CENTRAL INSTITUTE OF TECHNOLOGY KOKRAJHAR
(Deemed to be University)
KOKRAJHAR :: BTR :: ASSAM :: 783370
END – SEMESTER EXAMINATION
DEGREE

Session: January-May, 2025 Semester: 6th Time: 3 Hrs. Full Marks: 100
Course Code: **UIE 603** Course Title: **Optical Fiber & Optoelectronics**

QUESTION NO. 1 IS COMPULSORY AND ANSWER ANY FOUR (4) FROM THE REST

Q1:

a) Choose the correct answer. (5-marks)

i) What is the primary mechanism of laser marking?
   a) Chemical etching
   b) Local surface evaporation
   c) Magnetic imprinting
   d) Mechanical engraving

ii) Which property of laser light is primarily utilized in medical diagnostics?
   a) High power density
   b) Monochromaticity and coherence
   c) Broad wavelength spectrum
   d) Diffuse reflection

iii) What is the primary advantage of LIDAR over RADAR?
   a) Longer operating distance
   b) Ability to detect small objects due to shorter wavelengths
   c) Better performance in cloudy weather
   d) Lower cost

iv) What is the primary difference between a photograph and a hologram?
   a) A photograph uses laser light, while a hologram uses sunlight.
   b) A hologram records light scattered from multiple directions, while a photograph captures light from one direction.
   c) A photograph is always three-dimensional, while a hologram is two-dimensional.
   d) A hologram does not require a recording medium.

v) What is the term for the quantum of charge density oscillations supported by a metal-dielectric interface?
   a) Surface plasmon waves
   b) Evanescent waves
   c) Surface plasmons
   d) Resonance waves

b) State True or False. If false, write the correct statement. (5-marks)

i) Laser marking can be done on materials like semiconductors, ceramics, and plastics.
ii) The speed of sound is faster than the speed of light.
iii) Reflection holograms are less expensive to produce than transmission holograms.
iv) The resonance condition in SPR involves matching of momentum of surface plasmon wave and evanescent wave.
v) The fiber optic gyroscope operates based on the Faraday effect.

c) Fill in the gaps with correct answer. (5-marks)

i. Laser Distance Meters use _____waves to measure distance.
ii. In holography, the interference pattern is created by the interaction of the _____ beam and the _____ beam.
iii. In an FBG sensor, external parameters like temperature or strain change either the _____ or the effective refractive index.
iv. The evanescent field absorption sensor measures changes in output power due to modifications in the _____ portion of the fiber.
v. In holography, the _____ beam is directed onto the object, and its scattered light falls onto the recording medium.

d) Match the followings. (5-marks)

Column-A	**Column-B**
(a) Typical core diameter of a single-mode fiber (SMF)	*(i) 1300nm*
(b) The intrinsic strength of glass	*(ii) 0.5 µm*
(c) Zero dispersion wavelength	*(iii) 9µm*
(d) Fiber Bragg grating (FBG) includes periodic modulation of refractive index with a period of	*(iv) 1595nm*
(e) Bragg wavelength for an FBG sensor with effective refractive index 1.45 and grating period 0.55 µm	*(v) 2,000,000 lb/in^2*

Q2:

a) Why are optical fibers preferred over metal wires for communication? (2-marks)
b) Compare the bandwidth capabilities of fiber optics and copper cables (Cat5, Cat6, Cat7). (2-marks)
c) Discuss the three key properties of glass that make it ideal for optical fiber manufacturing. (3-marks)
d) A fiber optic system requires a bandwidth of 50 MHz. Two LEDs are under consideration:
LED-A: Rise time = 0.7 ns
LED-B: Rise time = 3.5 ns
Which LED meets the bandwidth requirement? (4-marks)
e) What are the advantages of plastic fibers over glass fibers? (2-marks)
f) Why is cladding necessary in optical fibers? Explain its role in light confinement. (4-marks)
g) How does the refractive index difference (Δ) affect the numerical aperture (NA)? (3-marks)

Q3:

a) A PIN photodiode produces a current of 12 µA when exposed to an optical power of 20 µW. Calculate its responsivity.? (3-marks)
b) Compare the terms "critical angle" and "acceptance angle" in optical fibers. (4-marks)
c) Explain why single-mode fibers are unsuitable for use with LEDs. (2-marks)
d) How does the V-number relate to the number of propagation modes in a fiber? (3-marks)
e) How does the choice of fiber type (SMF/MMF) affect communication system design? (3-marks)
f) A graded-index fiber has a parabolic profile (α=2) with n_1=1.47(core axis) and n_2=1.45(cladding). Calculate the refractive index at a radial distance r=20 µm if the core radius a=50 μm. (5-marks)

Q4:

a) An optical detector generates 8×10^6 from 2×10^7 incident photons. Determine its quantum efficiency. (3-marks)
b) Compare attenuation loss and dispersion loss in optical fibers. (3-marks)

c) A multimode fiber has a BWL of 200 MHz-km. If the spectral width of the source is 40 nm and the fiber length is 5 km, calculate the pulse broadening Δt. (4-marks)
d) Compare modal, material, and waveguide dispersion in terms of causes, effects, and mitigation strategies. (5-marks)
e) Explain how numerical aperture mismatch causes intrinsic loss in fiber joints. (3-marks)
f) What is the purpose of a fusion splicer? (2-marks)

Q5:

a) With the help of a diagram, explain the structure and operation of a four-port optical coupler, including the types of losses associated with it. (5-marks)
b) A fiber has a core refractive index n_1=1.48 and cladding index n_2=1.46. Calculate Δ and determine the micro bend period Λ if the core radius is 25 μm. (3-marks)
c) What is the role of a GRIN lens in T coupling? (2-marks)
d) Compare the efficiency of 3-level and 4-level lasers in achieving population inversion. (3-marks)
e) In a 3-level laser, the energy difference between the ground state (E_1) and the pump state (E_3) is 2.0 eV. Calculate:
    i) The wavelength of the pumping light required to excite electrons from E_1 to E_3.
    ii) The frequency of the pumping light.
(Use h = 4.1357 × 10^{-15} eV-s, c = 3 × 10^8 m/s). (4-marks)
f) A LIDAR system uses a laser with a pulse duration of 5 ns. Determine its range resolution (smallest detectable distance difference). (3-marks)

Q6:

a) With the help of an energy level diagram, explain the working principle of a semiconductor laser under forward bias conditions. (4-marks)
b) An OTDR measures a time delay of 3.2 μs for a micro bend event. Assuming the fiber's effective refractive index is 1.45, calculate the distance to the micro bend location. (3-marks)
c) Differentiate between a homojunction and a heterojunction LED. (2-marks)
d) What is meant by the full width at half maximum (FWHM) in spectral width? (1-mark)
e) Compare the advantages and disadvantages of LEDs and semiconductor lasers as light sources for optical fibers, with reference to the operational parameters. (4-marks)
f) What is shot noise, and how does it affect detector performance? (2-marks)
g) Describe the process of photomultiplication in an avalanche photodiode (APD). (4-marks)

Q7:

a) Explain how a fiber optic sensor based on fiber core misalignment can be used to detect acoustic waves. (4-marks)
b) If the desired phase shift is $\Delta\phi$=0.5 rad, angular velocity Ω=75 rad/s, A=0.005 m^2, and light of wavelength λ_0=1.55 μm is used, determine the minimum number of fiber turns N required. (3-marks)
c) With the help of a diagram, explain the working principle of a fiber optic liquid-level sensor and discuss its advantages in monitoring inflammable liquids. (4-marks)
d) Discuss the design and operation of a micro bend hydrocarbon sensor, including the role of the polymer coating and OTDR in detecting hydrocarbon leakage. (4-marks)
e) Discuss how the Mach-Zehnder sensor detects external perturbations such as pressure or temperature. (4-marks)
f) Define the Bragg wavelength in the context of FBG sensors. (1-mark)

Q8:

a) How does a reagent-mediated sensor achieve selectivity for a target analyte? (3-marks)

b) Describe the role of lasers in ophthalmology. Mention specific types of lasers used for different eye treatments, such as retina surgery and cataract removal. (4-marks)

c) How does Laser Doppler Velocimetry (LDV) measure fluid velocity? Explain the theory behind the Doppler shift and its significance in the process. (5-marks)

d) Compare LIDAR and RADAR in terms of their working principles, advantages, and limitations. Mention at least two key differences between the two technologies. (5-marks)

e) Mention the basic principle of holography and how it differs from conventional photography. Mention at least three key differences between the two techniques. (3-marks)

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