Assignment - 1

Unit - 4.

A. choose the correct options:

1. (c)
2. (a)
3. (c)
4. (c)
5. (d)
6. (d)
7. (c)
9. (a)
10. (a)
11. (d)
12. (b)
13. (d)
14. (b)
15. (c)
16. (a)

B. Question & Answers:

1. What are the difference between an ordinary and LASER light?

Ans: Ordinary light:

1. It is a mixture of electromagnetic waves of different wavelength.
2. It is non-directional and inconsistent, which means it travels without following any direction.
3. Ordinary light has a wide spectrum of light that moves irregularly at different wavelengths.
4. Ordinary light does not contain photons of the same frequency.
5. Example for ordinary light. Sunlight, flurescent and incandescent etc..
6. Intensity of light decreases rapidly as it travels along distance.

Laser light:

1. Laser light is monochromatic.
2. Laser light shows directional and highly consistent distribution.
3. It has a focused beam in which all photons move at the same wavelength and same direction.
4. Laser light are spectrally pure.
5. Lasers have narrow frequency range and directional distribution.
6. Laser light emitted from a narrow beam. Laser light with naked eye can damage eye.

2. Mention 3 important requirements for lasing action.

Ans: Requirements to achieve laser action

(i) there must be an inverted population i.e, more atoms in the excited state than in the ground state.

(ii) the excited state must be a metastable state.

(iii) the emitted photons must stimulate further emission.

3. State two conditions needed for confining light within the fibre.

Ans: Two conditions needed for confining light within an optical fiber are:

1. Total Internal Reflection: Light must undergo total internal reflection at the core-cladding interface, meaning it reflects back into the core rather than escaping into the cladding.

2. Higher Refractive Index of the Core: The core of the fiber must have a higher refractive index than the cladding, ensuring that light is effectively trapped and guided within the core.

4. Discuss the components of a laser device. what is the significance of an optical resonator in a lasing system?

Ans: The components of a laser device typically includes:

1. Gain Medium: this is the material where stimulated emission occurs, generating photons of light. Common gain mediums include gasses (eg. helium-neon), semiconductors (eg. gallium arsenide), and solid-state materials (eg. ruby crystal).

→

2. Pumping Sources: Energy is typically supplied to the gain medium to excite its atoms or molecules to higher energy states. This excitation prepares the medium for stimulated emission. Pumping sources can be flash lasers, electrical currents, or other lasers.

3. Optical Resonators: The optical resonator consists of mirrors placed at both ends of the gain medium. It provides the feedback neccessary for sustained lasing action by reflecting photons back and fourth through action by, amplifying them in the process.

4. Output Couplers: One of the mirrors in the optical resonator is partially reflective, allowing a portion of the amplified light to exit the laser cavity as the laser beam.

→ The optical resonator in a lasing system is of significant importance because it serves several crucial functions:

→ It provides the necessary feedback mechanism for stimulated emission to occur.

→ It helps in maintaining the coherence and directionality of the laser beam, ensuring it has the desired properties for various applications.

→ It selects specific modes or wavelengths of light to be emitted by the laser, depending on the design of the resonator.

5. write four advantages of fibre optics over traditional metal communication lines.

Ans: 1. Greater Bandwidth:

fibre optics offer much higher bandwidth compared to traditional metal lines. This means they can carry more data over longer distances without signal degradation, making them ideal for high-speed internet.

2. Lower Signal Attenuation:

Fibre optic cables have significant lower signal attenuation compared to metal lines, meaning they can transmit signals over longer distances without requiring signal boosters.

3. Immunity to Electromagnetic Interface (EMI):

fibre optics are immune to electro-magnetic interference, which can degrade signal quality in traditional metal lines. This makes fibre optics ideal for environments where EMI is a concern, such as near power lines or in industrial setting.

4. Lightweight and Compact:

Fibre optic cabels are lighter and more compact than traditional metal cable, making them easier to install and requiring less physical space, which can be particularly advantageous in densely populated urban areas.

6. Write short notes on:

(a) Population Inversion: Population inversion is a state in which more atoms or molecules are in higher energy states than in lower energy states. In the context of lasers, it's a crucial condition for achieving laser amplification.

(b) Metastable states: Metastable states are excited states of atoms or molecules that have relatively long lifetimes compared to typical excited states. They are important in laser technology because they provide the necessary conditions for population inversion and sustained laser action.

(c) Coherence length: Coherence length refers to the distance over which a wave maintains a constant phase relationship. In optics, especially in laser technology, coherence length is essential for maintaining the coherence of laser light.

(d) Stimulated Emission: Stimulated emission is a process in which an incoming photon interacts with an excited atom or molecule, causing it to transition to a lower energy state and emit a second photon with the same energy, phase, and direction as the incoming photon.

7. Deduce the relation between Einstein's A and B coefficients. state the physical significance of the relations.

Ans: The relation between Einstein's A and B Coefficients can be deduced using the principle of detailed balance,

$$\boxed{B_{12}n_1 = B_{21}n_2}$$

where,

- B_{12} is the Einstein coefficient for absorption.
- B_{21} is the Einstein coefficient for stimulated emission.
- n_1 is the number density of atoms in lower
- n_2 is the number density of atoms in higher

→ Einstein's A coefficient, which represents the rate of sponteroues emission,

$$\boxed{A = \frac{8\pi h v^3}{c^3} B_{21}}$$

where;

- h is planck's constant
- ν is the frequency of the emitted radiation.
- c is the speed of light.

Relation between A and B_{21}:

- A demonstrate how the rate of spontaneous emission is related to the rate of stimulated emission (B_{21}) under the influence of the radiation field.

8. Explain the construction and working of Ruby Laser with necessary diagrams.

Ans

Ruby Laser

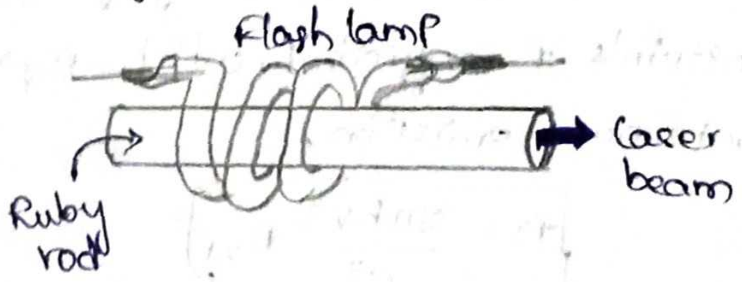
→ First laser developed in 1960. A synthetic pink Ruby Crystal. Contains Cr^{3+} ions with 0.05% of concentration.

Construction:

→ Ruby Crystal as Cylindrical rod with 4cm length 0.5cm in diameter.

→ Aluminium & oxygen ions are inert.

→ Helical photographic flash lamp filled with xenon.



Working:

→ A three level Laser System

→ E_2 - metastable state (3ms)

→ Ruby rod pumped with an instance xenon flash lamp.

→ Ground state of Cr^{3+} ions absorb light at pump bands.

→ 550nm and 400nm

→ Non-radiative transitions to E_2

→ Population inversion at E_2.

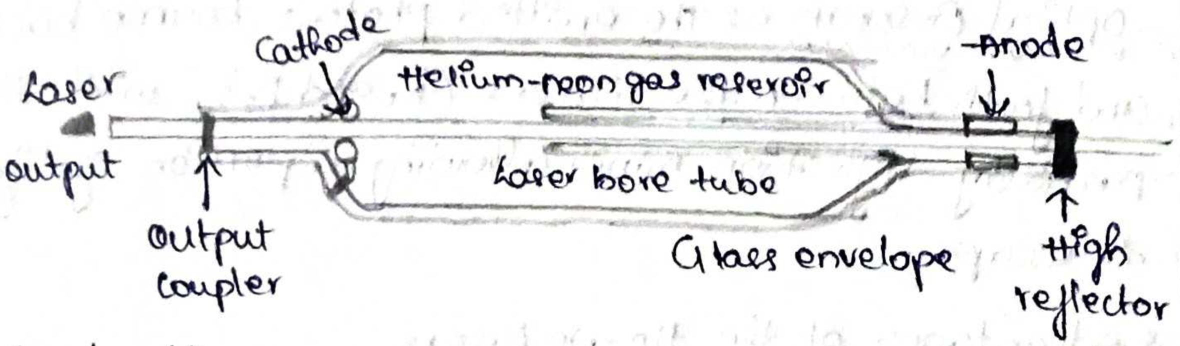
→ Radiative transitions from E_2 to E_1 Red wavelength at 694.3nm.

→ A spontaneous fluorescent photon (red) acts as input and trigger.

→ Stimulated emission.

9. a. Explain the working principle of the He-Ne laser with a neat diagram showing its construction and energy level diagram.

Ans

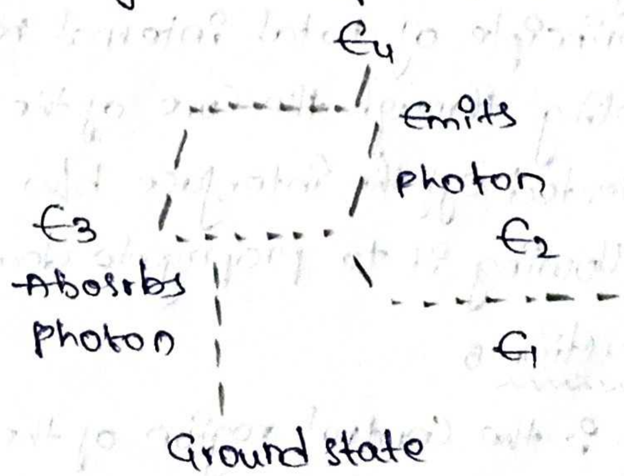


Constructions

1. Gas tube: The main Component of the He-Ne laser is a sealed glass tube filled with mixture of helium (He) and neon (Ne) gas at low pressure.

2. Electrical Discharge: Electrodes at each end of the tube apply a high-voltage electrical discharge.

3. Optical Resonator: The gas tube is situated between two mirrors: one mirror is partially reflective (R_2). these mirrors form an optical resonator.



Working Principles

1. Electrical Discharge: when the high-voltage electrical discharge is applied to the gas mixture, electrons gain enough energy to excite helium atoms from the ground state (E_1) to the metastable state (E_3).

2. Stimulated Emissions: As the excited helium and neon atoms return to their lower energy states, they emit photons of specific wavelengths.

3. Optical Resonance: The emitted photons bounce back and forth between the mirrors (R_1 and R_2), with the partially reflection mirror allowing a portion of light to escape.

* Advantages of the He-Ne Lasers:

* Monochromatic
* Long operating lifespan
* Coherent
* Low power cosumption
* Low noise

10. What is an optical fibre? Discuss the structure/construction of an optical fibre with a suitable diagram.

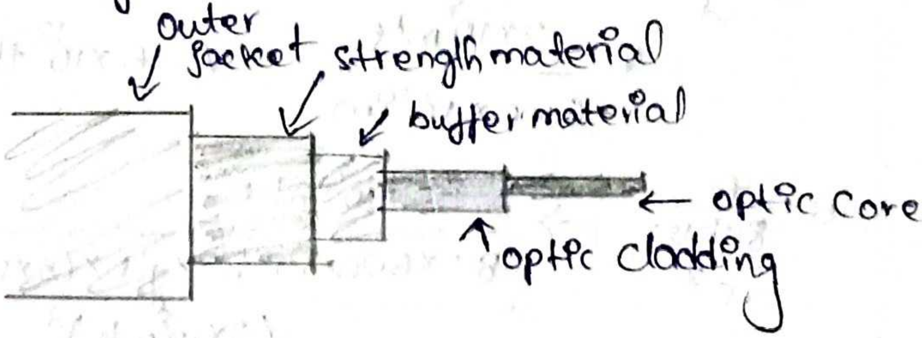
Ans: An optical fibre is an thin, flexible, and transparent fibre made of glass or plastic used to transmit light signals over long distances with minimals loss. It works on the principle of total internal reflection, where light traveling through the core of the fibre is continuously reflected off the interface b/w the core and cladding, allowing it to propagate down the fibre.

Structure/Construction:

1. Core: The core is the central region of the optical fibre through which light is transmitted. It is made of a highly transparent material, usually glass or plastic, with a higher refractive index than the cladding.

2. Cladding: Surronding the core is the cladding, which is also made of glass or plastic but with a slightly lower refractive index than the core.

3. Buffer Coatings To further protect the fibre from mechanical stress and environment factors, a buffer coating made of a polymer material is applied directly onto the cladding.



12. (a) Define the numerical aperture and acceptance cone of an optical fibre.

Ans: Numerical Aperture (NA): the numerical apperture of an optical fibre is a dimensionless parameter that describes the light-gathering ability of the fibre.

Acceptance Cone (AC): the acceptance cone of an optical fibre is the angular range within which light can enter the fibre and propagate through it via total internal reflection.

(b) Deduce the expression of the numerical aperture of an optical fibre.

the numerical aperture (NA) of an optical fibre is given by the formula.

$$NA = n \sin(\theta_{max})$$

$$\sin(\theta_{max}) = \frac{n_2}{n_1}$$

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

13. The wavelength of emission is 6000A° and the coefficient of spontaneous emission is 106 m/s. Determine the coefficient of stimulated

Sol:

$$A = \frac{8\pi h\nu^3}{C^3} B$$

$$\lambda = 6000A^\circ = 6000 \times 10^{-10} m$$

$$\nu = \frac{C}{\lambda}$$

$$\nu = \frac{3\times10^8 m/s}{6000\times10^{-10} m} \quad \nu = 5\times10^{13} Hz$$

$$B = \frac{A}{\frac{8\pi h\nu^3}{C^3}} \Rightarrow \frac{10^6 m/s}{\frac{8\pi\times6.26\times10^{-34} m^2 kg/s \times (5\times10^{13} Hz)^3}{(3\times10^8 m/s)^3}}$$

$$B = \frac{10^6 m/s \times 27\times10^{24} m^3 s^{-3}}{8\pi\times6.26\times10^{-34} m^2 kg/s \times 125\times10^{39} Hz^3}$$

$$B \approx 6.45 \times 10^{-10} m^3 s^{-1}$$

14. Sodium d1 and d2 lines have wavelength 5890A° and 5896A°. Find the coherence length of the sodium vapour lamp.

Sol:

$$L_c = \frac{c}{\Delta\nu} = \frac{\lambda^2}{\Delta\lambda}$$

$$\Delta\lambda = \lambda_2 - \lambda_1 = 5896A^\circ - 5890A^\circ = 6A^\circ$$

$$L_c = \frac{\lambda^2}{\Delta\lambda} = \frac{(5893A^\circ)^2}{6A^\circ}$$

$$L_c = \frac{(5893\times10^{-10} m)^2}{6\times10^{-10} m}$$

$$L_c = \frac{34765649\times10^{-20} m^2}{6\times10^{-10} m}$$

$$L_c = \frac{34765649}{6} \times 10^{-10} m$$

$$L_c \approx 5794.42 \times 10^{-10} m$$

$$L_c \approx 5.79442 mm.$$

15. A step-index fibre has a core of refractive index 1.40. If the fibre is used in a water environment, find its NA and Acceptance angle. the refractive index of water is 1.33.

Sol: The critical angle (θ_c)

$$\Rightarrow \sin(\theta_c) = \frac{n_{clad}}{n_{core}}$$

$\because n_{clad} = 1.40$

$n_{core} = 1.50$

$$\sin(\theta_c) = \frac{1.40}{1.50}$$

$$\sin(\theta_c) \approx 0.9333$$

$$\theta_c = \sin^{-1}(0.9333)$$

$$\theta_c \approx 69.54^\circ$$

$$NA = n_{core} \sin(\theta_c)$$

$$NA = 1.50 \times \sin(69.54^\circ)$$

$$NA = 1.50 \times 0.9333$$

$$NA \approx 1.40$$

16. An optical fibre power after propagating through a fibre of 1.5 Km length is reduced to 25% of its original value. Compute the fibre loss in dB/Km.

Sol:
$$\text{Attenuation (dB)} = 10 \log_{10}\left(\frac{P_{initial}}{P_{final}}\right)$$

$$P_{final} = 0.25 \times P_{initial}$$

→

$$dB = 10\log_{10}\left(\frac{P_{initial}}{0.25 \times P_{initial}}\right)$$

$$dB = 10\log_{10}\left(\frac{1}{0.25}\right)$$

$$dB = 10\log_{10}(4)$$

$$= 10 \times 0.602$$

$$dB = 6.02\,dB$$

$$\text{fiber Loss}\,(dB/Km) = \frac{dB}{Km}$$

$$(dB/Km) = \frac{6.02\,dB}{1.5\,Km}$$

$$= 4.013\,dB/Km$$

(4). (a) Cladding Index:

$$n_{clad} = n_{core} \times (1 - \text{fractional Index difference})$$

$$n_{clad} = 1.5 \times (1 - 0.0005)$$

$$n_{clad} = 1.5 \times 0.9995$$

$$n_{clad} = 1.49925$$

(b) Critical Angle:

$$\sin(\theta_c) = \frac{n_{clad}}{n_{core}}$$

$$\sin(\theta_c) = \frac{1.49925}{1.5}$$

$$\theta_c = \sin^{-1}(0.9995)$$

$$\theta_c = 89.83^\circ$$

(c) Acceptance Angle:

$$NA = \sqrt{n_{core}^2 - n_{clad}^2}$$

$$NA = \sqrt{(1.5)^2 - (1.49925)^2}$$

$$NA = \sqrt{2.25 - 2.2475062 5}$$

$$NA = \sqrt{0.00249375}$$

$$NA \approx 0.04994$$

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