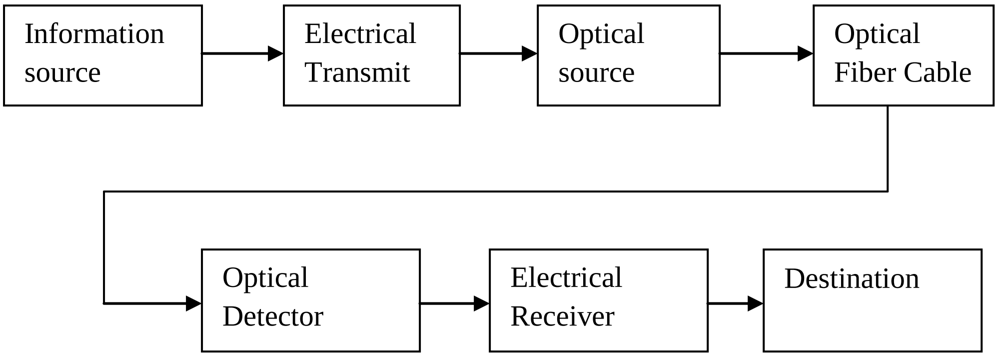
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1. Attempt any FIVE of the following: 20

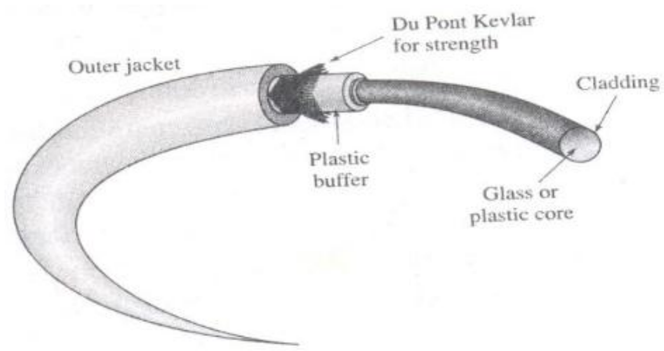
a) Draw and explain block diagram of optical fiber communication system. (Diagram 2M; Explanation 2M)



The information source provides an electrical signal to a transmitter comprising an electrical stage which drives an optical source to give modulation of the light wave carrier. The optical source which provides the electrical optical conversion may be either a semiconductor laser or LED. The transmission medium consists of an optical fiber cable and the receiver consists of an optical detector which drives a future electrical stage and hence provides demodulation of optical carrier. Photo diodes (pn, P-i-N or avalanche) and, in some instances; phototransistor and photoconductors are utilized for the detection of the optical signal and the optical electrical conversion.

Thus there is a requirement for electrical interfacing at either end of the optical link and at present the signal processing is usually performed electrically.

b) Draw and explain the construction of fiber optics cable.
(Diagram 2M; Explanation 2M)



The optical fiber consists of three parts.

1. **Glass core**: - The innermost layer in an optical fiber cable is the glass core. The light rays pass through this innermost glass core.
2.
3. **Cladding layer**: - The innermost glass layer is covered by the cladding layer. This layer is also made up of glass. But the refractive index of this layer is less than that of core layer.
   The cladding layer performs the following functions:
   1.It provides strength to the optical fiber cable.
   2.The cladding layer acts like a mirror. It will reflect the light rays and will not allow them to escape outside the fiber.
   3.When many optical fibers are packed in one cable the cladding layer avoids the interference between the light rays in the adjacent fibers.
4. **Jacket layer or Protective layer :-**

i. Outmost layer in an optical fiber.
ii. Provides mechanical strength to the optical cable.
iii. Provides protection against environmental factors

c) Define following terms:

i. Numerical aperture
ii. Acceptance angle
iii. Critical angle
iv. Total internal reflection
(Each Definition 1M)

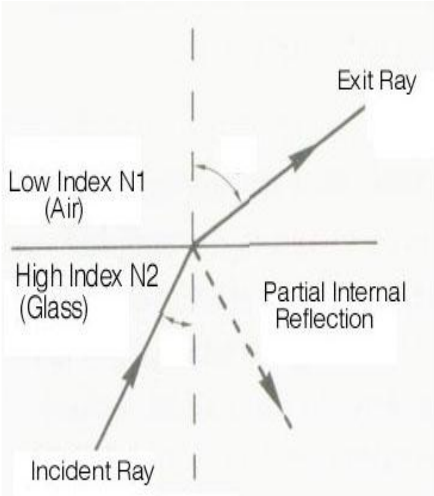
i) Numerical Aperture (NA):

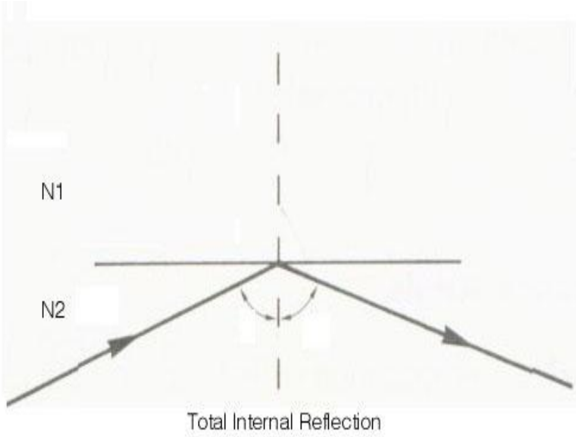
The numerical aperture (NA) is a measurement of the ability of an optical fiber to capture light. The NA is also used to define the acceptance cone of an optical fiber.

$$NA = \eta_0 \sin\theta_a = (\eta_1{}^2 - \eta_2{}^2)^{\frac{1}{2}}$$

ii) Total internal reflection:

Total internal reflection is a phenomenon that happens when a propagating wave strikes a medium boundary at an angle larger than a particular critical angle with respect to the normal to the surface.





Light ray Diagram

iii) Critical angle:

The critical angle (Φc) is defined as the maximum value of angle of incidence up to which the internal reflection will take place. Mathematically the critical angle is $\boldsymbol{\phi_C = \sin^{-1}\frac{\eta_2}{\eta_1}}$

$$where\ \eta_2\ is\ refractive\ index\ of\ rarer\ medium$$
$$and\ \eta_1 is\ refrective\ index\ of\ denser\ medium$$

iv) Acceptance Angle [θo (max)]:

The maximum value of the incident angle θ_a i.e. θ_a (max) for which the incident light can propagate through the fiber to the far end is called as the acceptance angle.

$$\sin\theta_{0\max} = n_1\cos\phi_1' = n_1\sqrt{1-\sin^2\phi_1'}$$

$$= n_1\sqrt{1-\frac{n_2^2}{n_1^2}} = \sqrt{n_1^2 - n_2^2}$$

Acceptance Cone:

The angle θ_a(max) is called as acceptance angle. If we rotate the acceptance angle around the fiber axis then it forms a cone called acceptance cone.

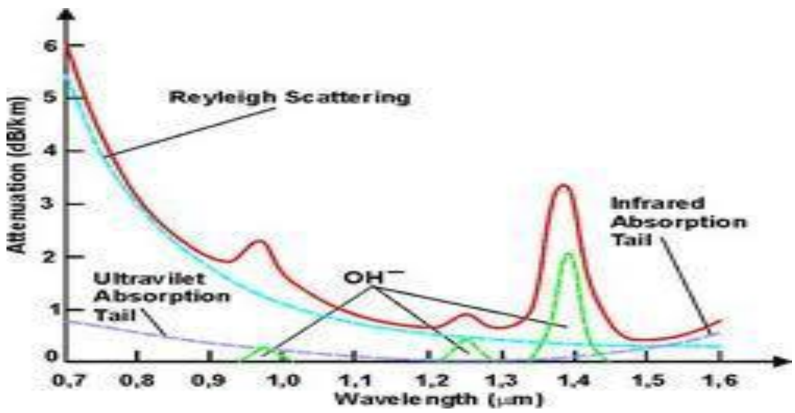
d) Classify optical fiber with respect to index profile and mode of Propagation. (Each classification 1M)

According to index profile, optical fiber is classified as step index and graded index fiber.
According to mode of propagation optical fibers is classified as single mode and multimodes fiber.

Thus fibers are classified as

1) Single Mode step Index
2) Multi Mode step Index
3) Single Mode Graded Index
4) Multi Mode Graded Index

e) Explain absorption and scattering losses in fiber optics.
Absorption Loss: 2Marks
Light travels best in clear substances. Impurities such as metal particles or moisture in the fiber can block some of the light energy, it absorb the light and dissipate it in the form of heat energy, which caused absorption loss. The solution is to use ultra-pure glass and do paint chemicals to minimize impurities, and to eliminate loss at the water peak wavelength during the process of fiber manufacturing.



Rayleigh scattering loss: - 2Marks
1. During the manufacturing process of glass used for the optical fiber submicroscopic variations in the density of glass takes place.
2. Also in the process of doping the impurities get frozen inside the glass and act as reflecting and refracting facets.
3. The tiny impurities will then scatter a small percentage of light passing through the optical fiber.
4. The power loss resulting due to this scattering is called as "Rayleigh scattering loss".
5. It can be reduced by using improved manufacturing techniques but cannot be completely eliminated.

f) Determine NA, acceptance angle and critical angle of the Fiber having core refractive index is 1.5 and cladding. Refractive index is 1.45.
(For Given statement 1M; Each Part 1M)
Given:

$$\eta_1 = core\ refractive\ index = 1.5$$

$$\eta_2 = Cladding\ refractive\ index = 1.45$$

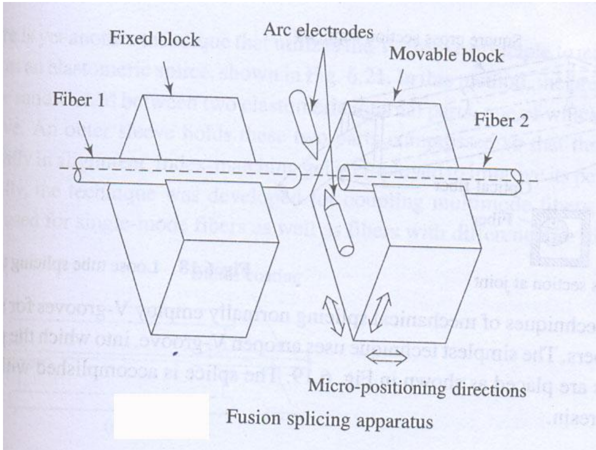
To Determine:
i. **NA**
ii. **Acceptance angle**
iii. **Critical angle**

i. $Numeric\ Aperture = NA = \sqrt{\eta_1^2 - \eta_2^2} = \sqrt{(1.5)^2 - (1.45)^2} = 0.1475$

ii. $Acceptance\ angle = \theta_A = \sin^{-1}\sqrt{\eta_1^2 - \eta_1^2} = \sin^{-1} NA = 8.48^0$

iii. $\boldsymbol{Critical\ angle\ \phi_C = \sin\phi_C = \frac{\eta_2}{\eta_1} = \phi_C = \sin^{-1}\frac{\eta_2}{\eta_1} = \sin^{-1}\frac{1.45}{1.5} = \sin^{-1}0.966 = 75.01^0}$

g) Define splicing? Explain fusion splicing of optical fiber.
(Definition 1M; Explanation 2M; Diagram 1M)



A fiber splice is a permanent joint formed between two optical fibers. Splicing is required when (i) length if the system is more than manufactured cable length (ii) when cable is broken and needs to be splicing techniques.
There are two basic types of splices.

1. Fusion
2. Mechanical

The steps involved in making this splice are as follows

1. By mechanical or chemical method, clean all coatings from fiber.
2. Scratch the fiber with a diamond scribe to induce a clean square break (this process is called cleaning.
3. Place the fibers to be spliced into the alignment assembly; inspect them with a microscope for accurate alignment; fuse the fibers with an electric arc and re inspect the fiber with a microscope.
4. Reinstall protective coatings according to the manufacturer's specifications.
5. Test the splice optically for attenuation losses

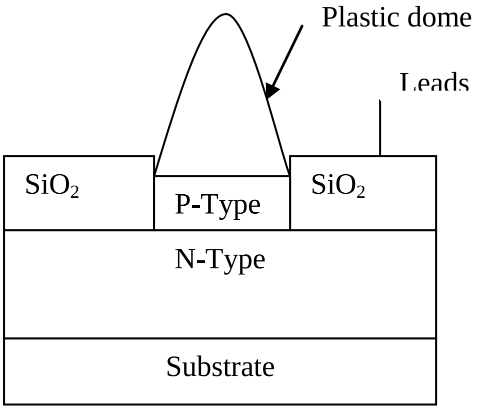
Q.2. Attempt any FOUR of the following: 16

a) With neat sketch explain working LED as optical source with diagram.
(Diagram 2M; Explanation 2M)

LED: Light emitting Diode

Symbol

Construction:



Principle of LED:
It involves the emission of optical radiation by converting electrical energy into light.

Construction:
The surface layer is a P-type region. A shallow P-N junction is formed on a epoxy substrate. The upper part of P-type material is uncovered. Leads are provided for electrical contacts.
The difference process that are involved in a LED are

1) The process of excitation in which on an application of potential difference electron hole pair are produced and the electrons move into the excited state.
2) The process of recombination in which the excited carrier give up their energy through a radiative or non radiative process. This energy is in the form of photons whose wavelengths correspond to energy difference associated with these transitions in the form of light
3) The extraction of these emitted photons from the active region of a semi conductor to the observer.

b) Explain lateral and angular fiber misalignment.
(Lateral 2M with diagram; Angular 2M with diagram)

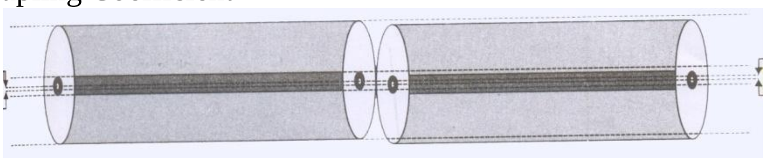
Fiber misalignments are classified into three categories

a) Lateral
b) Longitudinal
c) Angular

Lateral and angular misalignments are main contributors to insertion losses.
Lateral misalignment occurs when the core axis of both fibers to joined are misaligned. The insertion losses based on lateral misalignment are expressed as

$$L_{lat} = 10 \log C_{lat}$$

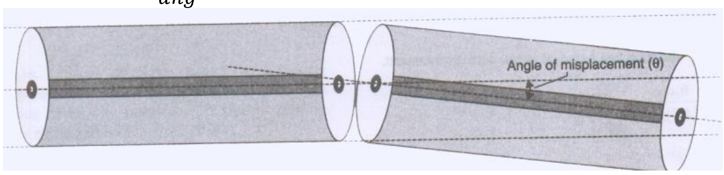
L_{Lat}- Insertion Loss based on lateral coefficient
C_{Lat}- Lateral coupling Coefficient



Angular misalignment occurs when the core of the fiber are not parallel to each other. The insertion Losses due to angular displacement is calculated as follows

$$L_{SIM_{ang}} = -10 \log \left(1 - C_{SIM_{ang}}\right)$$

$$where\ L_{SIM_{ang}} is\ insertion\ Loss\ due\ to\ angle\ misalignment. and$$
$$C_{SIM_{ang}}\ is\ angular\ coupling\ coefficient$$

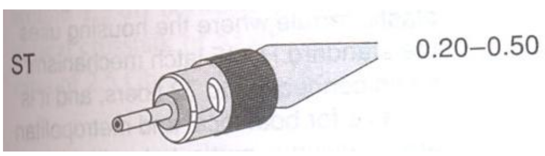


c) Explain ST and SMA optical fiber connector.
(ST 2M; SMA 2M with Diagram)

Two important cylindrical sleeve ferrule connectors are

1) Straight tip(ST)
2) Subminiature Assembly(SMA)

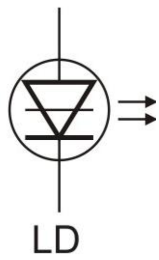
1) Straight tip (ST): A slotted bayonet type of metallic multimode or single mode fiber connector with a ceramic ferrule. Widely used in inter/intra building communication and also telecommunication applications. The insertion loss is 0.2-0.5dB.



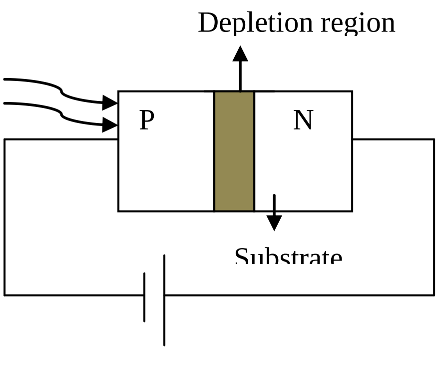
2) Subminiature Assembly (SMA): A slotted screw-on connector preferred in multimode fiber wide used in data communication, multimedia and instrumentation connections. Insertion loss is 1-1.5dB

d) Compare LED and LASER diode. (Any four points) ·

i. Intensity of light
ii. Spectral width
iii. Efficiency
iv. Symbol.
(Each point 1M)

	LED	**LASER Diode**
Intensity of light	**Less optical output power**	**More optical output power**
Spectral width	**Wide**	**Narrow**
Efficiency	**Optical detector responsivity is Less**	**Optical detector responsivity is good**
Symbol		

e) Draw construction of photo diode and explain its working as optical detector.
(Construction with diagram 2M; Explanation 2M)
P-N Photo Diode
Construction:
It is a thin P layer deposited on N type substance. The light passes through player. It has a very thin depletion zone when reverse biased.
Diagram:



Working:
Photons of light entering the depletion zone ionize the hole-e-pair when they encounter atoms within the crystal structure in the depletion zone. The e-hole pair moves across the junction due to reverse bias and contribute leakage current. This leakage current is proportional to the intensity of light current.

Disadvantages:

i. Conversion efficiency is very low.
ii. Life time of e^--hole pair generated is very short, hence sensitivity is very low.

Advantages:

i. Speed is satisfactory
ii. Response time is good

f) State any four properties of good optical connectors.
(Each Property 1M)

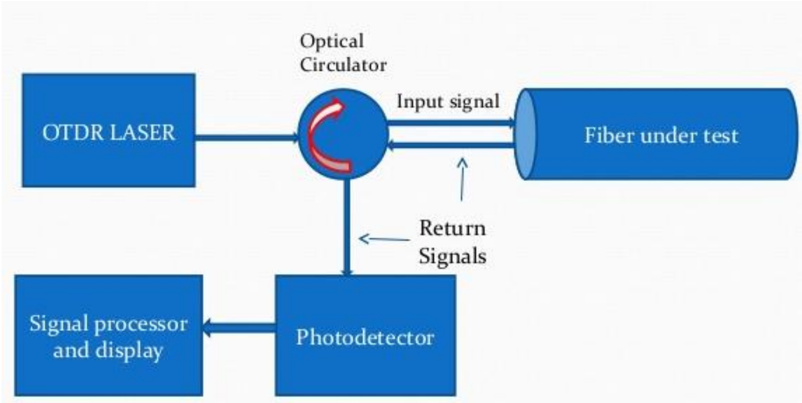
1) Connectors should have low insertion loss.
2) Reflection Loss/Return Loss should be high
3) Connector design must allow for repeated connection and disconnection without problems of fiber alignment.
4) Connector should be able to couple light between fibers efficiently.

Q.3. Attempt any FOUR of the following: 16

a) Draw block diagram of OTDR and ·explain its working.
(Diagram 2M; Explanation 2M)

An Optical time domain reflectometer (OTDR) is a versatile portable instrument that is used widely to evaluate the characteristics of an installed optical fiber link. In addition to identifying and locating faults or anomalies within a link, this instrument measures parameters such as fiber attenuation, length, optical connector and splice losses and light reflectance levels

An OTDR is fundamentally optical radar. As shown in fig, the OTDR operates by periodically launching narrow laser pulses into one end of fiber under test by using either a directional coupler or a circulator. The properties of the optical fiber link then are determined by analyzing the amplitude and temporal characteristics of the waveform of the reflected and back-scattered light. A typical OTDR consists of a light source and receiver, data-acquisition and processing modules, an information-storage unit for retaining data either in the internal memory or on an external disk, and display. Figure shows a portable OTDR for making measurements in the field.



b) State any two advantages and disadvantages of wave division multiplexing optical fiber communication (OFC) system.

Advantages: (Any two; 2M)

1. Works with existing single mode communication fiber.
2. Works with low speed equipment.
3. Is transparent: Doesn't depend on the protocol that has to be transmitted.
4. Is scalable: Instead of switching to a new technology, a new channel can easily be added to existing channels. Companies only have to pay for the bandwidth they actually need.
5. It is easy for network providers to add additional capacity in a few days if customers need it. This gives companies using WDM an economical advantage. Parts of a fiber can be leased to a customer who then gets fast network access without having to share the connection with others. The telecommunication company on the other hand still has an independent part of the fiber available for other customers.

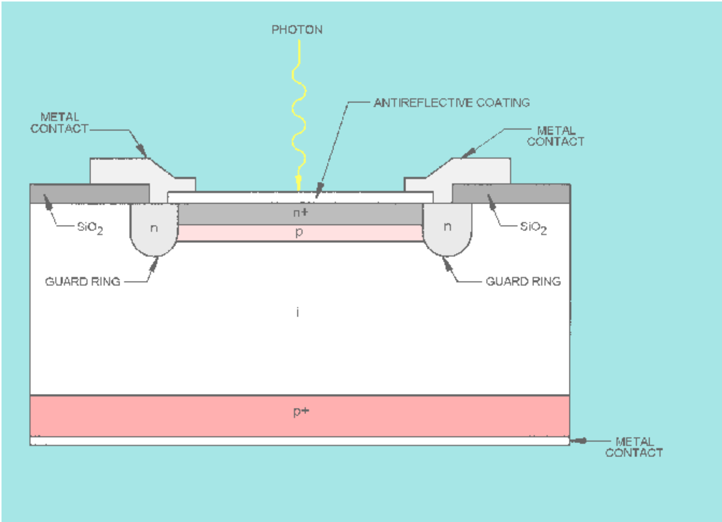
Disadvantages: (Any two; 2M)

1. Large delay
2. Longer user access time
3. Not suitable for high bit rates as chromatic dispersion increases
4. Nonlinear effects of the fiber

c) Explain the working of avalanche diode as optical detector and state it's any two advantages.
(Diagram 1M; Explanation 2M; Advantages 1M)
AVALANCHE PHOTODIODES
An **avalanche photodiode (APD)** is a photodiode that internally amplifies the photocurrent by an avalanche process.
Figure shows an example APD structure. In APDs, a large reverse-bias voltage, typically over 100 volts, is applied across the active region. This voltage causes the electrons initially generated by the incident photons to accelerate as they move through the APD active region.
As 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.

Figure - The basic structure of an APD.



The gain of the APD can be changed by changing the reverse-bias voltage. A larger reverse-bias voltage results in a larger gain. However, a larger reverse-bias voltage also results in increased noise levels. Excess noise resulting from the avalanche multiplication process places a limit on the useful gain of the APD. The avalanche process introduces excess noise because every photogenerated carrier does not undergo the same multiplication.

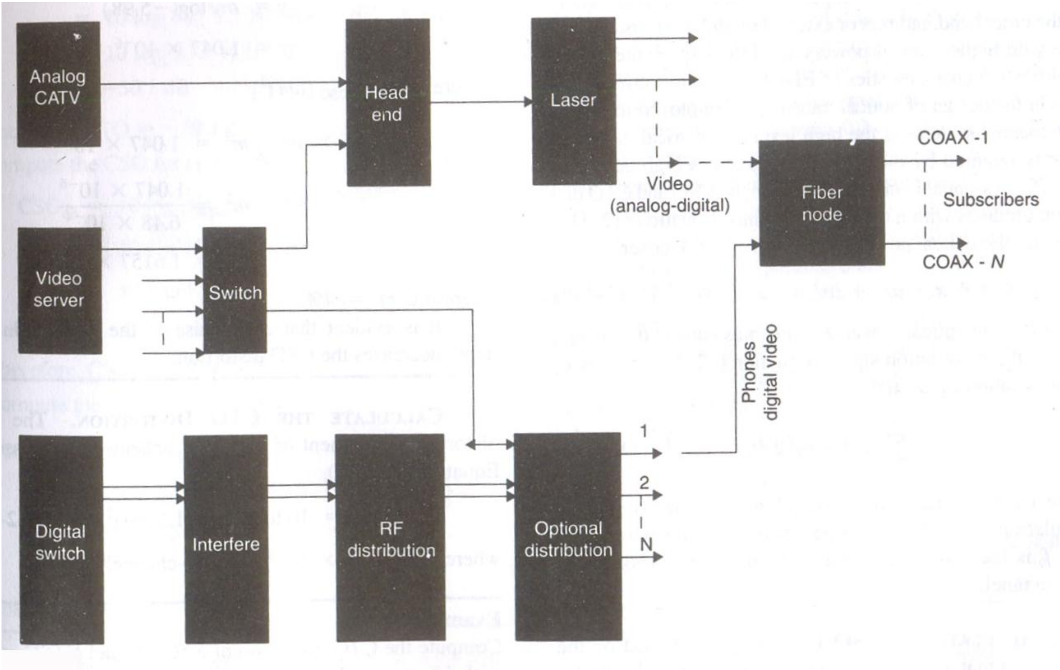
The noise properties of an APD are affected by the materials that the APD is made of. Typical semiconductor materials used in the construction of low-noise APDs include Silicon (Si), Indium Gallium Arsenide (InGaAs), and Germanium (Ge).

Trade-offs are made in APD design to optimize responsivity and gain, dark current, response time, and linearity. The factor affecting the response time of an APD is the additional time required to complete the process of avalanche multiplication.

Advantages: (Any Two)

1) Insensivity to magnetic field
2) Linear dynamic range of 10^6
3) Fast response(<1ns)
4) High quantum efficiency in the range from 200nm to 1100nm

d) Draw and explain block diagram of optical analog system. (Diagram 2M; Explanation 2M)



Analog optical fiber link.

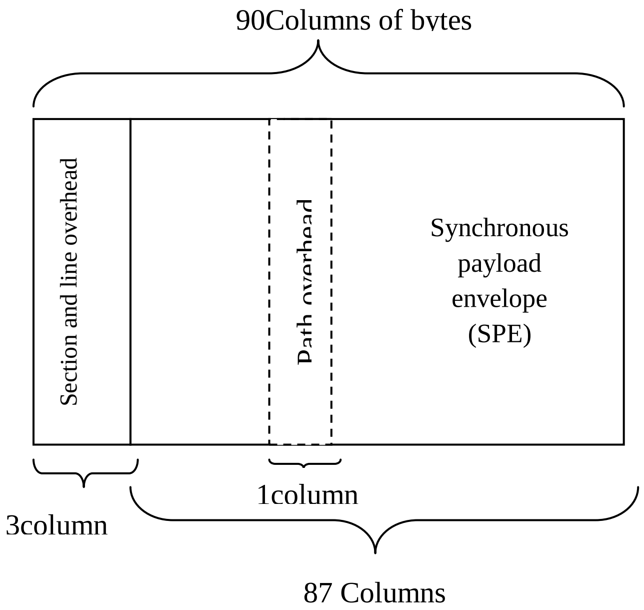
- The primary function of an analog optical link is to accept a number of FDM video channels at the input, to directly or indirectly modulate a laser diode and to convey the modulated optical signal to a desirable distance through an optical fiber.
- At the final destination, the optical signal is detected by the receiver module and converted back to an electrical signal that is ready for final distribution.

e) Explain the concept of synchronous optical networking (SO NET) using its architecture diagram. (Diagram 2M; Concept 2M)

Figure shows the basic structure of a SONET frame. This is a two dimensional structure consisting of 90 columns by 9rows of bytes, where one byte is eight bits. Here, in standard SONET terminology a section connects adjacent pieces of equipment, a line is a longer link that connects two SONET devices, and a path is a complete end to end connection. The fundamental SONET frame has 125-μs duration. Thus the transmission bit rate of the basic SONET signal is

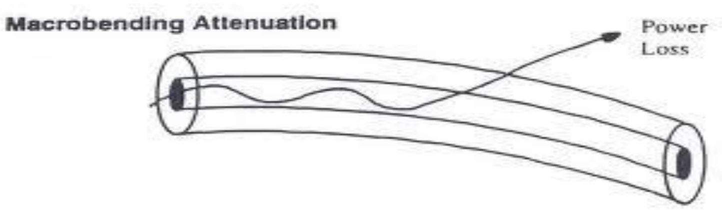
STS-1=(90 bytes/row)(9 rows/frame)(8 bits/byte)/(125 μs/frame)=51.84Mb/s

This is called an STS-1 signal, where STS stands for synchronous transport signal. All other SONET signals are integer multiples of this rate, so that an STS-N signal has a bit rate equal to N times 51.84 Mb/s



f) Explain bending losses in optical fibers.

1. Bending losses occurs in two forms - macrobending and microbending. When a cable is bent and it disrupts the path of the light signal. The tighter the bends of a cable, the greater it is of the light loss.



(i) **Macro bends: (2M)**

Macro bends describes the bending of the fiber optic cable in a tight radius. The bend curvature creates an angle that is too sharp for the light to be reflected back into the core, and some of it escapes through the fiber cladding, causing optical loss. This optical power loss increases rapidly as the radius is decreased to an inch or less. Different fiber optic cables have different specifications on how much the cable can bend without affecting the stated performance or loss. The industry has seen gradual improvements in the bending performances of the fiber. One such example is the recent G.657.B.3 fiber standard recommended by the
International Telecommunication Union (ITU), where the bending radius is standardized as low as 5mm.

(ii) **Micro bends: (2M)**

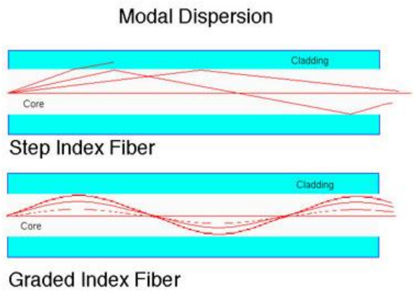
Micro bends refer to minute but sever bends in fiber that result in light displacement and increased loss, it typically caused by pinching or squeezing the fiber. Micro bends deform the fiber's core slightly, causing light to escape at these deflections. Most micro bending can be avoided by the correct selection of materials and proper cabling, handling, and installation techniques.

Q.4. Attempt any FOUR of the following: 16

a) Explain inter modal and intra modal dispersion which occurs in optical fiber.
(Intermodal Delay 2M; Intramodal Dispersion 2M)

Signal distortion is a consequence of factors such as intermodal delay, intramodel dispersion, polarization-mode dispersion, and higher-order dispersion effects,. These distortions can be explained by examining the behavior of the group velocities of the guided modes, where the group velocity is the speed at which energy in a particular mode travels along the fiber.

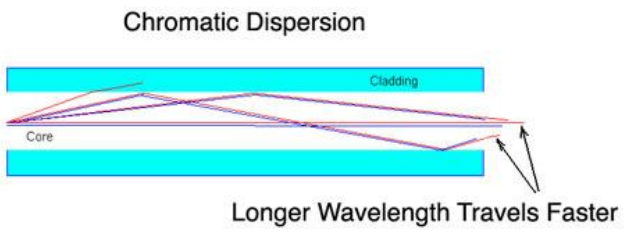
Intermodal Delay (or simply modal delay) appears only in multimode fibers. Modal delay is a result of each mode having a different value of the group velocity at a single frequency. From this effect one can derive an intuitive picture of the information-carrying capacity of a multimode fiber.



Intramodal Dispersion or Chromatic Dispersion is pulse spreading that takes place within a single mode. This spreading arises from the finite spectral emission width of an optical source. The phenomenon also called as group velocity dispersion, since the dispersion is a result of the group velocity being a function of the wavelength. Because intramodal dispersion depends on the wavelength, its effect on signal distortion increases with the spectral width of the light source.

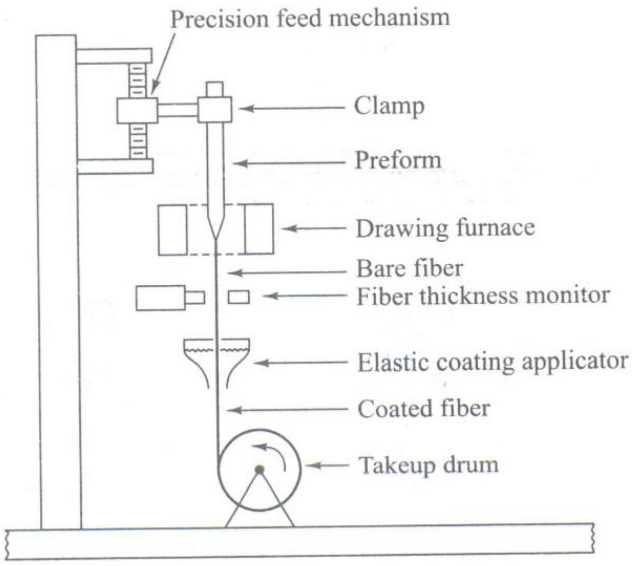
The two main causes of intramodel dispersion are as follows:

1. Material dispersion arises due to the variations of the refractive index of the core material as a function of wavelength.
2. Waveguide dispersion causes pulse spreading because only part of the optical power propagation along a fiber is confined to the core. Dispersion arises because the fraction of light power propagation in the cladding travels faster than the light confined to the core, since the index is lower in the cladding.



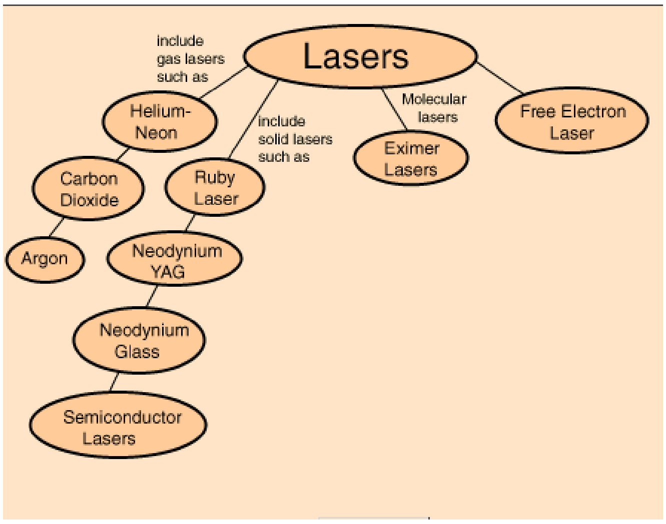
b) With help of diagram explain fiber optic cable fabrication.
(Diagram 2M; Explanation 2M)

Two basic techniques are used in the fabrication of all glass optical waveguides. These are the vapor-phase oxidation process and the direct-melt methods. The direct-melt method follows traditional glass-making procedures in that optical fibers are made directly from the molten state of purified components of silicate glasses. In the vapor-phase oxidation process, highly pure vapor of metal halides (e.g. $SiCl_4$ and $GeCl_4$) react with oxygen to form a white powder of SiO_2 particles. The particles are then collected on the surface of a bulk galss by one of four different commonly used processes and are sintered (transformed to a homogenous glass mass by heating without melting) by one of a variety of techniques to form a clear glass rod or tube (depending on the process). This rod or tube is called perform. It is typically around 10-25 mm in diameter and 60-120 cm long. Fibers are made from the perform by using the equipment shown in figure. The perform is precision fed into a circular heater called the drawing furnace. Here the perform end is softened to the point where it can be drawn into a very thin filament, which becomes the optical fiber. The turning speed of the take-up drum at the bottom of the draw rower determines how fast the fiber is drawn. This in turn, will determine the thickness of the fiber, so that a precise rotation rate must be maintained. An optical fiber thickness monitor is used in a feedback loop for this speed regulation. To protect the bare glass fiber from external contaminants, such as dust and water vapor, an elastic coating is applied to the fiber immediately after it is drawn.



Schematic of a fiber-drawing apparatus

c) State different non-semiconductor laser diode. Explain any one in brief. (Types 2M ; Explanation with diagram of any one type 2M)

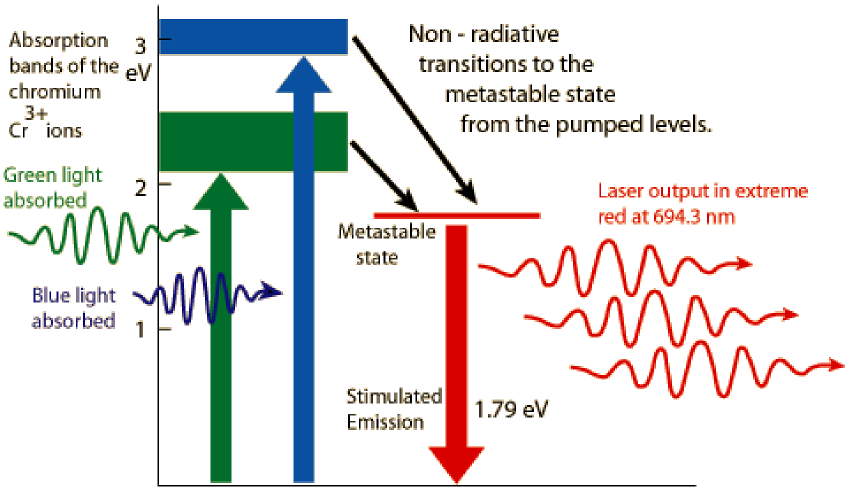


Ruby Laser

The ruby mineral (corundum) is aluminum oxide with a small amount (about 0.05%) of chromium which gives it its characteristic pink or red color by absorbing green and blue light.

The ruby laser is used as a pulsed laser, producing red light at 694.3 nm. After receiving a pumping flash from the flash tube, the laser light emerges for as long as the excited atoms persist in the ruby rod, which is typically about a millisecond.

.



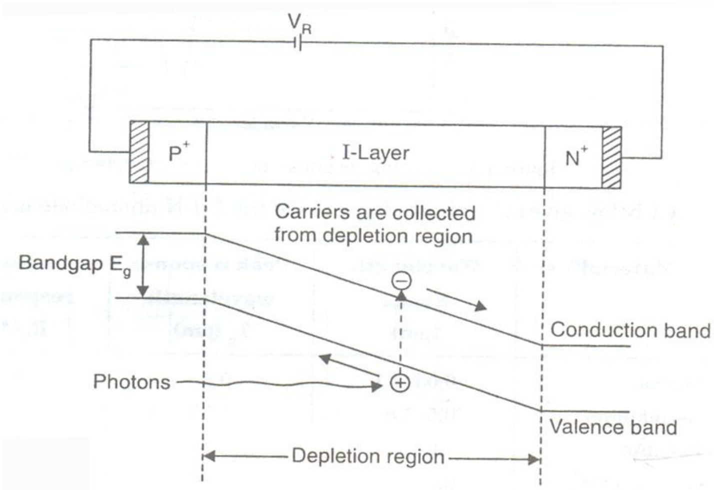
- A flashing light pumps electrons from the ground state (E0) to the two excited states E2 and E3 and create a condition of population inversion. Electrons from these levels undergo a fast decay to the energy level E1 where the electrons wait to get stimulated down to the ground state by emitting photons.
- The emitted photons have wavelength of about 6943 Å which corresponds to Red colour in the visible spectrum.

- As the electrons decay down to the ground state by emitting photons, the population inversion condition weakens and the rate of photon emission decreases.
- The pumping light is then flashed to pump the electrons to the excited state and maintain the population inversion condition and the rate of photon emission increases. Hence, in the output waveform of the ruby LASER, this rate of increase and decrease of the photons would be seen, rather than a constant output.
- This process happens very rapidly due to the tiny time constants as indicated in the figure. Therefore, in the ON state, the waveform consists of very narrow spikes which almost appear to be a continuous pulse of light as shown in figure.

d) Draw the construction of PIN diode and explain its working.
(Diagram 2M; Explanation 2M)

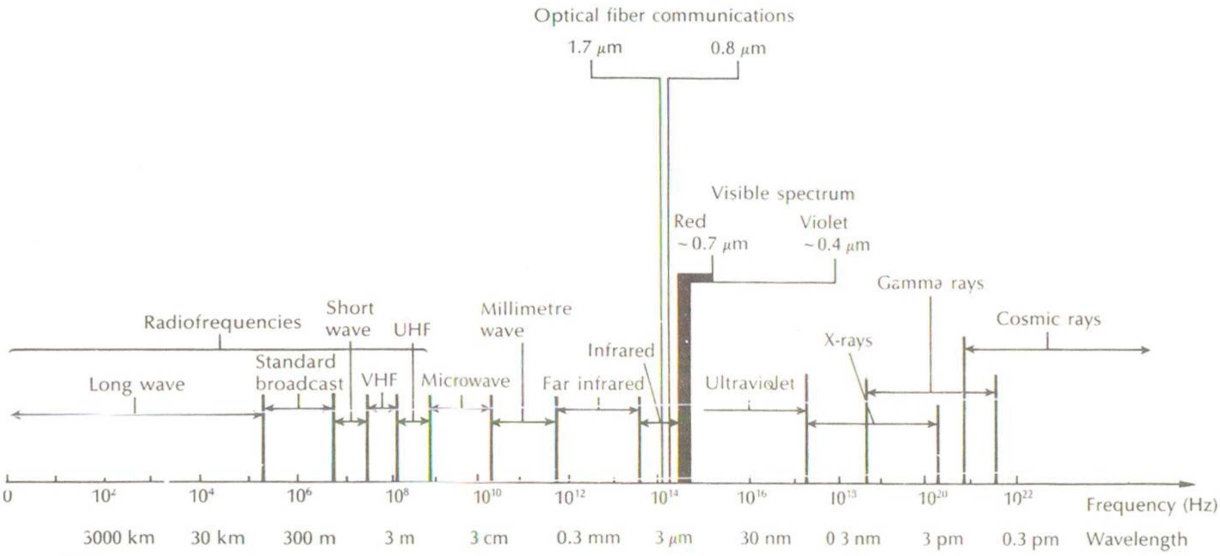
The most common semiconductor photodetector is the pin photodiode, shown schematically in figure. The device structure consists of p and n regions separated by a very lightly n-doped intrinsic (i) region. In normal operation a sufficiently large reverse-bias voltage is applied across the device so the intrinsic region is fully depleted of carriers. That is , the intrinsic n and p carrier concentrations are negligibly small in comparison with the impurity concentration in this region.

When a incident photo has an energy greater than or equal to band gap energy of the semiconductor material, the photon can give up its energy and excite an electron from the valance band to the conduction band. This process generates mobile electron-hole pairs, as fig shows. These electrons and holes are known as photocarriers, since they are photon-generated charge carriers that are available to produce a current flow when a bias voltage is applied across the device. The number of charge carriers is controlled by the concentration level of impurity elements that are intentionally added to the material. The photodetector is normally designed so that these carriers are generated mainly in the depletion region (the depleted intrinsic region) where most of the incident light is absorbed. The high electric field present in the depletion region causes the carriers to separate and be collected across the reverse-biased junction. This gives rise to a current flow in an external circuit, with one electron flowing for every carrier pair generated. This current flow is known as the photocurrent.



P-I-N photodetector construction and energy band diagram.

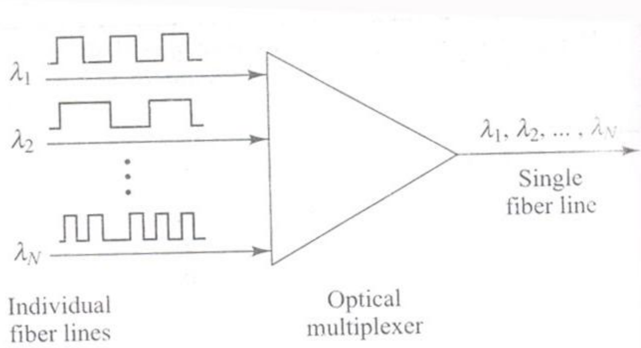
e) Draw frequency spectrum for communication and show the region for optical communication system. (Labeled Diagram 4M)



The electromagnetic spectrum showing the region used for optical fiber communications.

f) Explain the concept of wavelength division multiplexing in optical fiber communication system.
(Diagram 1M; Concept 3M)

The use of wavelength division multiplexing (WDM) offers a further boost in fiber transmission capacity. The basis of WDM is to use multiple sources operating at slightly different wavelengths to transmit several independent information streams simultaneously over the same fiber. Figure shows the basic WDM concept. Here N independent optically formatted at a different wavelength, are combined by means of an optical multiplexer and sent over the same fiber. Each of these streams could be at a different data rate. Each information stream maintains its individual data rate after being multiplexed with the other traffic stream and still operates at its unique wavelength.



Q.5. Attempt any FOUR of the following: 16

a) Explain the concept of hybrid multichannel analog optical fiber communication system. (Explanation 4M)

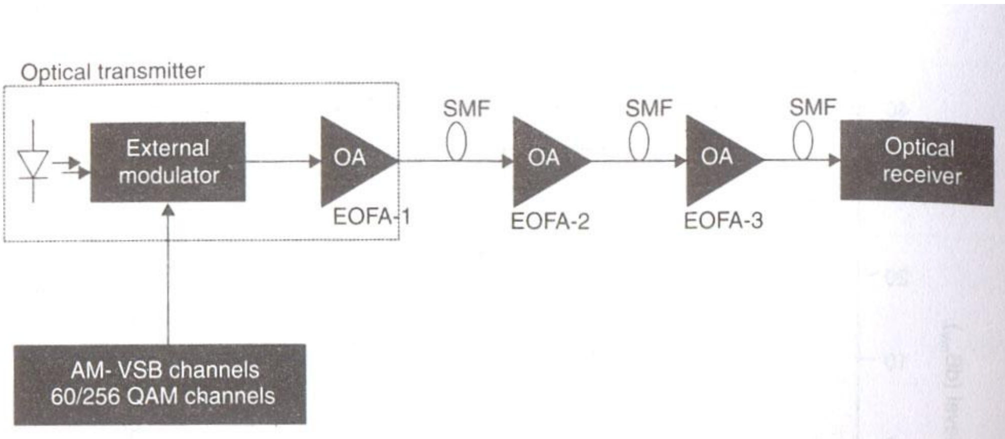
Combination of AM-VSB and M-level quadrature amplitude modulation (QAM) multichannel video signals for transmission over optical link to distances over 100 km utilizing NDS-SM fibers is hybrid multichannel analog and digital optical systems.

The possibility of jointly transmitting analog and digital video signals over optical links at relatively low cost. Example 79-AM-VSB video channel and 4-QAM (digital) channel signal over a 120km optical link.

If analog and digital video signals are to be simultaneously transmitted through the same optical transmitter, attention must be given to the maintenance of the required CNR at levels dictated by video channel specifications. This is because analog video channels are more susceptible to noise and nonlinear distortion. In such systems, maintaining the appropriate CNR levels will necessitate a 10dB optical power margin.

An additional problem encountered during the experimentation with the optical links was the degradation of the link performance due to the interaction between analog and digital video channels.

At the receiver end, a broadband optical receiver was used to detect the optical power, which was amplitude modulated by the composite (analog and digital) signal. After detection, the composite signal was separated through a filtering mechanism and the digital signal was demultiplexed to individual channels.



b) Explain construction and working of edge emitter LED.
(Diagram 2M; Explanation 2M)

An LED that emits light from its edge, producing more directional output than LEDs that emit from their top surface. In ELED , Active layer is usually lightly doped or undoped and a very large population for recombination is created in this region by forward bias injection.
Edge-emitting LEDs have a structure similar to that of edge-emitting semiconductor lasers is as shown in fig.1. They are emitting from the edge of a cleaved wafer, where the active region meets the cleaved surface. Such devices allow more efficient fiber coupling than surface-emitting LEDs. Applied in optical fiber communications, they allow higher data rates.
The high radiance ELED used in optical communications is similar to a conventional contact stripe injection LASER. This structure forms a waveguide channel that directs the optical radiation toward the fiber core.
Most of the propogation light is emitted at one end face only due to a reflector on the other end face. The emission patterns of this ELED is more directional than that of the SLED.

A variant of the edge-emitting LED is the super luminescent diode (SLD), where the spontaneous emission is substantially amplified within a waveguide. Here, the emission is much more directional, and as a consequence the brightness is much higher, even for SLDs with quite low output power.

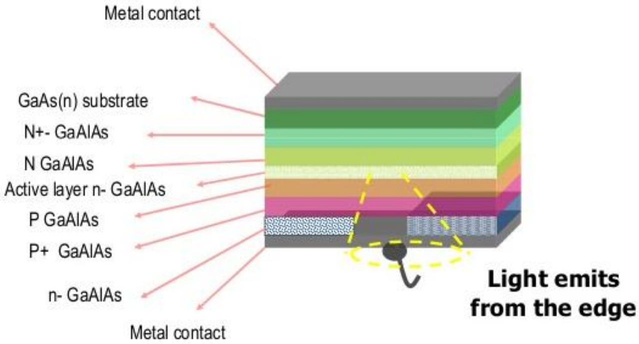
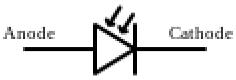
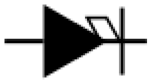
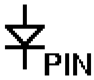


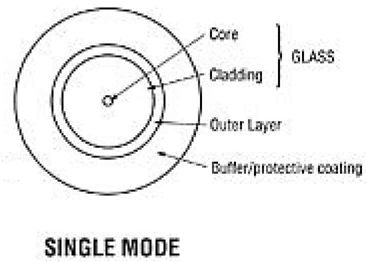
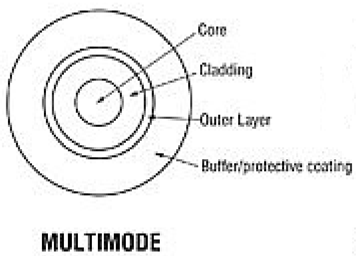
Fig.1 Structure of edge emitter LED

c) Explain chromatic losses in brief which occurs in fiber optics.
(Explanation 4M)
Material dispersion (or) chromatic dispersion: This dispersion arises due to the variation of the refractive index of the core material with the wavelength or frequency of light.
This causes a wavelength dependence of the group velocity of any given mode that is pulse spreading occurs even when different optical wavelength follow the same optical path.
It is directly proportional to the frequency bandwidth of the transmitted pulse. For pure silica, the material dispersion tends to zero at the wavelength of 1.3 mm. Further by using an optical source with a narrow spectral width, the material dispersion can be reduced. For shorter wavelengths around 0.6 mm to 0.8 mm, the material dispersion exponentially rises to a higher value.

d) Compare photo diode and PIN diode (Four points).
(Any four points 4M)

Photo Diode	**PIN Diode**
	 **OR** 
A photodiode is a semiconductor device that converts light into current.	A PIN Diode converts optical signals into electrical signals. The p-i-n diode or PIN diode is a photodiode with an intrinsic layer between the P and N-regions
Silicon , Germanium , Indium gallium arsenide , these materials are used for producing photodiode.	Silicon, Germanium, Indium gallium arsenide, Indium gallium arsenide phosphorous these material are used for producing PIN Diode
A photodiode can be used in solar cells, in photometry, or in optical communications, consumer electronics devices such as compact disc players, smoke detectors, accurate measurement of light intensity in science and industry.	PIN diodes are useful as RF switches, attenuators, photo detectors, and phase shifters.

e) Compare single mode and multi mode fiber. (Any four points).
(Any four points 4M)

Parameters	Single Mode Fiber	Multimode Fiber
Cross Section:		
Size of core	Small	Large
Dispersion	Less	Greater
Bandwidth and attenuation	High bandwidth and low attenuation	Lower bandwidth and high attenuation
Suited for	Long distance communication	Short distance communication
Applications	Used in telecom and CATV network	Used in LAN, Security Systems and General fiber networks.
Light source	LASER as a light source	LED as a light source

f) Explain scattering and dispersion of light through optical fiber cable.

Dispersion: (2M)

Dispersion in the fiber means the broadening of the signal pulse width due to dependence of the refractive index of the material of the fiber on the wavelength of the carrier.

If we send digitized signal pulses in the form of square pulses, they are converted into broadened gaussian pulses due to dispersion. The dispersion leads to the distortian (or) degradation of the signal quality at the output end due to overlapping of the pulses.

There are two kinds of dispersion mechanisms in the fiber: (i) Intramodal dispersion and (ii) Intermodal dispersion.

The dispersion effects can be explained on the basis of behavior of group velocities of the guided modes in the optical fiber. Group velocity is the velocity at which the energy in a particular mode travels along the fiber.

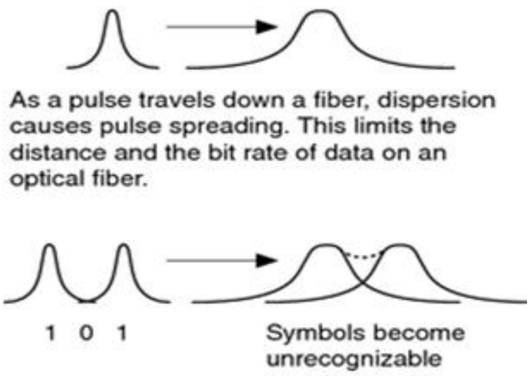


Figure 1 Dispersion in Optical fiber

SCATTERING: (2M)

In the fiber, light is scattered in all directions, including back toward the source as shown in Fig 2.

Scattering results in attenuation (in the form of radiation) as the scattered light may not continue to satisfy the total internal reflection in the fiber core.

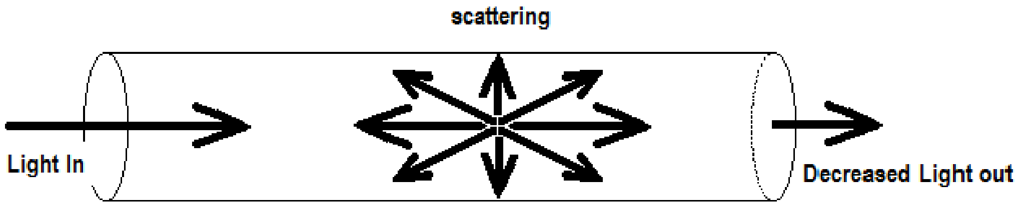


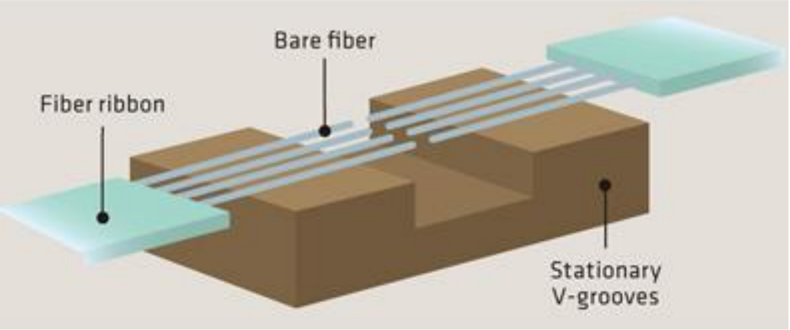
Fig.2 Scattering of light in an optical fiber

Scattering causes the dispersion of light energy in all directions, and one of the directions is the backward direction in this case the scattering is called "backscattering". Forward light scattering (Raman scattering) and backward light scattering (Brillouin scattering) are two additional types of scattering those can occur under high power conditions.

Q.6. Attempt any FOUR of the following: 16

a) What are the different mechanical splicing? Explain any one in detail.
(Different mechanical splicing 1M; Diagram 1M; Explanation of any one type 2M)
The types of mechanical splices that exist for mechanical splicing include glass, plastic, metal, and ceramic tubes, V-groove and rotary devices.

1) Stationary V-groove alignment method (cladding alignment)
This fusion splicing method uses V-grooves produced with high precision to position and orient optical fibers and utilizes the surface tension of melted optical fibers for alignment effects (cladding alignment). Splices made by this method achieve low loss thanks to the recent advancement of optical fiber production technology, which has improved the dimensional accuracy regarding the placement of core. This method is primarily used for splicing a multi-fiber cable in a single action.



2) Glass or Ceramic Alignment Tube Splices:
Mechanical splicing may involve the use of a glass or ceramic alignment tube, or capillary. The inner diameter of this glass or ceramic tube is only slightly larger than the outer diameter of the fiber. A transparent adhesive, injected into the tube, bonds the two fibers together. The adhesive also provides index matching between the optical fibers. Fig. 1 illustrates fiber alignment using a glass or ceramic tube. This splicing technique relies on the inner diameter of the alignment tube. If the inner diameter is too large, splice loss will increase because of fiber misalignment. If the inner diameter is too small, it is impossible to insert the fiber into the tube.

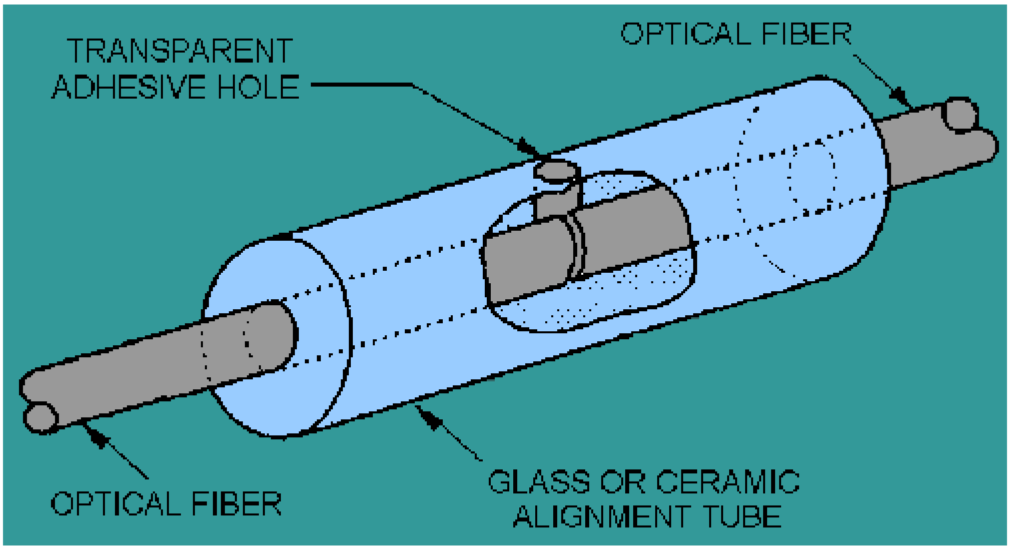


Fig.1 - A glass or ceramic alignment tube for mechanical splicing.

b) Explain optical isolator and circulator.

Opto-Isolator: (2M)

An **optical isolator**, or **optical diode**, is an optical component which allows the transmission of light in only one direction.

The opto-isolator is essentially a device that uses a short optical path to couple an electrical signal from one area to another.

Opto isolators are used for a variety of applications from providing voltage isolation between two circuits to coupling data circuits.

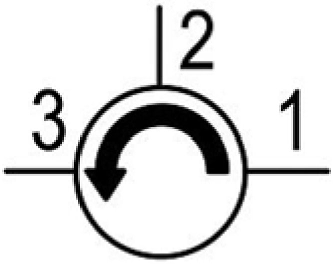
The Opto-isolator is generally used in power systems and used to transmit analogue or digital information between circuits where the potential difference is above 5,000 volts.

Optical circuit symbol for isolator

Optical circulator: (2M)

An optical circulator is a special fiber-optic component that can be used to separate optical signals that travel in opposite directions in an optical fiber, analogous to the operation of an electronic circulator.

An optical circulator is a three-port device designed such that light entering any port exits from the next. This means that if light enters port 1 it is emitted from port 2, but if some of the emitted light is reflected back to the circulator, it does not come out of port 1, but instead exits from port 3.



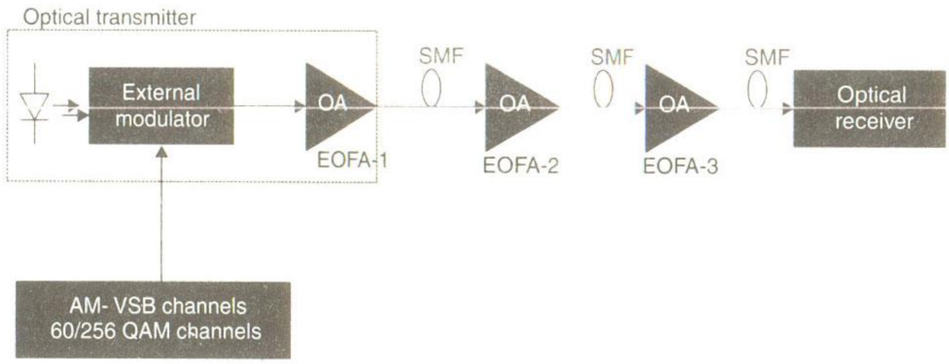
Symbol of Optical Circulator

Optical circulators are non-reciprocal optical device, which means that changes in the properties of light passing through the device are not reversed when the light passes through in the opposite direction.

Circulators can be used to achieve bi-directional transmission over a single fiber. Because of its high isolation of the input and reflected optical powers and its low insertion loss, optical circulators are widely used in advanced communication systems and fiber-optic sensor applications.

c) With block diagram explain the concept of undersea optical communication system. (Diagram 2M; Explanation 2M)

Undersea optical communication means to connect two continents via cable running under the sea. The first transcontinental telegraph cable was installed between North America and Europe. It was intended to provide telegraph service between the two continents.
The system operates at the low loss 1550nm wavelength window, with a corresponding increase of transmission capacity, to the level of 2.5 Gb/s per fiber, and with a simultaneous increase of the fiber span.



A hybrid multichannel analog and digital video optical link.

A block diagram of a typical undersea optical cable system is shown in figure.

One of the most important elements in the design of undersea optical links is the incorporation of a performance monitoring mechanism. Such a mechanism is accomplished through high loop back paths between EDFAs. A-45 dB signal identified by a specific delay time is allowed to travel in the opposite direction. At the land terminal, this small signal correlates with the outgoing 5Gb/s signal, and the gain of the loopback path is established by means of a set modulation depth. If the identified modulation depth increases by 100% then the system is out of services.

d) State any two advantages, two disadvantages optical fiber communication system.

Advantages: (Any two 2M)

1. **Wider Bandwidth:** The information carrying capacity of a transmission system is directly proportional to the carrier frequency of the transmitted signals. The optical carrier frequency is in the range 1013 to 1015 Hz while the radio wave frequency is about 106 Hz and the microwave frequency is about 1010 Hz. Thus the optical fiber yields greater transmission bandwidth than the conventional communication systems and the data rate or number of bits per second is increased to a greater extent in the optical fiber communication system.
2. **Low transmission loss:** Due to the usage of the ultra low loss fibers and the erbium doped silica fibers as optical amplifiers, one can achieve almost lossless transmission. In the modern optical fiber telecommunication systems, the fibers having a transmission loss of 0.002 dB/km are used.
3. **Dielectric waveguide:** Optical fibers are made from silica which is an electrical insulator. Therefore they do not pickup any electromagnetic wave or any high current lightning. the

optical fibers are not affected by any interference originating from power cables, railway power lines and radio waves. There is no cross talk between the fibers.

4. **Signal security:** The transmitted signal through the fibers does not radiate. Further signal cannot be tapped from a fiber in an easy manner. Therefore optical fiber communication provides hundred per cent signal security.
5. **Small size and weight:** Fiber optic cables are developed with small radii, and they are flexible, compact and lightweight. The fiber cables can be bent or twisted without damage. Further, the optical fiber cables are superior to the copper cables in terms of storage, handling, installation and transportation, maintaining comparable strength and durability.

Disadvantages: (Any other relevant disadvantage may be considered 2M)
1. Installation costs, while dropping, are high.
2. Special test equipment is required for trouble shooting.

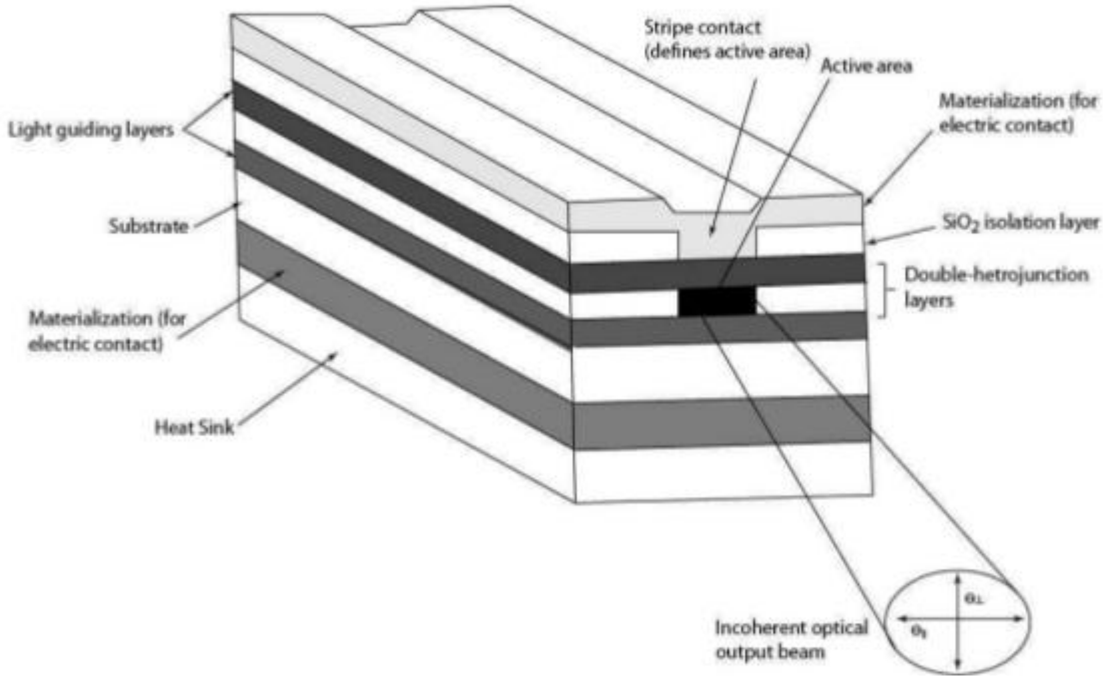
e) With structure of semiconductor LASER diode explain its working.
(Diagram 2M; Explanation2M)

A semiconductor laser diode is a specially fabricated pn junction device (both the p and n regions are highly doped) which emits coherent light when it is forward biased.

It is made from Gallium Arsenide (GaAs) which operated at low temperature and emits light in near IR region. Now the semiconductor lasers are also made to emit light almost in the spectrum from UV to IR using different semiconductor materials.

They are of very small size (0.1 mm long), efficient, portable and operate at low power. These are widely used in Optical fiber communications, in CD players, CD-ROM Drives, optical reading, laser printing etc. p and n regions are made from same semiconductor material (GaAs).

A p type region is formed on the n type by doping zinc atoms. The diode chip is about 500 micrometer long and 100 micrometer wide and thick. the top and bottom faces has metal contacts to pass the current. The front and rare faces are polished to constitute the resonator (fig.1).



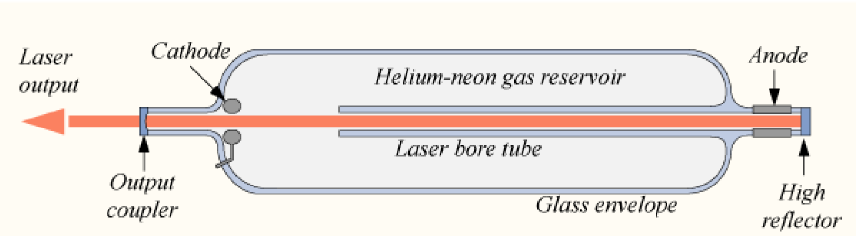
When high doped p and n regions are joined at the atomic level to form pn-junction, the equilibrium is attained only when the equalization of fermi level takes place in this case the fermi level is pushed inside the conduction band in n type and the level pushed inside the valence band in the p type.

When the junction is forward biased, at low voltage the electron and hole recombine and cause spontaneous emission. But when the forward voltage reaches a threshold value the carrier concentration rises to very high value. As a result the region "d" contains large number of electrons in the conduction band and at the same time large number of holes in the valence band. Thus the upper energy level has large number of electrons and the lower energy level has large number of vacancy, thus population inversion is achieved. The recombination of electron and hole leads to spontaneous emission and it stimulate the others to emit radiation. Ga As produces laser light of 9000 Å in IR region.

f) With neat sketch explain working of He-neon laser.
(Diagram 2M; Explanation2M)

A helium–neon laser or HeNe laser, is a type of gas laser whose gain medium consists of a mixture of helium and neon(10:1) inside of a small bore capillary tube, usually excited by a DC electrical discharge.
The pressure inside the tube is 1 mm of Hg. HeNe laser operates at a wavelength of 632.8 nm in the red part of the visible spectrum.

A helium-neon laser, usually called a He-Ne laser, is a type of small gas laser. It is a four level laser that operates in continuous working (CW).
He-Ne laser is most widely operated at a wavelength of 632.8nm in the red part of the visible spectrum.



Schematic Diagram of He-neon LASER

Working:

1) When the power is switch on, an energetic electron collisionally excites He atoms to the state labeled 2^1S_0, where the asterisk indicates that is in a excited state.
2) The excited $He^*2^1S_0$ atoms collides with an unexcited Ne atom and the atoms exchange internal energy, resulting in an unexcited He atom and excited Ne atom $Ne^*(3s_2)$.
3) This energy exchange process occurs with high probability because the two excitation energy levels of these atoms are nearly equal. Thus, the purpose of population inversion is fulfilled.
4) When the excited Ne atom passes from metastable state(3s) to lower level(2p), it emits photon of wavelength 632nm

5) This photon travel through the gas mixture parallel to the axis of tube, it is reflected back and forth by the mirror ends until it stimulates an excited Ne atom and causes it to emit a photon of 632nm along with the stimulating photon.
6) This process is continued and when a beam of coherent radiation becomes sufficiently strong, a portion of it escapes through partially silvered end.
7) The Ne atom passes to lower level is by spontaneous emission and finally the Ne atom comes to ground state through collision with tube wall and undergoes radiation less transition.