

Revision: 2015

Course Title: OPTICAL FIBER COMMUNICATION

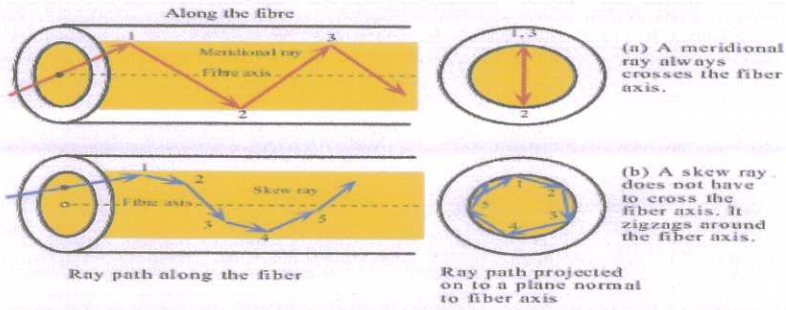
Qst No	Scoring Indicators	Split up score	Sub Total	Total
I	<u>PART A</u>			
1.	1. The maximum angle $\Phi_{max}$ with which a ray of light can enter rough the entrance end of the fibre and still be totally internally reflected is called acceptance angle of the fiber	2	2	
2.	it is defined as the. portion of attenuation resulting from the conversion of <b>optical</b> power into another energy. form, such as heat. .	2	2	
3.	<b>What is population inversion? ( A /M 2008)</b> To achieve optical amplification, it is must to create non-equilibrium distributions of atoms such that population of the upper energy level is greater than lower energy level i.e. $N_2$ is $> N_1$ this condition is known as population inversion	2	2	
4.	An <b>optical amplifier</b> is a device that amplifies an <u>optical signal</u> directly, without the need to first convert it to an electrical signal.	2	2	
5.	SPLICE is a permanent joint,where as CONNECTOR is a temporary joint	2	2	10

Scoring indicators

<b>PART B</b>			

II

1.



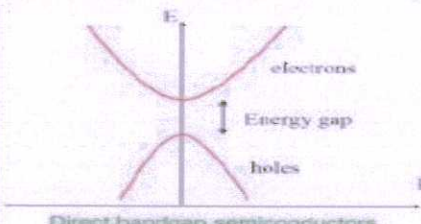
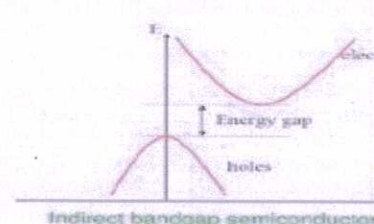
3+3 6

A meridional ray is a ray that passes through the axis of an optical fiber. A skew ray is a ray that travels in a non-planar zig-zag path and never crosses the axis of an optical fiber.

II.

2.

**Differentiate between direct and indirect band gap semiconductors.**

Direct band-gap (DBG) semiconductor	Indirect band-gap (IBG) semiconductor
A direct band-gap (DBG) semiconductor is one in which the maximum energy level of the valence band aligns with the minimum energy level of the conduction band with respect to momentum.	An Indirect band-gap (IBG) semiconductor is one in which the maximum energy level of the valence band and the minimum energy level of the conduction band are misaligned with respect to momentum.
In a DBG semiconductor, a direct recombination takes place with the release of the energy equal to the energy difference between the recombining particles.	In case of a IBG semiconductor, due to a relative difference in the momentum, first, the momentum is conserved by release of energy and only after the both the momenta align themselves, a recombination occurs accompanied with the release of energy.
The probability of a radiative recombination is high.	The probability of a radiative recombination is comparatively low.
The efficiency factor of a DBG semiconductor is higher. Thus, DBG semiconductors are always preferred over IBG for making optical sources.	The efficiency factor of a IBG semiconductor is lower.
Example, Gallium Arsenide (GaAs).	Example, Silicon and Germanium
	
Direct bandgap semiconductors	Indirect bandgap semiconductors

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II 3.

PARAMETERS	LED	LASER
Working Principle	Electro-luminance	Stimulated Emission
Full Form	Light Emitting Diode	Light Amplification by Stimulated Emission of Radiation
Response	Slow Response	Fast response in comparison to LED
Driving Current	It ranges from 50 to 100 mA.	It ranges from 5 to 40 mA.
Nature of Emitted Light	Incoherent and consists of various colours.	Coherent and Monochromatic.

6 6

Junction Area during Manufacturing	Wide Junction Area	Narrow and small Junction
Bandwidth Range	It lies in the range of 10 to 50 THz.	It lies in the narrow range i.e. from 1 MHz to 2 MHz.
Power to light Conversion Efficiency	Approx 20 %	Approx 70 %
Numerical Aperture of the obtained Light Beam	Higher in LEDs	Extremely low as compared to LEDs.
Cost	Low cost and thus economical.	High cost and thus used in the specific application.

Property	EDFA	Raman	SOA
Gain (dB)	> 40	> 25	>30
Wavelength (nm)	1530-1560	1280-1650	1280-1650
Bandwidth (3dB)	30-60	Pump dependent	60
Max. Saturation (dBm)	22	0.75 × pump	18
Polarization Sensitivity	No	No	Yes
Noise Figure (dB)	5	5	8
Pump Power	25 dBm	>30 dBm	< 400 mA
Time Constant	10 <sup>-2</sup> s	10 <sup>-15</sup> s	2 x 10 <sup>-9</sup>
Size	Rack mounted	Bulk module	Compact
Switchable	No	No	Yes
Cost Factor	Medium	High	Low

II  
4.

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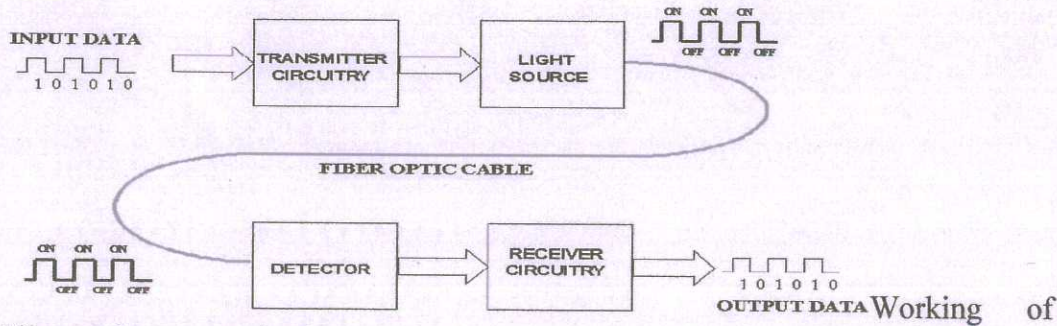
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II  
5.

The fiber optics transmission involves transmission of signals in the form of light from one point to the other. When the input data, in the form of electrical signals, is given to the transmitter circuitry, it converts them into light signal with the help of a light source. The light beam from the source is carried by a fiber optic cable to the destination circuitry wherein the information is transmitted back to the electrical signal by a receiver circuit.

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Fiber optic communication

The Receiver circuit consists of a photo detector along with an appropriate

electronic circuit, which is capable of measuring magnitude, frequency and phase of the optic field. This type of communication uses the wave lengths near to the infrared band that are just above the visible range. Both LED and Laser can be used as light sources based on the application.

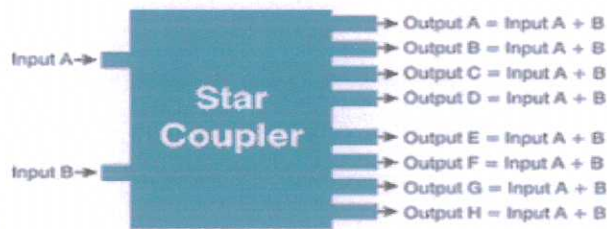
**Star Couplers**

Star couplers have multiple inputs and outputs.. Star couplers distribute the input power uniformly among the output fibers.

II  
6.

A) Directional Star Coupler

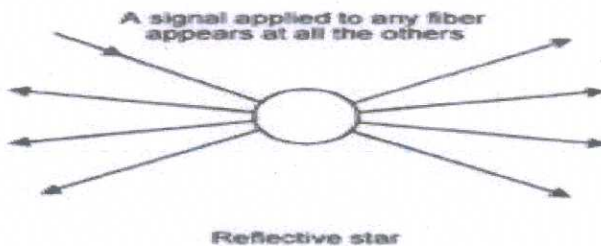
The first type is directional, mixing optical signals from all inputs and then distributes them among all outputs, as shown below. These are bidirectional devices because they also can transmit light in the opposite direction.



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This directional type of star coupler is made by fusing multiple fibers together. As shown below.

B) Non-Directional Star CouplerThe second type of star coupler is non-directional. It takes inputs from all fibers and then distribute them among all fibers, both input and output, as shown below.

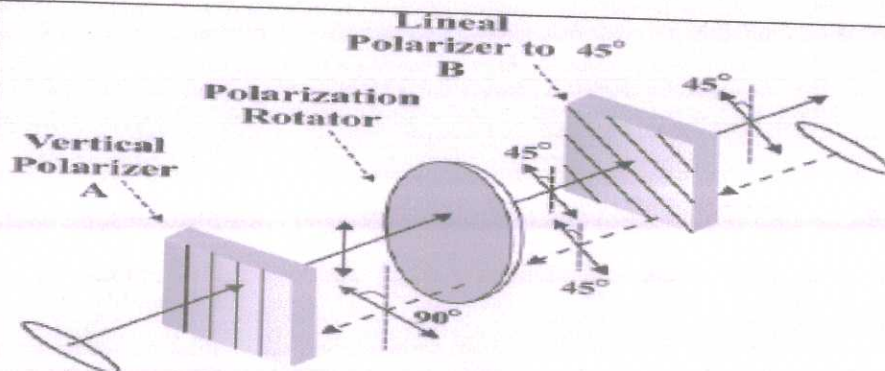


6x5  
=30

In a non-directional coupler, light going in any one port emerges from all the ports, including the input.. Non-directional coupler is made by reflecting the input light into all output ports. It has a mirror at the end as shown in the following figure.

II  
7. An optical isolator is also known as an optical diode, photocoupler, an optocoupler. It is a passive magneto-optic device, and the main function of this optical component is to permit light transmission in one direction only. So it plays a main role while preventing unnecessary feedback to an optical oscillator namely laser cavity. The working of this component mainly depends on the Faraday's effect which is used in the main component like Faraday rotor.

6 6



working-principle-of-optical-isolator

In forward mode, the light enters into the input polarizer then becomes linearly polarized. Once the light beam arrives at the Faraday rotator, then the rod of the Faraday rotator will turn with  $45^\circ$ . Therefore, finally, the light leaves from the o/p polarizer at  $45^\circ$ . Similarly in backward mode, initially the light enters into the o/p polarizer with a  $45^\circ$ . When it transmits throughout the Faraday rotator, rotates continuously for another  $45^\circ$  in a similar path. After that, the  $90^\circ$  polarization light turns into vertical toward the i/p polarizer & cannot depart the isolator. Thus, the light beam will be either absorbed or reflected.

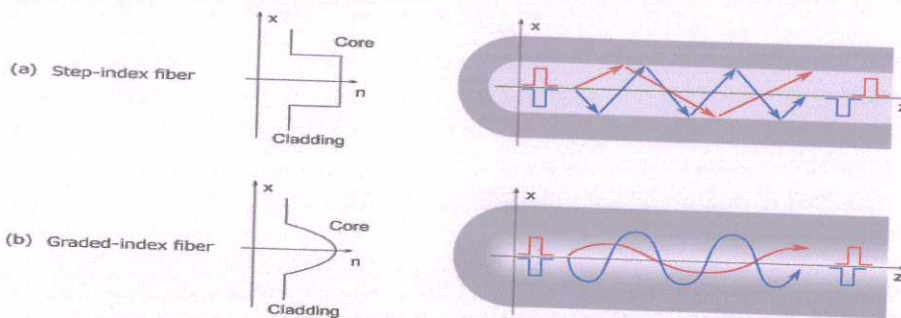
III

PART C

(a)

Step-index and graded-index fiber

There are two major types of refractive-index profiles – step index (SI) and graded index (GI) – and they are schematically shown in Figure. The core of a SI fiber has a uniformly raised refractive index profile, and that of a GI fiber has a continuously raised refractive index profile.



Light guidance in (1) step-index and (2) graded-index fiber.

When an optical pulse is launched into a SI fiber, the propagation velocity of the pulse is highly dependent on the incident angle. Figure explains that the light launched at a larger incident angle propagates at a slower velocity, as the path length is longer. This is problematic for high-speed optical communication as the incident pulse shape is degraded at the output.

GI fiber was introduced to overcome this limitation of SI fiber. Figure (b) shows that, light launched at a small angle mainly travel near the centre of the core, and light launched at a large angle travels at the outer side of the core. The path length is still longer for the blue ray; however the blue ray travels at a faster speed than

the red ray as the refractive index of the outer side of the core is lower than that of the centre. The difference in the propagation velocity, therefore, becomes much smaller and degradation in the pulse shape is reduced.

**Multimode and Single-mode fiber** The number of allowed optical paths in an optical fiber, called **modes**, depends on the refractive-index profile. If more than one mode is allowed to propagate in a fiber at a certain wavelength, the fiber is called a multimode fiber. If only one mode is allowed to propagate, the fiber is called a single-mode fiber. A single-mode fiber has a relatively smaller core size compared to a multimode fiber, and only one propagation mode is allowed

The use of single-mode fibers in an optical transmission line fundamentally eliminates signal distortions due to modal delay, and thus single-mode fibers have now become the most widely used type of optical fibers in optical communications.

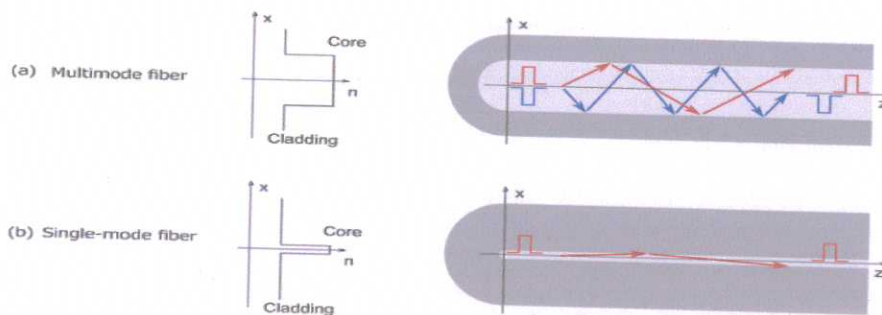


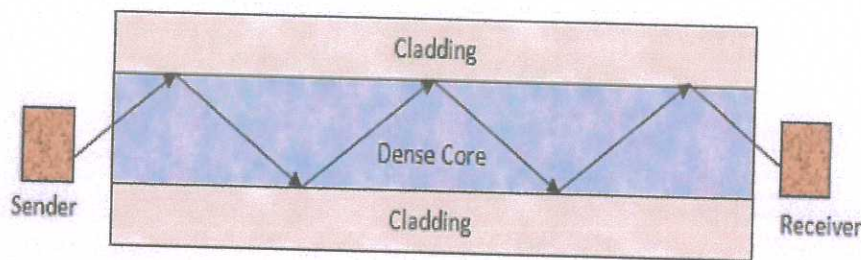
Figure 4: Multimode and single-mode fiber.

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### Transmission of Light in Fiber Optic Cable

Optical fibers use total internal reflection to transmit light. It has a solid core of dense glass surrounded by a less dense cladding. The light ray passing through the inner core is reflected back instead of being refracted to the rarer cladding.



Theoretically, there should not be any loss of light waves due to total internal reflection. However, attenuation of light occurs depending upon the wavelength of light waves and the properties of the glasses. The three commonly used wavelength bands for propagation are 0.85 microns, 1.30 microns, and 1.55 microns.

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There are two main types of material used for optical fibers: glass and plastic. They offer widely different characteristics and find uses in very different applications. Generally, **plastic fiber** is used for very short-range and consumer applications, whereas glass fiber is used for short/medium-range (**multi-mode**) and

	<p>long-range (<u>single-mode</u>) telecommunications.<sup>1</sup></p> <p>Requirement for selecting fiber materials</p> <ol style="list-style-type: none"> <li>1.The material should be ideal for making thin,flexible and reliable fiber</li> <li>2.The basic material must be transperant</li> <li>3.The material selected for the core and cladding should have different refractive index</li> </ol> <p>Types</p> <ol style="list-style-type: none"> <li>1. Glass fibers</li> <li>2. Halide glass fibers</li> <li>3. Active glass fibers</li> <li>4. Chalgenide glass fibers</li> <li>5. Plastic clad glass fiber</li> </ol> <p>1.Glass fiber: The glass fibers are made up of silica(SiO<sub>2</sub>) which has a refractive index of 1.458 at 850nm.For achieving two different refractive indexes dopants are added to the basic raw material. Properties of silica are</p> <ol style="list-style-type: none"> <li>1.Resistance to deformation at temperature 1000 degree centigrade</li> <li>2. High resistance to breakage from thermal shock.</li> <li>3.Good chemical durability</li> <li>4. High transparency</li> </ol> <p>2. Halide Glass Optical Fibers: These fibers having minimum losses of 0.01 to 0.001 db/km. Fabrication of these types of fiber is very difficult. First, ultra pure materials must be used to reach this low loss level. Secondly fluoride glass is prone to diversification</p> <p>3. Active glass optical fiber : When rare earth elements are added to the glass gives the material a new optical and magnetic properties. These new properties allow the material to perform amplification, attenuation and phase retardation on the light passing through it</p> <p>4. Chalgenide glass optical fiber : For some application like optical switches and fiber lasers, nonlinear properties should be achieved. This characteristic is utilised by chalgenide glass fibers. These types of glasses contain atleast one chalcogen element(S,Se or Te) and one other element such as P,I,Cl,Br,Cd,Ba,Si or Tl. AS<sub>2</sub>S<sub>3</sub> is one of the mostly used material among the various chalgenide glasses. Losses in this glasses range around 1dB/m.</p> <p>5. Plastic Clad Glass Fibers:For short distance (several 100m) communication where high losses are tolerable , less expensive plastic clad silica fibers are used. These fibers composed of silica cores with low refractive index being a plastic material</p> <p>6. Plastic fibers: For short distance (up to 100m) all plastic multimode step index fibers are used. The toughness and durability of plastic allow these fibers to be handled easily</p>	5		
IV (b)	<ul style="list-style-type: none"> <li>• Medical Used as light guides, imaging tools and also as lasers for surgeries</li> <li>• Defense/Government Used as hydrophones for seismic waves and SONAR ,</li> <li>• Data Storage Used for data transmission</li> <li>• Telecommunications Fiber is laid and used for transmitting and receiving purposes</li> </ul>	10	10	

- **Networking**  
Used to connect users and servers in a variety of network settings  
**Industrial/Commercial**  
Used for imaging in hard to reach areas, as wiring where EMI is an issue, as sensory devices to make temperature, pressure and other measurements
- **Broadcast/CATV**  
Broadcast/cable companies are using fiber optic cables for wiring CATV, HDTV, internet, video on-demand and other applications

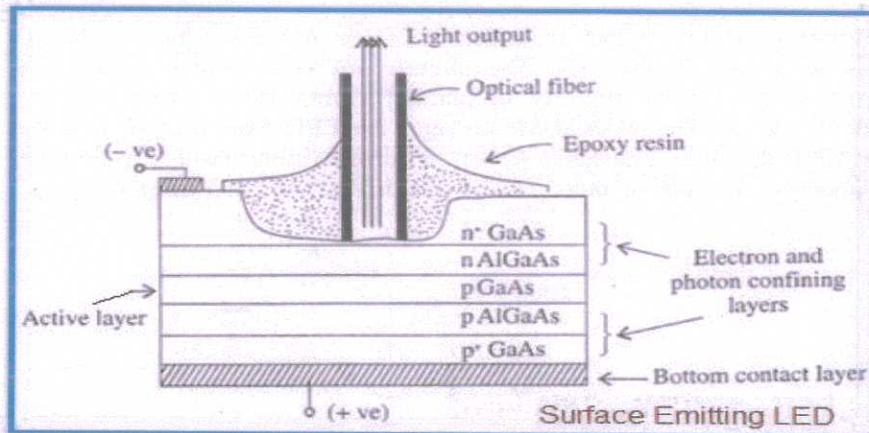
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V  
(a)

- The surface emitting LED structure consists of thin central active layer of p type GaAs.
- This central layer is bounded by n-type AlGaAs/n<sup>+</sup>-type GaAs at the top side.
- This central layer is bounded by p-type AlGaAs/p<sup>+</sup>-type GaAs at the bottom side.
- The extreme top n<sup>+</sup> type GaAs and bottom p<sup>+</sup>-type GaAs layers are used to provide low resistive ohmic contacts only.
- The external optical fiber is butt connected by etching the top layers and by shielding with epoxy resin.
- When refractive indices of both p-type and n-type materials are same, light is free to come out from all the sides of the semiconductor device due to no confinement. However only active region near the surface will emit the significant amount of light while absorbing from the other parts. Hence it is known as surface emitting LED.



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#### Advantages of Surface Emitting LED

- ➔ Optical coupling coefficient of LED with external fiber system is relatively higher..
- ➔ Optical loss is very low.
- ➔ InP/InGaAsP based LED is used for long wavelength applications.
- ➔ It offers higher efficiency with low to high radiance.
- ➔ The top n-GaAs contact layer ensures low thermal resistance and contact resistance.
- ➔ The internal absorption in the device is very low

#### Disadvantages of Surface Emitting LED

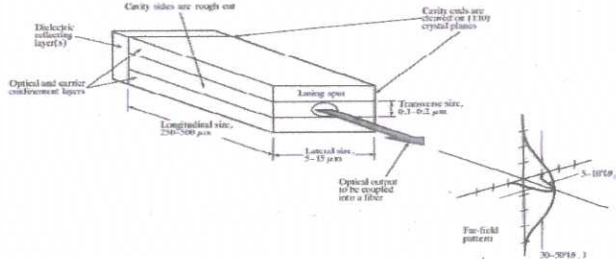
- ➔ The surface emitting LED can transmit data rate less than 20 Mbps than edge emitting LED.
- ➔ It contains short optical link with large NA (Numerical Aperture).

V

(b)

### Laser Diode

- Laser diode is an improved LED, in the sense that uses stimulated emission in semiconductor from optical transitions between distribution energy states of the valence and conduction bands with optical resonator structure such as Fabry-Perot resonator with both optical and carrier confinements.



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VI

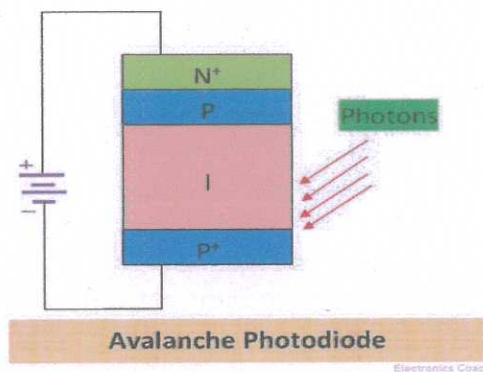
(a)

### Avalanche Photodiode

**Definition:** Avalanche photodiode is a photo detector in which more electron-hole pairs are generated due to impact ionisation. It is like P-N photodiode or PIN photodiode where electron-hole pairs are generated due to absorption of photons but in addition to this avalanche photodiode uses the **impact ionisation** principle for increasing magnitude of photocurrent.

#### Construction of Avalanche Photodiode

It has four regions N<sup>+</sup> region, P region, an intrinsic layer and P<sup>+</sup> region. The N<sup>+</sup> and P<sup>+</sup> region are heavily doped and the intrinsic layer is lightly doped. Its construction can be understood more clearly with the help of the below diagram.



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#### Working of Avalanche Photodiode

We have already discussed in Photodiodes and PIN Photodiodes that photons striking the surface of diodes contribute to the photocurrent. But in the case of avalanche diode, an additional factor is introduced to impact ionisation which increases photocurrent several times. This additional factor is called avalanche multiplication factor.

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**Impact ionisation** is the process in which one energy carrier with sufficient high kinetic energy strikes bounded energy carrier and imparts its energy to it so that the bounded energy carrier can move freely. This leads to higher concentration of energy carriers and thus higher magnitude of current.

This phenomenon of impact implantation plays a significant role in increasing photocurrent. The **current – gain bandwidth** product of Avalanche photodiode is about **100 GHz**. Thus, this type of photodiode can respond to light modulated at microwave frequencies.

#### Advantages and Disadvantages of Avalanche Photodiode

1. It can detect very weak signal due to high current-gain bandwidth product.
2. The construction is quite complicated i.e. care should be taken about the junction. The junction should be uniform and the guard ring is used to protect the diode from edge breakdown.

#### Applications of Avalanche photodiode

Due to its ability to detect low-level signals it is used in fibre optic communication Systems. A properly designed silicon avalanche photodiode can provide a response time of about 1ns.

#### Advantages of PIN Photodiode

1. The advantage is its high-frequency response and its frequency response is also greater than Cadmium – Sulphide photo detector.
2. It is inexpensive and the response time is in nanoseconds which make it appropriate for electronic circuitry.
3. These diodes have a broad spectral response and they can process even very weak signals.
4. The disadvantage of PIN diode is that it requires large reverse bias for its operation which sometimes reduces the signal to noise ratio.

Characteristics	PIN diodes			Avalanche photodiodes	
	Silicon	Germanium	InP	Silicon	Germanium
Wavelength Range ( $\mu\text{m}$ )	0.4 to 1.1	0.5 to 1.8	1 to 1.6	0.4 to 1.1	0.5 to 1.65
Wavelength of peak sensitivity ( $\mu\text{m}$ )	0.85	1.5	1.26	0.85	1.5
Quantum Efficiency (%)	80	50	70	50	70
Rise time, (ns)	0.001	0.3	0.1	0.5	0.5
Bias voltage (VB)	5	6	10	170	40
Responsivity (A/W)	0.5	0.5	0.4	0.7	0.6
Avalanche gain	1.0	1.0	1.0	80-150	80-150

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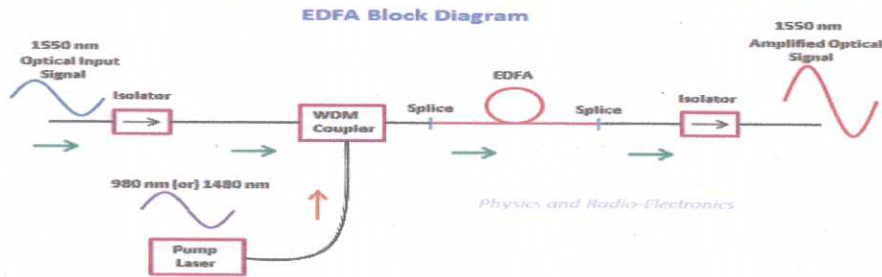
VI  
(b)

VII

(a)

Optical signal amplifiers provide amplification of optical signals by using a method called stimulated emission of photons. The most common type of optical amplifiers are EDFA. EDFA stands for Erbium-Doped Fiber Amplifier.

The working principle of EDFA is same as that of lasers excepting that EDFA do not require a cavity where as cavity is required for laser oscillation.



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EDFA amplifies multiple optical signals simultaneously. It is capable of directly amplifying optical signals before transmission of it in optical fiber.

**Advantages of EDFA**

EDFA amplifies the optical signals without optoelectronic and electro optical conversion.

EDFA amplifies multiple optical signals simultaneously.

The optical signal amplification is independent of data rate.

High gain

Low noise figure

Do not require high speed electronics

No distortion at high bit rates.

**Applications of EDFA**

Dense Wavelength Division Multiplexing (DWDM)

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VII

(b)

**Advantages & Disadvantages of SOA**

Advantages

- The semiconductor optical amplifier is of small size and electrically pumped.
- It can be potentially less expensive
- All four types of nonlinear operations (cross gain modulation, cross phase modulation, wavelength conversion and four wave mixing) can be conducted.
- SOA can be run with a low power laser.

Disadvantages

The performance of SOA is still not comparable with the EDFA. The SOA has higher noise, lower gain, moderate polarization dependence and high nonlinearity with fast transient time.

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VIII

(a)

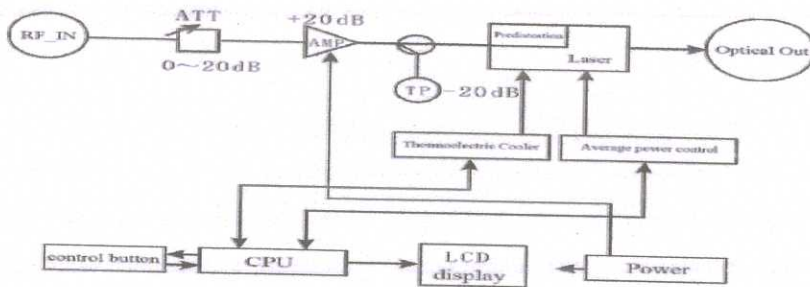
An optical transmitter is any device that sends information in the form of light.

**Explanation:**

Generating an optical signal is the job of the optical transmitter, which encodes the information to be transmitted on the light that it generates..

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Optical transmission falls into one of two categories. Guided-wave or free-space. The most common guided wave optical transmission system uses fiber optic cable. Light is transmitted through the fibre which uses total internal reflection to keep the light trapped inside.



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In the FOC system, the light source like an LED or laser diode is used as a transmitter. The main function of a light source is to change an electrical signal into the light signal. These light sources are small semiconductor devices which efficiently converts electrical signal to light signal. These light sources require connections of power supply and modulation circuitry. All these are generally connected within one IC package.

The optical receiver is a critical element of an optical communication system since it often determines the overall system performance. The function of the optical receiver is to detect the incoming optical power and extract from it the signal that is being transmitted. Block diagrams of typical optical receivers figures

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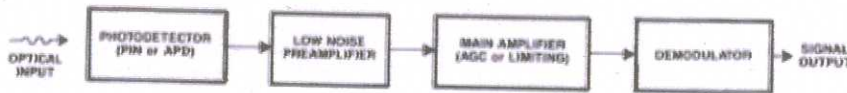


Figure 16.1 Block diagram of an analog optical receiver.

The incident optical power is detected by a photo detector. The detected signal is then amplified by the amplifier chain, which includes a low-noise preamplifier and a post amplifier.. A clock extraction circuit is then used to recover the timing clock, which is used to strobe the sampler and threshold detector. The transmitted data are thus regenerated.

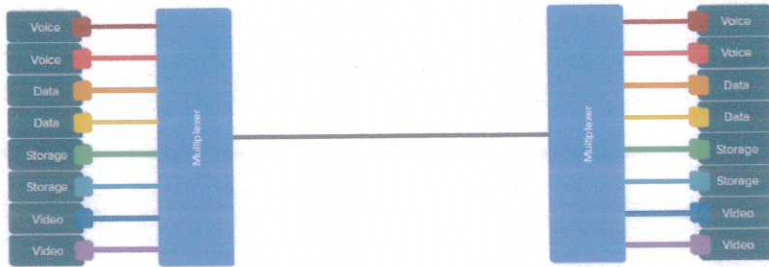
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VIII

(b) **Wavelength division multiplexing (WDM)** is a technology or technique modulating numerous data streams .The WDM multiplexer, sometimes referred to as the passive mux, is the key to optimizing, or maximizing, the use of the fiber. The multiplexer is at the heart of the operation, gathering all the data streams together to be transported simultaneously over a single fiber. At the other end of the fiber the streams are demultiplexed,

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Multiplexing combines multiple channels on a single dark fiber

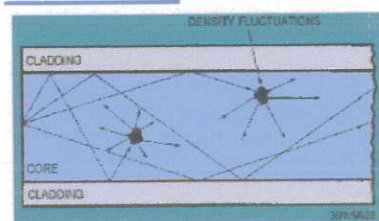
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IX

(a)

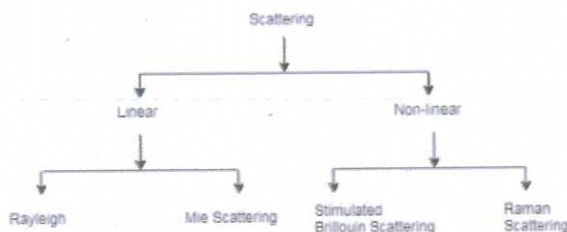
Basically, scattering losses are caused by the interaction of light with density fluctuations within a fiber. Density changes are produced when optical fibers are manufactured. During manufacturing, regions of higher and lower molecular density areas, relative to the average density of the fiber, are created. Light traveling through the fiber interacts with the density areas as shown in Light is then partially scattered in all direction.

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Scattering losses in glass arise from microscopic variations in the material density, from compositional fluctuations and from structural inhomogenities or defects occurring during fiber manufacture.



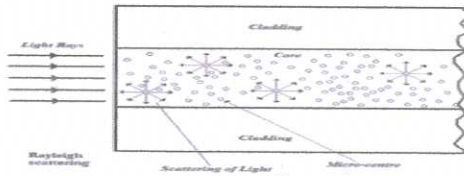
### I. Linear Scattering mechanism:

- It causes the transfer of some or all of the optical power contained within one propagating mode to be transferred linearly into a different mode.
- This process tends to a result in attenuation of the transmitted light as the transfer may be to a leaky or radiation mode which does not continue to propagate within the fibre core, but is radiated from the fibre. With all linear process there is no change of frequency on scattering.
- Linear scattering may be categorized as:
  - a. Rayleigh scattering
  - b. Mie scattering

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### a. Rayleigh scattering:

- For glass fibers the foremost type of scattering is Rayleigh scattering. With this process, atoms or other particles within the fiber absorb the light signal and instantly re-emits the light in another direction.
- In this way Rayleigh scattering appears very much like absorption but it absorbs and redirects the light so quickly that is considered scattering.

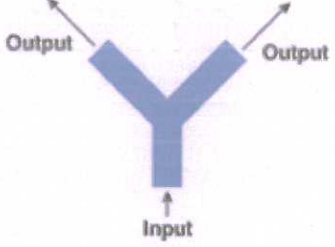
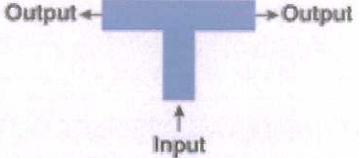


### b. Mie scattering:

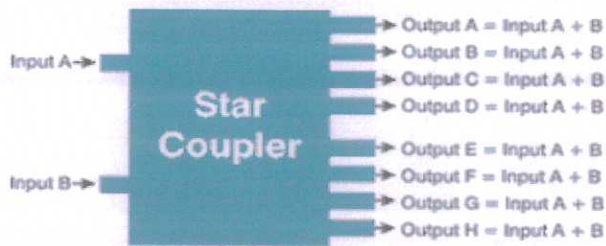
- Imperfections caused due to inhomogenities at the core- cladding interface which causes scattering of light.
- The scattering created by such inhomogenities is mainly in the forward direction and is called Mie scattering.
- It can be reduced by removing imperfections of glass at the time of manufacture, increasing the relative refractive index of the core and the cladding.

## II. Non Linear Scattering Losses:

- This scattering cause disproportionate attenuation, usually at high optical power levels.
  - This non linear scattering causes the optical power from one mode to be transferred in either the forward or backward direction to the same, or other modes, at a different frequency.
  - Non Linear scattering may be categorized as:
    - a. Stimulated Brillouin scattering (SBS)
    - b. Stimulated Raman scattering (SRS)
- a. Stimulated Brillouin scattering (SBS):**
- In SBS strong optical signal generates acoustic waves. These waves produce variations in refractive index.
  - It causes lightwaves to scatter in backward direction towards transmitter called as backward scatter wave which affects the forward signal leading to depletion in signal power.
- b. Stimulated Raman scattering (SRS):**
- SRS is transferring of energy from short wavelengths to neighbouring high wavelength channels.
  - If two input signal with equal power are transmitted than the former will lose its own energy and the latter will gain this energy, this limits the performance of the system.

IX (b)	<p><b>Intra-modal dispersion :-</b>In single mode optical fiber different colour of light travel at different speed in different material and different waveguide structure. Hence light will exit at different time for each colour hence causing dispersion.</p>	5		
	<p><b>Inter-modal diapersion :-</b> In inter-modal dispersion which occur in multimode fiber the incoming light signal has different modes of propagation. Each wave hence will reach at different time at the exit and hence will cause dispersion</p>		5	
X	<p><b>Passive and Active Couplers</b></p>			
(a)	<p><b>Passive</b> fiber optic couplers are said to be passive as no power is required for operation</p>			
	<p><b>Active</b> fiber optic couplers require an external power source. They receive input signal(s), and then use a combination of fiber optic detectors, optical-to-electrical converters, and light sources to transmit fiber optic signals.</p>			
	<p><b>FIBER OPTIC COUPLER TYPES</b></p>			
	<p><b>1. Y Coupler</b></p>			
	<p>Y coupler is also called tap coupler. This type of coupler simply divides the signal into two outputs. The power distribution ratio between two outputs can be precisely controlled, such as 10/90 percent, 20/80 percent, 30/70 percent, 40/60 percent or 50/50 percent.</p>			
				
	<p><b>2. T Coupler</b></p>		10	
	<p>T coupler functions the same as Y coupler.</p>			
				
	<p><u>Advantages of T and Y Coupler</u></p>			
	<p>T couplers are readily available and can be terminated with standard connectors such as SC, ST, FC, LC, etc.</p>	10		
	<p><b>3. Star Couplers</b></p>			
	<p>Star couplers have multiple inputs and outputs. The input and output port number could be the same or not, such as 2×2, 4×4, 8×8, etc. Star couplers distribute the input power uniformly among the output fibers.</p>			15
	<p><u>A) Directional Star Coupler</u></p>			

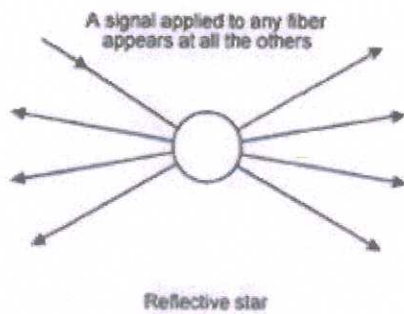
The first type is directional, mixing optical signals from all inputs and then distributes them among all outputs, as shown below. These are bidirectional devices because they also can transmit light in the opposite direction.



5

.B) Non-Directional Star Coupler

The second type of star coupler is non-directional. It takes inputs from all fibers and then distribute them among all fibers, both input and output, as shown below.



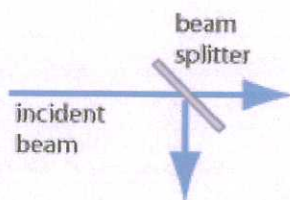
15

X  
(b)

In a non-directional coupler, light going in any one port emerges from all the ports, including the input.. Non-directional coupler is made by reflecting the input light into all output ports. It has a mirror at the end as shown in the following figure.

5

A beam splitter is an optical device which can split an incident light beam (e.g. a **laser beam**) into two (or sometimes more) beams, which may or may not have the same optical power.



QUESTION WISE ANALYSIS

COURSE: OPTICAL FIBER COMMUNICATION

VERSION: 2015

Qn NO	Specific outcome (as per syllabus)	Module	Content details	score	Time in minutes
PART A I 1	1.1.2	I		2	3.6m
I 2	1.1.1	I		2	3.6m
I 3	2.1.4	II		2	3.6m
I 4	3.1.2	IV		2	3.6m
I 5	4.2.1	IV		2	3.6m
PART B					
II 1	1.2.1	I		6	10.8m
II 2	2.1.1	II		6	10.8m
II 3	2.1.5	II		6	10.8m
II 4	3.1.3	III		6	10.8m
II 5	3.1.1	III		6	10.8m
II 6	4.2.1	IV		6	10.8m
II 7	4.2.3	IV		6	10.8m
PART C					
III (a)	1.2.3 & 1.2.4	I		10	18m
III (b)	1.1.2	I		5	9m
IV (a)	1.2.5	I		10	18m
IV (b)	1.2.6	I		5	9m
V (a)	2.1.2	II		10	18m
V (b)	2.1.4	II		5	9m
VI (a)	2.2.3	II		10	18m
VI (b)	2.2.4	II		5	9m
VII (a)	3.1.3	III		10	18m
VII (b)	3.1.3	III		5	9m
VIII (a)	3.2.1,3.2.3	III		10	10m
VIII (b)	3.2.4	III		5	18m
IX (a)	4.1.1	IV		10	9m
IX (b)	4.1.1	IV		5	18m
X (a)	4.2.2	IV		10	9m
X (b)	4.1.4	IV		5	18m
Total time					363.6m

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VERSION:2015

CODE:5045

COURSE: OPTICAL FIBER COMMUNICATION

SL NO	MODULE	TYPE OF QUESTIONS							
		PART-A		PART-B		PART-C		TOTAL	
		No of questions	score	No of questions	score	No of questions	Score	No of questions	score
1	I	1	2	2	12	4	30	7	44
2	II	2	4	2	12	4	30	8	46
3	III	1	2	2	12	4	30	7	44
4	IV	1	2	1	6	4	30	6	38
Total		5	10	7	42	16	120	28	172

Signature:



Name: JMA CMA