

## UNIT V

### Photonics and Fiber Optics

#### Part-A

**1. What is laser?**

LASER is the acronym for Light Amplification by Stimulated Emission of Radiation. The absorption and emission of light by materials has been very ingeniously and skillfully exploited in making a device that amplifies light and generates extremely intense, highly directional, more coherent and monochromatic radiation. This device is called "Laser".

**2. What are the coherent sources?**

Coherent sources are the sources which have same wavelength and frequency. It has correlation with the amplitude and phase at any point with any other point.

**3. What are the characteristics of Laser light. ( Or) State the properties of laser beam? The four important characteristics of the laser beams are:**

- i. It is highly directional.
- ii. It has high intensity.
- iii. The beam is purely monochromatic.
- iv. It has coherence.

**4. What is Stimulated Emission?**

An atom in the excited state is induced to return to ground state thereby resulting in two photons of same frequency and energy is called as stimulated emission.

**5. What is Spontaneous Emission?**

The atom in the excited state returns to ground state thereby emitting a photon, without any external inducement is called as spontaneous emission.

**6. What is stimulated absorption?**

An atom in the ground state with energy  $E_1$  absorbs a photon of energy  $h\nu$  and go to the excited state ( higher state ) with energy  $E_2$  provided the photon energy  $h\nu$  is equal to the energy difference (  $E_2 - E_1$  ). This process is called stimulated absorption or simply absorption.

**7. What is meant by population inversion?**

In general the number of atoms in the ground state will be more than that of the atoms in the excited state and it is called as usual population. The reverse of this ( i.e.) a state of achieving a more number of atoms in the higher energy level than that of the lower energy level is called population inversion.

**8. What is meant by pumping?**

Naturally, the population inversion is achieved only at negative temperature which is impossible . Thus the laser beam is produced. Hence, population inversion is a must for the production of Laser beam.

**9. What are different methods of pumping?**

There are five methods by which the pumping can be made, viz.,

- i. Optical pumping.
- ii. Direct electron excitation (Electron Discharge)
- iii. Inelastic atom — atom collision
- iv. Chemical process

**10. What are the conditions required for laser action?**

The two important conditions required for laser action are

- i. Population inversion should be achieved.
- ii. Stimulated emission should be predominant over spontaneous emission.

**11. What is the effect of negative temperature in population inversion?**

Under the conditions of thermal equilibrium, Boltzmann's distribution function relating  $N_1$  and  $N_2$  is given by

$$\frac{N_1}{N_2} = e^{-(E_2 - E_1)/K_B T}$$

When  $N_1$  and  $N_2$  are the number of atoms in lower and higher states respectively. In the above equation, if  $T$  is negative, then stimulated emission will dominate over stimulated absorption, (i.e) population inversion will be achieving only. If the temperature is negative. In the above equation, if  $T$  is negative, then stimulated emission will dominate over stimulated absorption, (i.e) population inversion will be achieving only. If the temperature is negative.

**12. What is the difference between ordinary and Laser light.**

S.No	Ordinary Light	Laser light
1	Light emitted is not monochromatic	Light emitted is highly monochromatic
2	Light emitted has not high degree of coherence	It has high degree of coherence.
3	Emits light in all direction (not directional)	Emits light only in one direction (directional)
4	Light is not intense and bright	Laser light is much intense and bright.

**13. Define active medium.**

The medium in which the populations inversion can be achieved is called active medium.

**14. What is meant by optical resonator (or) Resonance cavity?**

An optical resonator (or) a resonance cavity is a feed back system, which consists of an active medium kept in between a 100% mirror and a partial mirror. Here, the intensity of light produced in the active medium is increased by making the light to bounce back and forth between the mirrors. Finally the laser beam comes through the partial mirror

**15. What are the three important components of any laser device?**

- i. Active medium
- ii. Pumping source.
- iii. Optical reaonator.

**16. What is the use of nitrogen and Helium in CO2 laser?**

In CO2 laser the nitrogen helps to increase the population of atoms in the upper level of CO2 while helium helps to depopulated the atoms in the lower level of CO2 and also to cool the discharge tube.

**17. State some of the applications of lasers in engineering and Industry field.**

- i. High power laser are useful to blast holes in diamonds and hard steel.
- ii. They are used to test the presence of pores, cracks flows, blow holes etc in the materials.
- iii. They are used for welding and cutting.

**18. What is Nd - YAG laser?**

Nd - YAG is a Neodymium based laser. Nd - Neodymium ( rare earth element  $Nd^{3+}$  \*) YAG - Yittrium

Aluminium Garnet which is  $Y_3Al_5O_{12}$  It is a four level solid state laser.

### 19. What is CO<sub>2</sub> laser?

The active medium for this laser is CO<sub>2</sub> gas. Laser transition takes place between the vibrational states of the CO<sub>2</sub> molecules. It is a very useful and efficient laser. It is a four level molecular gas laser.

### 20. What is the active medium in CO<sub>2</sub> laser?

It is a gas mixture consisting of CO<sub>2</sub>, nitrogen and additives such as helium and water vapour.

### 21. What is Semiconductor laser?

Semiconductor diode laser is a specially fabricated pn junction device. It emits laser light when it is forward biased.

### 22. Distinguish Homojunction and Heterojunction laser

S.No.	Homojunction Laser	Heterojunction Laser
1.	Homojunction Laser is made by a single crystalline material.	Heterojunction Laser is made by different crystalline materials.
2.	Power output is low.	Power output is high.
3.	Pulsed output ( some-times continuous)	Continuous output.
4.	It has high threshold current density.	It has low threshold current density.

### 23. What is meant by TEA Laser?

TEA laser is Transversely Excited Atmospheric pressure CO<sub>2</sub> laser. Here the gas flow is maintained along the axis of the discharge tube and the current in the arc, flows at right angles to the axis of the discharge tube. Hence the CO<sub>2</sub> molecule will be transversely excited.

### 24. What is meant by LIDAR ? Give its use.

LIDAR stands for light Detection And Ranging. It is used in Laser Remote Sensing applications such as

1. Measuring atmospheric pollutant concentration
2. Ozone concentration
3. Vapour ( water) concentration etc.

### 25. What is holography?

Holography deals with image construction by means of interference techniques without using lenses. Here the distribution of amplitude and phase is recorded in 3D manner so as to get complete information of the object to be photographed. I

**26. Explain the importance of holographic storage.**

- i. Each point of an object is recorded on the whole hologram.
- ii. From each piece of a hologram we can reconstruct the image.
- iii. Laser is used for recording and reconstruction processes.
- iv. The phase and amplitude information in the reflected waves from the object are completely recorded in the hologram.

**27. What are the difference between photography and Holography?**

No.	PHOTOGRAPHY	HOLOGRAPHY
1.	Ordinary light is used.	Laser light is used.
2.	The variation of amplitude alone is recorded.	The distribution of amplitude and phase is recorded.
3.	It gives 2D picture. -	It gives 3D picture i.e., Complete picture.
4.	Lens is used.	No lens is used.

**28. What is optical fiber?**

Optical fiber is a wave guide , made up of transparent dielectric like glass or plastices in cylindrical form through which a light is transmitted by total internal reflection . an optical fiber consists of a central core glass about 50 $\mu$ m diameter surrounded by cladding about 125 $\mu$ m to 200 $\mu$ m diameter which is slightly lower refractive index than core material.

**29. Define the acceptance angle.**

Acceptance angle may be defined as the maximum angle at 0 below which the light can suffer total Internal Reflection is called as acceptance angle . The cone is referred as acceptance cone.

**30 . What are the condition to obtain the total internal reflection?**

- Light should travel from denser medium to rarer medium
- The angle of the incidence an core medium should be greater than the critical angle.

**31. What are the feature of optical fiber?**

- It is light in weight
- It has high band width and low loss
- There is no internal noise or cross talk

**32. Define numerical aperture of a fiber.**

The sine of the acceptance angle ( $\sin\theta_a$ ) of the fiber is known as numerical aperture . it denotes the light gathering capacity of the optical fiber.

**33. What is meant by fractional index change?**

The fractional difference between the refractive indices of the core and cladding to the refractive index of core is known as fractional refractive index change .

**34. List out the three difference types of losses in fiber optics.**

- Absorption.
- Rayleigh scattering and
- Geometric effects.

**35. what is splicing?**

The particular technique is selected for joining the fibers depending on whether a permanent bond or on easily demountable connection is desired . A permanent bond is generally referred as splice . where as easily demountable connection is known as connector.

**36. What are the different types splicing technicque? Among which one give the permanent joint.**

- Fusion splice
- V-groove mechanical splice
- Elastic –tube splice. Here the fusion splice is the permanent joint

**37. Define dispersion.**

In fiber optical communication, the signal is launched in the form of pulse of light with a given width, amplitude spacing between pulses .during transmission, several effects results in spreading of pulse width, this effect is called dispersion.

**38. Distinguish between active and passive sensors?**

Active sensors:

1. It senses physical properties
2. Eg. Pressure sensor

Passive Sensor:

1.it has separate sensing element and fiber act as wave guide

Eg. Displacement sensor

**39. Distinguish between step-index and graded index fiber.**

step-index

1.The refractive index of the core is uniform through out step change at the cladding

boundary

2. Attenuation is more

3. Numerical aperture is more.

#### Graded index fiber

1. The refractive index of the core is made to vary in the parabolic manner such that the maximum refractive index is presented at centre of the core

2. Attenuation is less

3. Numerical aperture is less

#### **40. Differentiate between single mode and multimode fiber .**

#### Single mode fiber

1. Only one mode can propagate through the fiber

2. It has smaller core diameter

3. Fabrication is difficult and costly

#### Multi mode

1. It allows large number of modes

2. It has a large core diameter

3. Less difficult and not costly

#### **41. Define numerical aperture ?**

Numerical aperture determines the light gathering ability of the fiber . it is a measure of the amount of light that can be accepted by a fiber .

Numerical aperture (NA) can also be defined as the sine of the acceptance angle ( $i_m$ ). If  $n_1$  and  $n_2$  are refractive index of the core and cladding respectively. Then

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

#### **42. What is meant by attenuation ?**

It is defined as the ratio of the optical power output from the fiber of length  $L$  to the power of input  $P_{in}$  i.e attenuation (pin)

$$\text{i.e Attenuation } \alpha = \frac{10}{L} \log \frac{P_m}{P_{out}} \text{ dB / Km}$$

#### **43. What is meant by a photo detector ?**

Photo detector is a device used to detect the light falling over it. It convert the light falling energy onto electrical energy i.e when the light fall on the photo detector , it produces the electron –holes pairs and their by generates current in the output . Examples (i) pin photo diode(ii) avalanche photo diode (APD).

**44. What is the principle used in pin photo diode?**

This diode works in reverse bias. Under reverse bias what they made to fall on the neutral (or) intrinsic region "I" electron hole pairs are generated. These electrons and holes are accelerated by the external electric field, which results in photo current. The light is converted into electric signal.

**45. Give the principle used in APD?**

The diode works in reverse bias. Under reverse bias when light is made to fall in intrinsic region "I" electron hole pairs are generated. by avalanche effect more number of electron-hole which result in large photo current than that

**46. Mention any 4 advantages of LED in electronic display (jan 2006)?**

1. Very small in size.
2. Different colours of display
3. Works under a wide range of temperature.
4. It has a very wide range of operation.

**47. What is meant by endoscope?**

A medical endoscope is a tubular optical instrument used to inspect or view the internal parts of the human body which are not visible to naked eye. A photograph of an internal part can also be taken using endoscopes.

**PART-B**

1. Explain the propagation of light through optical fiber and the application of optical fiber as waveguide and sensor.
2. Define numerical aperture and derive an expression for numerical aperture and angle of acceptance of fiber in terms of refractive index of the core and fiber.  
Mention six advantages of optical fiber for communication as a waveguide.
3. Describe the Double-Crucible or Crucible-Crucible technique for manufacturing An optical fiber.
4. Explain modes in detail the types of optical fibers based on materials and refractive indices.
5. Write differences between (i) single and multimode (ii) Step index fiber and graded index (GRIN) fiber.



6. Write notes in detail (i) Splicing (ii) losses in optical fibers. (iii) Distortion and Dispersion
7. Describe in detail any one of the light source and detector used in fiber optical communication system. Note: Light source (i) Light emitting Diode (LED), (ii) Semiconductor Laser diode (SLD). Light detector (i) Pin photo diode (PIN Diode), (ii) Avalanche Photo Diode (APD).
8. Explain in detail with a neat block diagram of fiber optical communication system. What are the advantages of fiber optical communication over the conventional methods (Radio wave communication system).
9. Explain with basic principle, the construction and working of an intrinsic sensors and extrinsic sensors.  
Intrinsic Sensors: (i) Temperature / pressure Sensor.  
Extrinsic Sensors: (i) Displacement Sensor.
10. (i) Describe the construction and working of a medical endoscope and give its applications in medical fields.  
(ii) Discuss the applications of fiber optics in engineering, medical and industrial applications.
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### Problems to solve

1. A step-index fiber has a numerical aperture of 0.26, a core refractive index of 1.5 and a core diameter of  $100\mu\text{m}$  calculate (a) The refractive index of the cladding (b) The acceptance angle  $i_m$  (c) The maximum number of modes with a wavelength of  $1\mu\text{m}$  that the fiber can carry.
2. Estimate NA when the core refractive index is 1.48, relative refractive index is 2%. Also calculate the critical angle.
3. Calculate the total number of guided modes propagating in the multimode step index fiber having diameter of  $60\mu\text{m}$  and numerical aperture of 0.25, operating at a wavelength of  $2.7\mu\text{m}$
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7. Calculate the wavelength of emission from GaAs semiconductor laser, whose band gap energy is  $1.44\text{eV}$ .
8. Helium neon laser emits light at a wavelength of  $632.8\text{nm}$  and has output power of laser is  $5\text{mWatt}$ . How many photons are emitted per second by this laser when operating?
9. . For InP laser diode, the wavelength of light emission is  $1.55\mu\text{m}$ . What is its band gap in eV?
10. Calculate the refractive indices of core and cladding materials of an optical fibre if its numerical aperture is  $0.22$  and relative refractive index difference is  $0.012$ .
11. Calculate the Numerical Aperture and Acceptance angle of an optical fibre from the following data. Refractive index of core is  $1.54$  and cladding is  $1.50$
12. A silica optical fibre has a core refractive index of  $1.50$  and cladding refractive index of  $1.47$ . Calculate the critical angle of the core-cladding interface.

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