

Engineering Physics Module–4 Notes Lasers and Optical Fiber

MODULE–4 TOPICS

- Einstein's Theory of Matter Radiation Interaction
- Einstein A and B Coefficients
- Population Inversion
- Amplification of Light
- Gas Lasers (He-Ne and CO₂ Laser)
- Solid State Lasers (Ruby and Nd:YAG Laser)
- Properties of Laser Beams
- Laser Speckles
- Applications of Lasers
- Optical Fiber
- Acceptance Angle and Acceptance Cone
- Numerical Aperture
- V Number
- Attenuation in Optical Fiber

1. INTRODUCTION TO LASERS

LASER stands for:

Light Amplification by Stimulated Emission of Radiation

Laser is a device that produces highly intense, coherent, monochromatic and directional light.

Applications:

- Optical communication
- Medical surgery
- Industrial cutting and welding
- Scientific research

2. EINSTEIN THEORY OF MATTER RADIATION INTERACTION

Einstein explained interaction between matter and radiation using three processes:

(a) Absorption

Atom absorbs photon and electron moves to higher energy state.

(b) Spontaneous Emission

Excited atom returns to lower energy state automatically and emits photon.

(c) Stimulated Emission

Incoming photon stimulates excited atom to emit another photon.

Stimulated emission is the basic principle of LASER.

3. EINSTEIN A AND B COEFFICIENTS

Einstein introduced coefficients to explain probabilities of radiation processes.

A Coefficient:

Represents probability of spontaneous emission.

B Coefficient:

Represents probability of absorption and stimulated emission.

4. POPULATION INVERSION

Population inversion is the condition in which number of atoms in excited state becomes greater than number of atoms in ground state.

Population inversion is essential for laser action.

Methods of Achieving Population Inversion:

- Optical pumping
- Electrical discharge
- Chemical pumping

5. AMPLIFICATION OF LIGHT

Amplification occurs due to repeated stimulated emission inside resonant cavity.

Main Components of Laser:

- Active medium
- Pumping source
- Resonating cavity

6. He-Ne LASER

He-Ne laser is a gas laser using helium and neon gases.

Working Principle:

- Electrical discharge excites helium atoms.
- Helium transfers energy to neon atoms.
- Population inversion occurs in neon atoms.
- Laser beam produced at 632.8 nm wavelength.

Applications:

- Holography
- Barcode scanners
- Alignment systems

7. CO₂ LASER

CO₂ laser is high power gas laser.

Features:

- Infrared laser
- High efficiency
- High output power

Applications:

- Industrial cutting
- Welding
- Surgery

8. RUBY LASER

Ruby laser is solid state laser using chromium doped ruby crystal.

Features:

- Produces red light
- Pulsed output laser

Applications:

- Holography
- Medical applications

9. Nd:YAG LASER

Nd:YAG laser uses neodymium doped yttrium aluminium garnet crystal.

Features:

- High efficiency
- High power output

Applications:

- Medical surgery
- Material processing

10. PROPERTIES OF LASER BEAMS

(a) Monochromaticity

Laser light contains single wavelength.

(b) Coherence

Laser waves maintain fixed phase relation.

(c) Directionality

Laser beam travels long distance without spreading much.

(d) Brightness

Laser light has very high intensity.

11. LASER SPECKLES

Laser speckles are random bright and dark patterns produced due to interference of scattered laser light.

Applications:

- Surface analysis
- Medical imaging

12. APPLICATIONS OF LASERS

In Science:

- Spectroscopy
- Holography

In Engineering:

- Cutting and welding
- Communication systems

In Medicine:

- Eye surgery
- Dental surgery
- Cancer treatment

13. OPTICAL FIBER

Optical fiber is a thin transparent dielectric medium used to transmit light signals.

Principle:

Total internal reflection.

Main Parts:

- Core
- Cladding
- Protective coating

Applications:

- Optical communication
- Internet systems
- Medical endoscopy

14. ACCEPTANCE ANGLE AND ACCEPTANCE CONE

Acceptance angle is the maximum angle at which light can enter optical fiber and still propagate through it.

Acceptance cone is the cone formed by acceptance angle.

15. NUMERICAL APERTURE (NA)

Numerical aperture determines light gathering capacity of optical fiber.

Formula:

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

Where:

n_1 = refractive index of core

n_2 = refractive index of cladding

16. V NUMBER

V number determines number of propagation modes in optical fiber.

Formula:

$$V = (2\pi a/\lambda) NA$$

Where:

a = core radius

λ = wavelength

17. ATTENUATION

Attenuation is reduction in optical signal strength during transmission.

Causes:

- Absorption
- Scattering
- Bending losses

MOST IMPORTANT 14 MARK QUESTIONS

1. Explain Einstein theory of matter radiation interaction.
2. Explain Einstein A and B coefficients.
3. Explain population inversion and amplification of light.
4. Explain construction and working of He-Ne laser.
5. Explain construction and working of CO₂ laser.
6. Explain Ruby laser and Nd:YAG laser.
7. Explain properties of laser beams.
8. Explain applications of lasers in science, engineering and medicine.
9. Explain optical fiber and principle of total internal reflection.

10. Explain numerical aperture, acceptance angle and V number.

IMPORTANT 7 MARK QUESTIONS

1. Define LASER.
2. Explain stimulated emission.
3. Explain population inversion.
4. Explain laser speckles.
5. Explain attenuation in optical fiber.
6. Explain acceptance angle.
7. Explain numerical aperture.

IMPORTANT NUMERICALS

1. Numerical on numerical aperture.
2. Numerical on V number.
3. Acceptance angle numerical.
4. Optical fiber attenuation problems.

EXAM TIPS

- Draw neat laser diagrams.
- Learn all laser properties carefully.
- Practice optical fiber numericals.
- Revise formulas regularly.
- Focus on applications and working principles.