Birla Institute of Technology and Science, Pilani
First Semester 2016-17
EEEF426 Fiber Optics and Optoelectronics
COMPREHENSIVE EXAM (December 12, 2016)
Part-A (Closed Book)

Max. Marks: 70 **Max. Time: 90 min.**

Note:- Answer in same sequence of questions and all sections of a question at same place.
All questions carry equal marks.

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1. (a) Explain the significance of numerical aperture of the fiber? (b) The speed of light in vacuum and in core of a SI fiber is 2.99×10^8 m/s and 2.01×10^8 m/s respectively. When the fiber is placed in air, the critical angle at core-cladding interface is 81°. Calculate NA of fiber and multipath time dispersion per unit length. (c) Calculate the maximum thickness of a dielectric material of refractive index 1.448 sandwiched between two infinite dielectric slabs of refractive index 1.436 so that it supports first three guided modes at a wavelength of 1550 nm.
2. (a) How can larger core diameters for single mode fibers be obtained to improve source-to-fiber coupling efficiency? (b) A graded index fiber with a triangular profile supports the propagation of 300 guided modes. The fiber has a relative refractive index difference of 0.03, a core index of 1.55 and a core diameter of 50 µm. Calculate the wavelength of light propagating in the fiber. (c) Also, estimate the maximum diameter of the fiber core which can give single-mode operation at the same wavelength.
3. (a) Explain fiber birefringence and how does it lead to dispersion in single mode fibers? (b) A beat length of 15 cm is observed in a typical SMF when light of 1.55 µm is launched into it. Calculate the modal birefringence. (c) Why is it necessary to cleave fibers before splicing them?
4. (a) On what factors does the gain coefficient of a semiconductor laser depend? (b) What are the factors that deviate Responsivity curve of a photodiode from its ideal characteristics? (c) An APD has a quantum efficiency of 40 % at 1.55 µm. When illuminated with optical power of 0.5 µW, it produces an output current of 10 µA, after avalanche gain. Calculate the multiplication factor of APD.
5. (a) Distinguish between Raman-Nath and Bragg AOMs. (b) Calculate the thickness of a half-wave plate made of quartz and to be used with sodium light (λ = 590 nm). The principal refractive indices n_e and n_o for quartz are 1.55 and 1.54 respectively. (c) List requirements which must be met so that a semiconductor DH functions efficiently as an optical amplifier?
6. (a) Explain and sketch how WDM is achieved using a Mach-Zehnder Interferometer? (b) A directional coupler uses two identical single-mode fibers. Determine the interaction length so that the input power is divided by a ratio of 1:3 at both output ports. (c) Discuss, how dispersion is managed using dispersion compensating fiber (DCF).
7. (a) Why Four-wave mixing effect in fiber is an issue at high bit-rates? (b) A 1.55 µm SMF based communication system is designed to operate at 2.5 Gbps. The connectors at each end of link exhibits a 1 dB loss. The InGaAsP laser is capable of coupling optical power of -10 dBm in the SMF. The fiber losses including the splicing losses accounts for 0.29 dB/km. The InGaAs p-i-n receiver has a sensitivity of -44 dBm. Calculate repeater-less distance if a safety margin of 6 dB is allowed. (c) Distinguish between intrinsic and extrinsic fiber-optic sensors.

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Part-B (Open Book)

Max. Marks: 70 **Time: 90 min.**

Note:- Answer in same sequence of questions. All questions carry equal marks.

1. Consider a fiber with 8 µm core radius, a core index of 1.5 and $\Delta = 0.01$. (a) If $\lambda = 1550$ nm, what is the value of V and how many modes propagate in the fiber? (b) What percent of the optical power flows in the cladding? (c) if the core-cladding difference is reduce to $\Delta = 0.001$, how many modes does the fiber support and what fraction of the optical power flows in the cladding?
2. Consider an optical link consisting of a 15-km long SI fiber with core index $n_1 = 1.51$ and relative index difference Δ = 2%. (a) Find the delay difference at the fiber end between the slowest and fastest modes. Find the rms pulse broadening caused by intermodal dispersion. (c) Estimate the maximum bit rate that can be transmitted over the fiber without significant errors. (d) Assuming the maximum bit rate equals the bandwidth, what is the bandwidth-distance product of the fiber.
3. A GaAs LED is forward biased with a current of 120 mA and a voltage of 1.5 V. Each emitted photon possesses energy of 1.43 eV, and the refractive index of GaAs is 3.7. The configuration of the LED is such that back emission and self absorption may be neglected within the semiconductor. Assuming the internal quantum efficiency of the LED to be 60%, calculate the internal and external power efficiency of the device.
4. For lasers with strong optical confinement, $g_{th} = \beta J_{th}$. Consider a GaAs laser with an optical cavity of length 225 µm and width 125 µm. At normal operating temperatures, the gain factor $\beta = 22 \times 10^{-3}$ A/cm^3 and the effective absorption coefficient α = 12/cm. (a) if the refractive index is 3.58, find the threshold current density and the threshold current I_{th}. Assume the laser end faces are uncoated and the current is restricted to the optical cavity. (b) What is the threshold current if the laser cavity width is reduced 10 times?
5. (a) Consider a KDP electro-optic intensity modulator of 2 cm length. Given that for KDP, $n_0 = 1.512$, $r_{63} = 10.5 \times 10^{-12}$ m/V, and applied voltage, V = 8.25 kV, which wavelength in visible region (400 to 800 nm) will be absent in the output. Assume vertical axis to be pass axis of polarizer on either side of KDP crystal. (b) In a MZI with unequal arm lengths, as the input wavelength is varied, the output reaches a maximum at 1.53 µm and becomes a zero at 1.56 µm (with no other zero between 1.53 µm and 1.56 µm). Assuming the mode effective index to be 1.5 (at both wavelengths), calculate the difference in arm lengths of the MZI.
6. (a) Consider an EDFA being pumped at 0.98 µm is used as a power amplifier. For a 0 dBm input power at 1.55 µm, EDFA produces an output of 20 dBm. Calculate the input pump power to achieve 20 dBm output. (b) The Raman gain coefficient for a 10 µm core diameter silica based fiber at a pump wavelength of 1200 nm is 6.3×10^{-14} mW^{-1}. Determine the Raman gain obtained in a 25 km length of the fiber when it is pumped at this wavelength with an input power of 1.4 W and when transmission loss is 0.8 dB/km. It may be assumed that the effective core radius is 1.15 times as large as the actual core radius.
7. Consider a 32-channel FDM system with an over-all modulation index of 0.40. Let RIN = -135 dB/Hz, and assume the p-i-n photodiode receiver has a Responsivity of 0.6 A/W, Δf = 5 GHz, I_D = 10 nA, $R_{eq} = 50\ \Omega$, and F_t = 3 dB. (a) Find the carrier-to-noise ratio for this link if the received optical power is -13 dBm. (b) Find the carrier-to-noise ratio if the modulation index is decreased to 0.25 and the received optical power is increased to -10 dBm.

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