ANSWER SHEET

B.Sc. Semester-VI Examination, 2023-24

Subject : – Physics(Honours)

Course ID : 62410 **Course Code : SP/PHS/604/SEC-4/T-8**

Course Title: Applied Optics

Time : 2 Hours. **Full Marks : 40**

Section I (2×5=10)

Answer any five of the following questions:

1. **What is the main function of cladding in an optical fiber cable?**
   Answer:
   The cladding in an optical fiber helps in maintaining total internal reflection by providing a lower refractive index, which ensures that light signals remain within the core of the fiber.

2. **Define spontaneous cavity lifetime.**
   Answer:
   Spontaneous cavity lifetime is the duration for which a photon or particle remains in a given quantum state before it transitions to a lower energy state.

3. **Why is Fourier Transform Spectroscopy used in forensic science?**
   Answer:
   It is used for its ability to precisely analyze material compositions and spectral data, aiding in the identification of substances in forensic evidence.

4. **Write down the characteristics of spatial and temporal coherence.**
   Answer:
   Spatial coherence refers to the uniform phase of light across different points in space, while temporal coherence refers to the consistent phase over time, indicative of monochromatic light.

5. **How to reduce crosstalk?**
   Answer:
   Crosstalk can be reduced by improving shielding, proper grounding, and maintaining sufficient spacing between transmission lines.

Section II (5×4=20)

Answer any four of the following questions:

1. **How does a semiconductor laser work?**
   Answer:
   In a semiconductor laser, electrons and holes recombine at the junction of the semiconductor, releasing photons and producing laser light through stimulated emission.

2. **Discuss spontaneous stimulated emission and absorption. What is metastable state?**
   Answer:
   Spontaneous emission is when an electron randomly emits a photon as it falls to a lower energy state. Stimulated emission occurs when an incoming photon causes the emission of another photon. Absorption happens when a photon is absorbed, raising an electron to a higher state. A metastable state is a long-lived excited state.

3. **Define spatial frequency. Explain spatial frequency filtering.**
   Answer:
   Spatial frequency measures the periodic variation of image intensity. Spatial frequency filtering enhances or reduces specific frequencies to alter image quality.

4. **Discuss fiber Bragg grating.**
   Answer:
   Fiber Bragg grating is a reflective grating constructed within optical fibers that reflects specific wavelengths of light while transmitting others, useful in optical communications and sensing.

Question 1:

How is attenuation measured in an optical fiber? Discuss the different sources of attenuation. Describe the advantages of optical fiber in comparison to copper cable.

- **Attenuation Measurement:** Attenuation in optical fiber is a measure of signal loss as the light travels through the fiber. It is expressed in decibels per kilometer (dB/km). To calculate attenuation, the input power (P_{in}) and output power (P_{out}) of the light at two points in the fiber are measured. The attenuation is calculated using the formula:

$$Attenuation\ (dB) = 10\ log_{10}\left(\frac{P_{in}}{P_{out}}\right)$$

This measurement helps assess the performance of optical fibers over a given distance.

- **Sources of Attenuation:**

    1. **Absorption:**
       This occurs due to impurities in the fiber material, such as water molecules or metal ions, which absorb light energy and convert it into heat, reducing the signal strength.

    2. **Scattering (Rayleigh Scattering):**
       Scattering results from microscopic variations in the material density of the optical fiber, which causes light to scatter in different directions, leading to signal loss. Rayleigh scattering is the dominant form of scattering in optical fibers.

    3. **Bending Losses:**
       When the fiber is bent beyond a certain critical radius, light can leak out of the core, causing attenuation. There are two types of bending losses:

        - **Macrobending:** Occurs when the fiber is bent on a large scale (e.g., coiling the fiber).
        - **Microbending:** Occurs due to small, unintentional bends or imperfections in the fiber's surface.

    4. **Connector and Splice Losses:**
       Attenuation can also occur at points where fibers are joined together using connectors or splices. If the fibers are not perfectly aligned, signal loss can happen at these junctions.

- **Advantages of Optical Fiber over Copper Cable:**

    1. **Higher Bandwidth:**
       Optical fibers have a much greater data transmission capacity than copper cables. They can carry more information at much higher speeds over long distances.

    2. **Lower Attenuation:**
       Optical fibers experience less signal loss over long distances compared to copper cables, reducing the need for repeaters or amplifiers to boost the signal.

3. **Immunity to Electromagnetic Interference (EMI):**
   Unlike copper cables, optical fibers are immune to electromagnetic interference because they use light (photons) rather than electrical signals (electrons). This makes them ideal for environments with high EMI, such as industrial or medical facilities.

4. **Lighter and Thinner:**
   Optical fibers are thinner, lighter, and more flexible than copper cables, making them easier to install and requiring less physical space.

5. **Higher Security:**
   Optical fibers are more secure as they are difficult to tap into without being detected, making them ideal for sensitive data transmission.

Question 2:

What is an optical resonator? Discuss the role played by it in a laser system. Draw the energy level diagram of the He-Ne laser and show different transitions. Write down two uses of the LASER beam.

- **Optical Resonator:** An optical resonator (or optical cavity) is a key component of a laser that consists of two or more mirrors placed facing each other. The resonator's function is to provide a closed path for the light to travel back and forth, amplifying it through repeated reflections. This structure forms standing waves that enhance certain frequencies, leading to the production of coherent light (laser).
- **Role in a Laser System:** In a laser system, the optical resonator plays a crucial role in amplifying the light produced by the gain medium. It does this by reflecting light multiple times through the medium, allowing for continuous stimulated emission of photons. The mirrors in the resonator enhance specific wavelengths and build up the laser beam's intensity. One mirror is partially reflective, allowing a portion of the amplified light to escape as the laser output, while still reflecting enough light back into the cavity to maintain the lasing process.
- **Energy Level Diagram of the He-Ne Laser and Transitions:**

In the Helium-Neon (He-Ne) laser, the energy transition happens in the neon atoms. The electrons in the neon atoms are excited by collisions with helium atoms. The energy level diagram involves transitions between the excited states and the ground state. The primary lasing transition occurs from the 3s3s3s state to the 2p2p2p state in neon atoms, producing light at a wavelength of 632.8 nm (visible red light).

- **Uses of the LASER Beam:**

1. **Medical Applications:**
   Lasers are extensively used in medical fields for surgeries (e.g., LASIK eye surgery), skin treatments, and dental procedures due to their precision and minimal damage to surrounding tissues.

2. **Industrial Applications:**
   In industries, lasers are used for cutting, welding, and engraving materials like metal, plastic, and ceramics with high precision and speed. Laser beams are also used in barcode scanning and material processing.