kinetics depend on the temperature in the tissue, on the time of heating and on the susceptibility of the tissue to thermal damage.

Mechanical effects

- Mechanical effects can result from either the creation of a plasma, an explosive vaporisation, or the phenomenon of cavitation, each of which is associated with the production of a shock wave.

  With nano- or pico-second pulsed Nd:YAG lasers, a very high intensity of luminous flux over a small area (between 10^{10} and 10^{12} W/cm2) ionises atoms and creates a plasma. At the boundary of the ionised region, there is a very high pressure gradient which causes the propagation of a shock wave. It is the expansion of this shock wave which causes the destructive effect. These lasers are used principally in ophthalmology to break the membranes which often develop after the implanting of an artificial lens. The laser allows this treatment to be carried out as an out-patient procedure.

  With multiple shots, one can make a small flap in the membrane with an opening in the shape of a cross. The patient does not feel any pain and does not see any flash of light because the laser beam is in the infra-red. The flap created in this way falls into the body of the vitreous cavity, freeing the optical axis.

3 The photoablative effect

This effect is defined by as a pure ablation of material without thermal lesions at the margins, such as one would get with a scalpel. It occurs because of the principle of dissociation. With very short wavelengths (190 to 300 nm), the electric field associated with the light is higher than the binding energy between molecules. The molecular bonds are broken and the tissue components are vaporised, without generation of any heat at the edges. This effect is obtained with lasers of very energetic wavelengths such as those emitting in the ultra-violet (excimer lasers emit at 193 nm (ArF), 248 nm (KrF) or 308 nm (XeCl)). The action is very superficial, only over several microns, because light at these wavelengths is very strongly absorbed by tissue.

4 The photodynamic effect

Photodynamic therapy (PDT) involves the relatively selective uptake of a photosensitising drug and subsequent irradiation with light of a suitable wavelength. In the presence of oxygen, singlet oxygen is produced with the induction of a cytotoxic action. Illumination is required at a wavelength corresponding to the peak absorption of the drug.

Localisation of the effect in the target tissue is most commonly achieved by intravenous injection of the photosensitiser. It can also be administered topically, by spraying the surface of the organ, or orally. The photosensitising drugs used are not toxic at the dose levels used.

Question Bank

1. Discuss in detail about the LASER characteristics.
2. Explain in detail the 3 level and 4 level system to produce LASER light.
3. Briefly describe Intensity of laser emission, Measurement of pulsed LASER and Polarization of LASER emission.
4. How does a LASER react on tissues? What is the pathological laser reaction in skin?
5. What are the thermal and non thermal reactions of laser energy in tissues?
6. Explain in detail about the single frequency operation, Coherence of LASER and spatial distribution of a LASER beam.

SCHOOL OF BIO AND CHEMICAL ENGINEERING

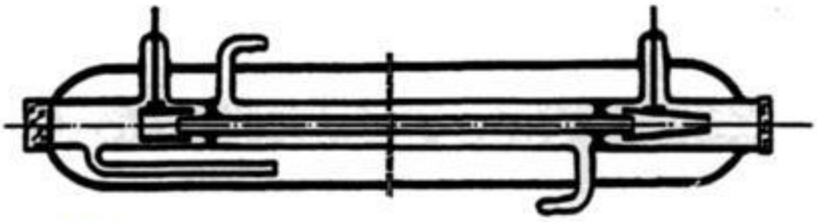
DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT – IV- FIBRE OPTICS & LASER FOR BIOMEDICAL APPLICATIONS – SBMA7003

LASER INSTRUMENTATION

I Advantage of CO_2 LASER surgery

- Accurate incision, precise excision
- Non contact.
- Highly sterile, visual control of operating field, bloodless surgery.
- Minimal damage to tissues. No electromagnet interference problem.
- Co2 LASERs are best suited for surgical applications when compared to other LASERs



Sealed-off CO_2 laser tube configuration

Carbon dioxide laser consists of a discharge tube having a diameter of 2.5cm and a length of about 5m. The discharge tube is filled with a mixture of carbon dioxide, nitrogen and helium gases in the ratio of 1:2:3 with water vapors. Pressures maintained are about P (for He)= 7 Torr, P (for N2)= 1.2 Torr and P (for CO2 = 0.33 Torr).

Active medium and active centers= The active medium is the CO2, N2 and He in the ratio of 1:2:3. The active centers are the carbon dioxide molecules because laser will be achieved due to these molecules.

- Pumping source= Electric discharge method is used for pumping and achieving population inversion. In this method, electrons will collide with CO2 molecules and pump them to excited states.
- The purpose of N2 is to help in excitation of CO2 molecules by colliding with CO2 molecules and transferring the energy to them. So N2 molecules increases the pumping efficiency.
- Optical resonator system= All the gas mixtures is enclosed between a set of mirrors which forms the optical resonator system. One of mirrors is completely reflecting and the other is partially reflecting.

- Pumping of nitrogen molecules: As electric discharge is used as pumping source and when electric discharge is passed through the mixture of CO2, N2 and He, electrons are accelerated down the tube. These accelerated electrons collide with the N2 molecules and excite them to higher vibrational energy levels. Let us say the N2 excited from level F1 to F2.
- The level F2 happens to be Metastable and thus the N2 molecules excited to F2 spend a sufficient amount of time before getting de- excited.
- Achievement of population inversion of CO2 molecules: The excited level (Metastable level) of CO2 molecules corresponds approximately to the same energy as the energy of the excited level F2 of nitrogen. Thus when N2 molecules in level F2 collide with the CO2 in the ground state E1, an energy exchange takes place and this result in the excitation of CO2 molecules to level E5 and de-excitation of N2 to the ground level F1.

- Thus population inversion is achieved between vibrational levels E5 and E4 or E5 and E3. Thus E5 is the upper laser level. E3 and E4 are lower laser levels.
- Achievement of laser: The following transitions will occur:
- E5 to E4 with laser wavelength of 10.6 μm.
- E5 to E3 with laser wavelength of 9.6 μm.
- Thus, these transitions produce lasers of wavelength 10.6 μm and 9.6 μm which lie in the far infra-red region.
- The CO2 molecules in the states E4 and E3 deexcite to state E2 through inelastic collision with unexcited CO2 molecules. This process is very fast so there will be accumulation of CO2 in this level and they can break the population inversion in upper levels because there is probability of excitation of molecules from E2 to E3 and/ or E4.
- To stop the accumulation of CO2 molecules in E2 special additives like He and water vapors are added into the gas mixture. CO2 molecules return to the ground state E1 through collisions with the He to which it transfers the excitation energy.

  Other function of He is to conduct the heat away to the walls keeping CO2 cold, this is because helium has high thermal conductivity.

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- To stop the accumulation of CO2 molecules in E2 special additives like He and water vapors are added into the gas mixture. CO2 molecules return to the ground state E1 through collisions with the He to which it transfers the excitation energy.
- Other function of He is to conduct the heat away to the walls keeping CO2 cold, this is because helium has high thermal conductivity.
- Wavelength and output of carbon dioxide laser:
- E5 to E4 with laser wavelength of 10.6 μm.
- E5 to E3 with laser wavelength of 9.6 μm.
- Thus, these transitions produce lasers of wavelength 10.6 μm and 9.6 μm which lie in the far infra-red region.

  Output of 10KW is achieved with transition of 10.6 μm and it is in continuous wave mode. Efficiency of CO2 laser is approximately 30%. The CO2 laser is more efficient than other gas lasers because in CO2 laser, the levels taking part in laser transitions are the vibrational rotational levels of the lowest electronic level and as these levels are very close to the ground level, thus a large part of the input energy is converted into output laser energy. Thus CO2 laser is more efficient than other gas laser.

II Nd YAG LASER

- Nd YAG laser has wavelength of about 10600 angstrom, that is in infrared region of spectrum. Nd YAG lasers may be operated in either a pulse mode or a continuous mode. The output powers for continuous wave mode range from 0.1 watts to 100 watts. The peak power for the pulse mode can range from tens or hundreds of kilowatts with a pulse lasting milliseconds. The pulse will last for 10-20 nanoseconds for a peak power of hundred megawatts.
- Nd YAG laser has following applications or uses or advantages:
- They produce continuous laser at room temperature
- They can be used as portable systems since the rods are small.
- they have surgical applications.
- they are used material processing such as drilling, spot welding and marking.
- They are used as pumping tunable visible light lasers.
- They have applications in military such as including range finders and target designators.

  Research applications such as Raman spectroscopy, remote sensing, mass spectrometry.

- Nd: YAG is a solid state laser four level laser. Nd stands for neodymium and YAG for Yttrium aluminium garnet ($Y_3Al_5O_{12}$). It is developed by J.E. Geusic, H.M. Marcos and L.G. Van Vitert in 1964. The rod of $Y_3Al_5O_{12}$ is doped 1% with triply ionized neodymium. Nd^{3+} ions will replace the Y^{3+} ions in the crystal. Maximum length of the rod is about 10 cm and diameter is 6-9 cm.
- **Active medium**: Nd^{3+} ions act as active medium or active centers.
  YAG is just the host.
- **Pumping source**: The pumping of Nd^{3+} ions to upper levels is done by krypton arc lamp. Xenon lamp can also be used as pumping source. Thus, the optical pumping is used to achieve population inversion.
  - **Optical resonator system**: The ends of the Nd:YAG rod are polished and silvered so as to act as the optical resonator system.

- Nd:YAG is a four level laser system. The pumping of neodymium (Nd3+) ions to upper state (E4) is done using krypton arc lamp. Thus optical pumping is used in this laser. The wavelength of light of wavelength 7200 Å to 8000 Å excites the ground state (E1) Nd3+ ions to E4 states. From E4 states, they make a non-radiative transition and come to E3 state. E3 is the metastable state so population inversion is achieved between the levels E3 and E2.

- After this, the process of stimulated emission will occur. Thus, the laser emission will occur in between the levels E3 and E2 with the process of stimulated emission. So E3 is the upper laser level and E2 is the lower laser level. Then Nd3+ ions come back to the ground state E1. Laser emission will have wavelength of 10600 Å so occur in the infrared range of spectrum.

- **Pumping of He atoms**: When electric discharge is passed through the gas mixture of He and Ne, electrons are accelerated down the discharge tube in which mixture of He-Ne is placed. These accelerated electrons collide with helium atoms and excite them to higher energy levels (let us say F2 and F3).

- These levels happen to be Metastable and thus the He atoms spend a sufficient amount of time there before getting de-excited.

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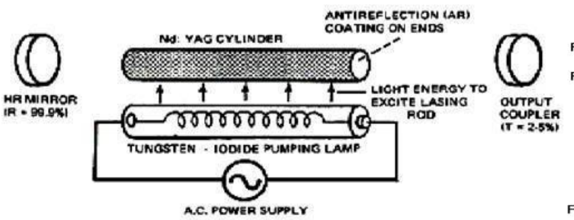
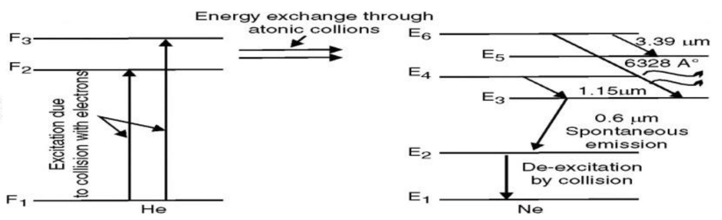




III Ruby Laser

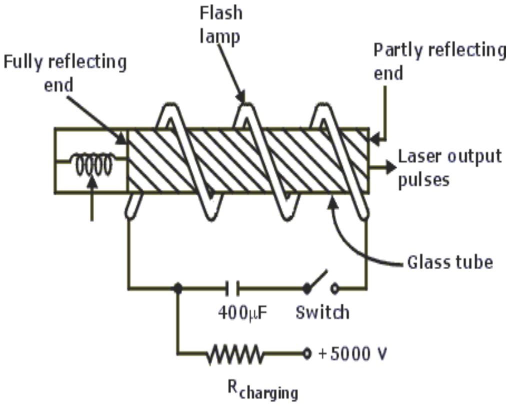
- The first laser to be operated successfully was ruby laser. First demonstration of laser action using ruby crystal was given by T.H. Maiman in 1960. It is a solid state laser.
- Construction
- Ruby is a crystal of aluminium oxide (Al2O3) in which some of the aluminium ions (Al3+) are replaced by chromium ions (Cr3+). This is done by doping small amounts of chromium oxide (Cr2O3) in the melt of purified Al2O3.
- These chromium ions give the crystal a pink or red color depending upon the concentration of chromium ions. Laser rods are prepared from a single crystal of pink ruby which contains 0.05% (by weight) chromium. Al2O3 does not participate in the laser action. It only acts as the host.

- The ruby crystal is in the form of cylinder. Length of ruby crystal is usually 2 cm to 30 cm and diameter 0.5 cm to 2 cm. As very high temperature is produced during the operation of the laser, the rod is surrounded by liquid nitrogen to cool the apparatus.
- Active medium or active center: Chromium ions act as active centers in ruby crystal. So it is the chromium ions that produce the laser.

- Pumping source: A helical flash lamp filled with xenon is used as a pumping source. The ruby crystal is placed inside a xenon flash lamp. Thus, optical pumping is used to achieve population inversion in ruby laser.
- Optical resonator system: The ends of ruby crystal are polished, grounded and made flat. The one of the ends is completely silvered while the other one is partially silvered to get the output. Thus the two polished ends act as optical resonator system.

- Ruby is a three level laser system. Suppose there are three levels E1, E2 and (E3 & E4). E1 is the ground level, E2 is the metastable level, E3 and E4 are the bands. E3 & E4 are considered as only one level because they are very closed to each other.
- Pumping: The ruby crystal is placed inside a xenon flash lamp and the flash lamp is connected to a capacitor which discharges a few thousand joules of energy in a few milliseconds. A part of this energy is absorbed by chromium ions in the ground state. Thus optical pumping raises the chromium ions to energy levels inside the bands E3 and E4. This process is called stimulated absorption. The transition to bands E3 and E4 are caused by absorption of radiations corresponding to wavelengths approximately 6600 angstroms and 4000 angstroms respectively. The levels inside the bands E3 and E4 are also known as pumping levels.
- Achievement of population inversion: Cr3+ ions in the excited state loose a part of their energy during interaction with crystal lattice and decay to the metastable state E2. Thus, the transition from excited states to metastable state is non- radiative transition or in other words there is no emission of photons. As E2 is a metastable state, so chromium ions will stay there for longer time. Hence, the number of chromium ions goes on increasing in E2 state, while due to pumping , the number in the ground state E1 goes on decreasing. As a result, the number of chromium ions become more in excited state(metastable state) as compared to ground state E1. Hence, the population inversion is achieved between states E2 and E1.

- **Achievement of laser**: Few of the chromium ions will come back from E2 to E1 by the process of spontaneous emission by emitting photons. The wavelength of a photon is 6943 Å. This photon travels through the ruby rod and if it is moving in a direction parallel to the axis of the crystal, then it is reflected to and fro by the silvered ends of the ruby rod until it stimulates the other excited ions and cause it to emit a fresh photon in phase with the stimulating photon. Thus, the reflections will result in stimulated emission and it will result in the amplification of the stimulated emitting photons. This stimulated emission is the laser transition.
- The two stimulated emitted photons will knock out more photons by stimulating the chromium ions and their total number will be four and so on. This process is repeated again and again, thus photons multiply. When the photon beam become sufficiently intense, then a very powerful and narrow beam of red light of wavelength 6943 Å emerges through the partially silvered end of the ruby crystal.
- In the energy level diagram, E2 is the upper laser level and E1 is the lower laser level because laser beam is achieved in between these levels. Thus, the ruby laser fits into the definition of three level laser system.
- **Output**: The output wavelength of ruby laser is 6943 Å and output power is 10 raise to power 4 to 10 raise to power 6 watts and it is in the form of pulses.



IV Helium Neon LASER

- Pumping of He atoms: When electric discharge is passed through the gas mixture of He and Ne, electrons are accelerated down the discharge tube in which mixture of He-Ne is placed. These accelerated electrons collide with helium atoms and excite them to higher energy levels (let us say F2 and F3).
- These levels happen to be Metastable and thus the He atoms spend a sufficient amount of time there before getting de-excited.
- Achievement of population inversion of Neon atoms: Some of the excited states of Ne atoms correspond approximately to the same energy of the excited levels F2 and F3 of He. Thus, when He atoms in levels F2 and F3 collide with the Ne atoms in the ground state E1, then energy exchange takes place and this results in the excitation of Ne atoms to the levels E4 and E6 and de-excitation of the He atoms to the ground level F1. As the helium atoms have longer life time in excited states F2 and F3, thus this process of energy transfer has high probability.
- Therefore, the electric discharge through the gas mixture continuously populates the Ne excited levels E4 and E6. This helps to create a state of population inversion between the levels E4 (or E6) and lower energy levels E5 and E3. Therefore the purpose of He atoms is to help in achieving a population inversion in the Ne atoms.

Achievement of laser: The following three transitions will occur:

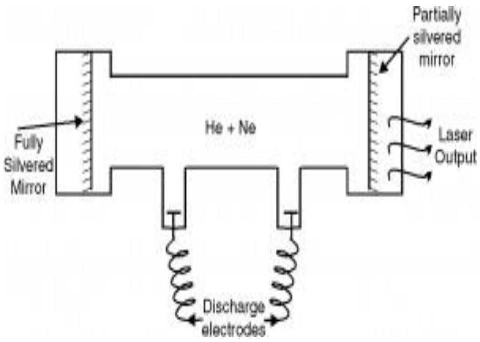
- E6 to E5 with laser wavelength of 3.39 μm or 33900 Angstroms.
- E6 to E3 with laser wavelength of 6328 Angstroms.
- E4 to E3 with laser wavelength of 1.15 μm or 11500 Angstroms.
- The wavelengths of 3.39 μm and 1.15 μm corresponds to infrared region and wavelength 6328 Angstroms corresponds to red light wavelength (visible region).
- Mirrors of the optical resonators are so designed to show low reflectivity for wavelengths 3.39 μm and 1.15 μm. Thus photons of these wavelengths will be eliminated. Therefore, the photons of wavelengths 6328 Angstroms will move back and forth in optical resonator system and thus laser of wavelength 6328 Angstroms emerges through the partially reflected mirror.
- The excited Ne atoms drop down from levels E3 to E2 through spontaneous emission and this process will emit a photon of wavelength 0.6 μm. As the level E2 is also Metastable, there is a probability of excitation of Ne atoms from E2 to E3 leading to quenching of the population inversion. To eliminate quenching, the narrow discharge tube is used because Ne atoms de-excited to level E1 from E2 through collisions with the walls of the tube.

- The helium-neon laser was the first gas laser to be operated successfully. It was fabricated by

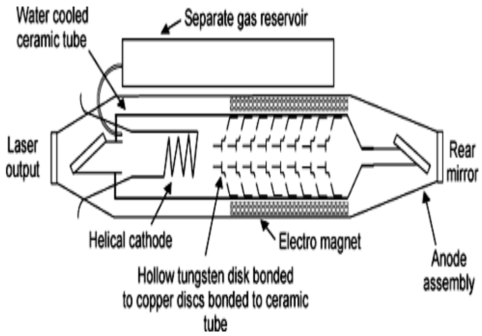
Ali Javan and his co-workers in Bell Telephone Laboratories in the USA in 1961.

- Helium neon laser used a mixture of 10:1 for its active medium. It consists of a long and narrow discharge tube of diameter of about 1 cm and about 80 cm long. The mixture is at a pressure of about 1 mm of Hg, the partial pressure of helium gas being 5 to 10 times that of neon.

- **Active medium**: The gas mixture of He and Ne forms the active medium. Ne act as active center.
- **Pumping Source**: Electric discharge method is used for pumping and achieving population inversion.
- **Optical resonator system**: A set of mirrors form the optical resonator system.



V Argon ion LASER



- Ion lasers consist primarily of lasers operating using ionoised species of the noble gases argon, krypton or xenon.
- Argon with strong emissions in the visible blue green and weaker lines in the ultra violet and infra red is the most important type commercially.
- The attraction of the argon-ion laser is the ability to produce CW (continuous wave) output from mW to tens of W in the visible part of the spectrum.
- Argon-ion lasers operate in high temperature plasma tubes with bores about 1.2mm diameter, and lengths up to 1.5m. Excitation is by a high current discharge that passes along the length of the tube, concentrated in the small bore. High current density in the centre of the tube ionises the gas and provides the energy to excite the ion to the lasing energy levels. The high current density leads to sputing of the bore materials by the plasma, which is generally detrimental. Extra gas is needed to replenish gas depleted during operation and the low efficiency (~0.1% wall plug) requires methods of removing waste heat. Solutions to these problems use high temperature ceramics, tungsten, separate gas flow paths and active cooling. In addition, magnetic fields are sometimes used to help conform the discharge current to the centre of the bore.
- Fused silicon or crystal quartz are usually used for the optics on these lasers, quartz being used for high power visible and UV applications.
- Typical values for beam diameters for argon ion lasers are from 0.6 to 2mm with beam divergences of 0.4 to 1.2 m radians.

Continues and Quasi Continues LASERS

- Continuous-wave (cw) operation of a laser means that the laser is continuously pumped and continuously emits light. The emission can occur in a single resonator mode (→ *single-frequency operation*) or on multiple modes.
- The first continuous-wave laser was a helium–neon laser operating at 1153 nm . A version working with the now common emission wavelength of 632.8 nm was demonstrated soon after that. Later on, many other types of lasers were developed which can also be operated continuously: other gas lasers, many types of solid-state lasers (including semiconductor lasers), and dye lasers.
- For many lasers with low-gain laser transitions, continuous-wave operation is difficult to achieve, while operation with pulsed pumping is easy to obtain. In some cases, continuous-wave operation is only possible with fibre lasers, but not with bulk lasers, as the fibre geometry greatly increases the gain efficiency. Some so-called *self-terminating laser transitions* are not suitable at all for continuous- wave operation.
- The output power of a continuous-wave laser is more or less constant on longer time scales, but it can exhibit substantial power variations e.g. due to mode beating (if single-frequency operation is not achieved) and other kinds of laser noise. Various techniques for the stabilization of lasers concerning output power and/or optical frequency can be applied, often involving additional optical elements in or around the laser resonator.

Quasi-continuous-wave Operation

- In continuous-wave operation, some lasers exhibit too strong heating of the gain medium. The heating can then be reduced by quasi-continuous-wave operation, where the pump power is only switched on for limited time intervals.

Surgical application of LASERs

Surgery in General - CO2 Nd:YAG, Ho:YAG
- Haemostasis
- Sealing of lymphatics
- Cutting

Urology - Pulsed dye, Ho:YAG, KTP, Diode
- Stones: bladder or kidney
- Tumours of bladder and upper renal tract
- Ureteric strictures
- Bladder neck incisions
- Prostate coagulation
- Prostate resection

Gynaecology - Nd:YAG, CO_2, Diode
- External - condylomas
- Laparoscopic treatment
- Hysteroscopic treatment
- Foetoscopic treatment
- Colposcopic treatment

ENT - CO_2, KTP, Nd:YAG, KTP, Diode
- Microlaryngeal/vocal chords
- Respiratory papillomas
- Middle ear
- Turbinates
- Polyps
- Sinus surgery

Gastroenterology - Nd:YAG, Diode
- Recanalisation of oesophagus
- Gastric tumours
- Actively bleeding ulcers
- Liver disease

Orthopaedic Surgery - Nd:Yag, Ho:YAG
- Cutting & ablating soft/hard tissue
- Smoothing cartilage
- Knee surgery
- Lumbar disc decompression

Oral & Maxillofacial Surgery - CO_2 Nd:YAG
- Tumour excision/biopsy
- Vaporisation of papillomas

Thoracics - Nd:YAG, CO_2
- Recanalisation of trachea
- Recanalisation of upper airways

Ophthalmology - Nd:YAG, Krypton, argon, excimer
- Diabetic retinopathy
- Macular degeneration
- Retinal vein occlusion
- Iridectomy
- Corneal ablation

Dermatology & Plastic Surgery - Pulsed dye, ruby, KTP, CO_2, Nd:YAG, diode, alexandrite
- Vascular & pigmented lesions
- Laser ablation & resurfacing
- Hair removal
- Photo-rejuvination
- Tattoo removal
- Excision of burns

Pain Therapy - Diode
- Acute pain therapy
- Chronic pain
- Wound healing

Thoracics - Nd:YAG, CO_2 • Recanalisation of trachea • Recanalisation of upper airways Ophthalmology - Nd:YAG, Krypton, argon, excimer • Diabetic retinopathy • Macular degeneration • Retinal vein occlusion • Iridectomy • Corneal ablation
Dermatology & Plastic Surgery - Pulsed dye, ruby, KTP, CO_2, Nd:YAG, diode, alexandrite • Vascular & pigmented lesions • Laser ablation & resurfacing • Hair removal • Photo-rejuvination • Tattoo removal • Excision of burns
Pain Therapy - Diode • Acute pain therapy • Chronic pain • Wound healing
Oncology - CO_2, KTP, Nd:YAG, KTP, Gold vapour • Tumour excision/biopsy • Photodynamic therapy (PDT) • Palliative tumour ablation

Question Bank

1. Explain the working and construction of CO2 LASER instrumentation.
2. Explain in detail how CO2 LASER is used in surgical applications.
3. Explain in detail the production of Ruby LASER and its medical applications.
4. What are the medical applications of Nd-Yag LASER and elaborate any two applications in detail.
5. With neat sketches explain the surgical instrumentation of He- Ne LASER.
6. How is Argon ion laser produced and give its surgical applications.
7. Write notes on
   a. Q- Switching operations
   b. Continuous and quasi continuous wave lasers.

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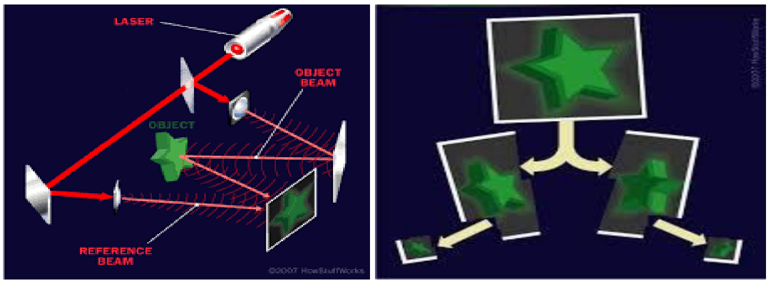
SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

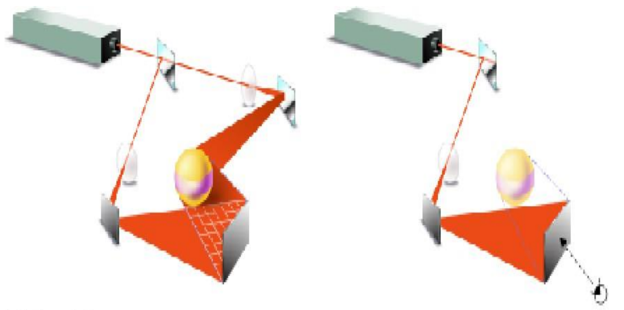
UNIT – V- FIBRE OPTICS & LASER FOR BIOMEDICAL APPLICATIONS – SBMA7003

HOLOGRAM AND MEDICAL APPLICATIONS

I HOLOGRAM



- A laser-generated image with three-dimensional properties
- Created by capturing the intensity and phase information produced by the interference of two (or more) beams of light
- 2 basic types of holograms: Transmission and Reflective



a) Making a hologram b) Viewing a hologram

Transmission Type Holograms

- the holographic plate is placed behind the object and laser, or to the side at 45 degree angle
- Must be viewed with laser light
- Captures an image much bigger than the holographic plate
- Allows an image can be projected onto a screen or other surface with a laser

Basic Holograms require just a few basic components:

- Light Source: The light source generally a laser, which provides monochromatic and coherent light. Different colors of lasers can be used according to the film.
- Spatial Filter: This is a combination of an objective lens and a pinhole. The light is focused into a pinpoint by the objective and then passes through the pinhole. This creates modes.
- Aperture: The aperture is closed or opened accordingly to select the central mode, which is the bright area in the center the pattern created by the spatial filter.

II Types of Holograms

-Transmission Holograms: Use two beams to create the interference pattern

recorded on the film.

- A beam splitter divides the laser beam into two parts. One becomes the reference Z

beam and the other, the object beam.

- The reference beam needs only go to the film. Generally, it is suggested that the reference beam intensity be around 3:1 or 4:1 so use of an ND filter may be necessary.
- The object beam passes reflects off of the object before hitting the film.

-Reflection Holograms: Place the film between the light source and the object, thus effectively creating two light sources, and an interference pattern.

Advantages/Disadvantages

Transmission Holograms:They take up more space, require more equipment, and require more adjustments and fine tuning to acquire a good hologram. However, the freedom to adjust many more parameters in a transmission hologram makes them a more powerful tool.

-Reflection Holograms:These are much simpler to create, and require little setup and equipment. They are limited in their ability to change relative intensities, and require transparent film. Plates will not work for reflection holograms.

Film

Holographic film, like photographic film uses a chemical emulsion to capture light information.

-There are a variety of holographic films for difference colors of laser light.

-The particular film used in our experiments is Slavich PFG-01, which is red light sensitive.

-Emulsion undergoes a chemical change when exposed to light, which then is exploited by the developer and fixer.

Developing

-Basics: Film developing is a process that takes exposed film through a set of chemical baths. In virtually all films, there is a developer, a stop bath, a fixer, and a rinse.

•The developer causes a reaction that transforms exposed emulsion on the film.

•The stop bath can be a water or chemical rinse that stops the developer.

•Fixer removes the remainder of the unexposed emulsion on the film.

•A final rinse then removes all chemicals from the film

•An agent such as PhotoFlo can then be used to enhance drying and decrease spotting on the film.

-Photographers Formulary JD-2: This particular developer works with film used for red-laser holography. It has a two-part developer, and a bleach in place of fixer. The stop and final rinses are both water.

III Lasers in Dentistry

Laser dentistry can be a precise and effective way to perform many dental procedures. The potential for laser dentistry to improve dental procedures rests in the dentist's ability to control power output and the duration of exposure on the tissue (whether gum or tooth structure), allowing for treatment of a highly specific area of focus without damaging surrounding tissues.

- Advantages of a laser (compared with the traditional dental drill)
    - May cause less pain in some instances, therefore reducing the need for anesthesia.
    - May reduce anxiety in patients uncomfortable with the use of the dental drill.
    - Minimize bleeding (high-energy beam photocoagulation) and swelling during soft tissue treatments.
    - May reduce bacterial infections because the high-energy beam sterilizes the area being workedon.
    - May preserve more healthy tooth during cavity treatment.
    - Laser disadvantages
    - Lasers can’t be used on teeth with fillings that are already in place.
    - Lasers can't be used in many commonly performed dental procedures. For example, lasers can't be used to fill cavities located between teeth, cavities around old fillings, and large cavities that need to be prepared for a crown, nor can they be used to remove defective crowns or silver fillings, or prepare teeth for bridges.
    - Traditional drills may still be needed to shape the filling, adjust the bite, and polish the filling even when a laser is used.
    - Lasers do not eliminate the need for anesthesia.

Laser treatment tends to be more expensive since the cost of the laser is much higher.

- *Viewing Tooth and Gum Tissues:* Optical Coherence Tomography is a safer way to see inside tooth and gums in real time.
- *Benign Tumors:* Dental lasers may be used for the painless and suture-free removal of benign tumors from the gums, palate, sides of cheeks and lips.
- *Cold Sores:* Low intensity dental lasers reduce pain associated with cold sores and minimize healing time.
- *Nerve Regeneration: Photobiomodulation* can be used to regenerate damaged nerves, blood vessels and scars.
- *Teeth Whitening:* Low intensity soft tissue dental lasers may be used to speed up the bleaching process associated with teeth whitening.
- *Temporomandibular Joint Treatment:* Dental lasers may be used to quickly reduce pain and inflammation of the temporomandibular jaw joint.

A *Gingivectomy* is a periodontal surgery that removes and reforms diseased gum tissue or other gingival buildup related to serious underlying conditions.

Performed in a dentist's office, the surgery is primarily done one quadrant of the mouth at a time under local anesthetic.

Periodontal surgery is primarily performed to alter or eliminate the microbial factors that create periodontitis, and thereby stop the progression of the disease.

LASER type used in this surgery is a CO_2 laser with wavelength of 10,600nm and the beam is located using usually a He-Ne guidance laser and the actual cutting is seen following the path of the guide laser.

Original procedures were to use a scalpel (and stitches) with Hemadent (to stop bleeding) which evolved over time to using electrosurgery.

Electrosurgery is the use of electricity to remove tissue and cauterize the wound.

IV LASER IN DERMATOLOGY
CUTANEOUS LASER SURGERY and
Cosmetic Dermatology

* Almost no area of dermatology is changing as rapidly as that of cutaneous laser surgery.
* Development of new laser, as well as improvements in existing laser, continues to advance the field.
* Laser surgery has become an effective therapeutic modality for a variety of dermatologic conditions.
* **The first laser, a ruby laser**, was operated in 1960 by **Theodore Maiman**.
* **Medical applications** were quickly recognized, & **Leon Goldman** pioneered their dermatologic use
* The **WL** is determined by the **active medium** of each particular laser.
* **Active medium** can consist of:
    1. Gas (i.e. argon or CO_2 laser),
    2. Liquid (i.e. dye laser), or
    3. A solid (ruby or yttrium-aluminum-garnet crystal laser)
* Light can interact with incident targets in1 of 3 ways:
* 1st . **Transmitted**
* 2nd . **Reflected**
* 3rd **Absorbed:** the light **has effect**

V LASERS IN OPTHAMOLOGY

- Use of Laser in Ophthalmology
- Lasers have been used widely in treatment of eye diseases. Such as,

1. Eyelid growths, including lid cancers
2. Trichiasis (Misdirected eye lashes)
3. Open up or block Lacrimal Puncta.
4. Pterygium (Conjunctival degeneration)
5. To alter corneal curvature and correct refractive errors as in PRK, LASIK

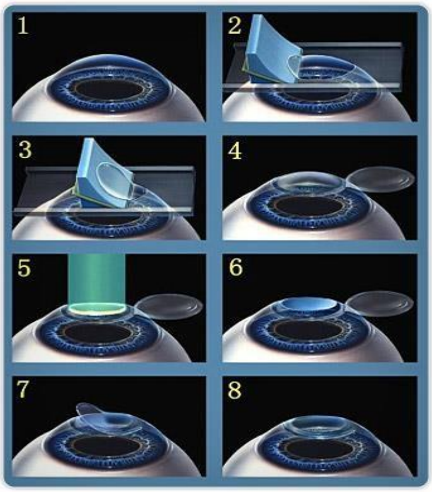
etc.

6. Glaucoma (Increased eye pressure)
7. To open opacified posterior capsule, about 6 months after cataract surgery
8. In closing Retinal tears in treatment and prevention of RD.
9. In Diabetic Retinopathy (DMR)

For treatment of tumors like Retinoblastoma

Photorefractive Keratectomy

- Photoablation occurs because the cornea has an extremely high absorption coefficient at 193 nm, with a single 193 nm photon having sufficient energy to break carbon-carbon and carbon-nitrogen bonds directly that form the peptide backbone of the corneal collagen molecules.
- Consequently, excimer laser radiation ruptures the collagen polymer into small fragments, and a discrete volume of corneal tissue is removed with each pulse of the laser



<u>Diode lasers</u>

- It emit an infrared (wavelength of 810 nm) in continuous wave mode.
- It is absorbed only by melanin i.e. why most

commonly used for retinal photocoagulation;

- low scattering of this wavelength ensures good penetration of the ocular media and of edematous retina. It also penetrates the sclera.
- The transparency of sclera to diode laser also allows photocycloablion of the ciliary body in 'end stage glaucoma.
- It has been used endoscopically to create a dacriocystorhinostomy (DCR).
- A. Give the difference between conventional photography and holography.

1. What are the conditions for recording a Hologram?
2. What are the conditions to be satisfied during reconstruction?
3. Discuss in detail all the methods of holographic interferometry.
4. Explain in detail about non destructive testing using hologram?
5. Elaborate on the how LASERS are used in dentistry.
6. How is LASER used for dermatological applications? How does it aid in cosmetic surgery?
7. Explain in detail how LASER is used in ophthalmological treatment and surgery.

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