Department of Electronics and Communication

Subject: OPTICAL FIBER COMMUNICATION (TEC 701)
Branch: 4TH YEAR

ASSIGNMENT 2

Theory Questions (PART A)

1. Explain intermodal dispersion.
2. What are dispersion-flattened fibers?
3. What is the cause of material dispersion and waveguide Dispersion?
4. What are fiber bending losses?
5. What do you mean by attenuation of an optical fiber? What are its units? What are different causes of attenuation in an optical fiber?

Numerical Problems (PART B)

1. A 15 km optical fiber link uses fiber with a loss of 1.5 dB km⁻¹. The fiber is jointed every kilometer with connectors which given an attenuation of 0.8 dB each. Determine the minimum mean optical power which must be launched into the fiber in order to maintain a mean optical power level of 3 µW at the detector.
2. (a) A multimode step index fiber gives a total pulse broadening of 95 ns over a 5 km length. Estimate the bandwidth-length product for the fiber when a non return to zero digital code is used.
   (b) A single mode step index fiber has a bandwidth-length product of 10 GHz km. Estimate the rms pulse broadening over a 40 km digital optical link without repeaters consisting of the fiber and using a return to zero code.
3. The material dispersion parameter for a glass fiber is 20 ps nm⁻¹ km⁻¹ at a wavelength of 1.5µm. Estimate the pulse broadening due to material dispersion within the fiber when light is launched from an injection laser source with a peak wavelength of 1.5 µm and an rms spectral width of 2 nm into a 30 km length of the fiber.
4. A multimode step index fiber has a numerical aperture of 0.2 and a core refractive index of 1.47. Estimate the bandwidth-length product for the fiber assuming only intermodal dispersion and a return to zero code when:
   (a) there is no mode coupling between the guided modes;
   (b) mode coupling between the guided modes give a characteristic length equivalent to 0.6 of the actual fiber length.
5. A multimode, optimum near parabolic profile graded index fiber has a material dispersion parameter of 30 ps nm⁻¹ km⁻¹ when used with a good LED source of rms spectral width 25 nm. The fiber has numerical aperture
of 0.4 and a core axis refractive index of 1.48. Estimate the total rms pulse broadening per kilometer within the fiber assuming waveguide dispersion to be negligible. Hence estimate the bandwidth-length product for the fiber.

6. The difference in the effective refractive indices \((n_x - n_y)\) for the two orthogonally polarized modes in conventional single mode fibers are in the range \(9.3 \times 10^{-2} < n_x - n_y < 1.1 \times 10^{-5}\). Determine the corresponding range for the beat lengths of the fibers when they are operating at a transmission wavelength of 1.3\(\mu\)m. Hence obtain the range of the modal birefringent for the fibers. The maximum bit rate that can be achieved over a 6 km length of highly birefringent single mode fiber is 400 kbits\(^{-1}\). Assuming polarization mode dispersion to be the dominant dispersive mechanism, calculate its value within the fiber.

7. The photo elastic coefficient and the refractive index for silica are 0.286 and 1.46 respectively. Silica has an isothermal compressibility of \(7 \times 10^{-11} \text{ m N}^{-1}\) and an estimated fictive temperature of 1400 K. Determine the theoretical attenuation in decibels per kilometer due to the fundamental Rayleigh scattering in silica at optical wavelengths of 0.85 and 1.55 \(\mu\)m. Boltzmann's constant is \(1.381 \times 10^{-23} \text{ J K}^{-1}\).

8. The threshold optical powers for stimulated Brillouin and Raman scattering in a long 8 \(\mu\)m core diameter single mode fiber are found to be 190 mW and 1.70 W, respectively, when using an injection laser source with a bandwidth of 1 GHz. Calculate the operating wavelength of the laser and the attenuation in decibel per kilometer of the fiber at this wavelength.
OPTICAL FIBER COMMUNICATION
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ASSIGNMENT 3
Theory Questions(PART 1)
1. What do you mean by internal quantum efficiency and external quantum efficiency of a Semiconductor injection diode?
2. What do you mean by population inversion?
4. Explain the terms:
   a) Spontaneous emission   c) Heterojunction
   b) Stimulated emission     d) Absorption
5. Explain the working of semiconductor injection laser. What are its advantages and disadvantages?
6. Briefly describe the characteristics of Semiconductor injection Laser.
7. How single mode operation is achieved in of Semiconductor injection Laser.
8. Write short notes on:
   a) Gain guided lasers
   b) Index guided lasers
   c) Quantum well lasers
9. Briefly outline the general requirements for a source in optical fiber communications.

Numerical Problems(PART 2)
1. The longitudinal modes of a gallium arsenide injection laser emitting at a wavelength of 0.87 μm are separated in frequency by 278 GHz. Determine the length of the optical cavity and the number of longitudinal modes emitted. The refractive index of gallium arsenide is 3.6.

2. When GaSb is used in the fabrication of an electroluminescent source, estimate the necessary hole concentration in the $p$ type region in order that the radiative minority carrier lifetime is 1 ns.

3. A DH injection laser has an optical cavity of length 50 μm and width 15 μm. At normal operating temperature the loss coefficient is 10 cm$^{-1}$ and the current threshold is 50 mA. When the mirror reflectivity at each end of the optical cavity is 0.3, estimate the gain factor $β$ for the device. It may be assumed that the current is confined to the optical cavity.

4. A gallium arsenide injection laser with a cavity of length 500 μm has a loss coefficient of 20 cm$^{-1}$. The measured differential external quantum efficiency of the device is 45%. Calculate the internal quantum efficiency of the laser. The refractive index of gallium arsenide is 3.6.
ASSIGNMENT 4
Theory Questions(PART 1)

1. Define LED internal quantum efficiency and external quantum efficiency.

2. Outline the common LED structures for optical fiber communication discussing their relative merits and drawbacks.

3. Give drawback and advantages of LED and LASERS.

4. Write short notes on:
   a) SLED
   b) ELED
   c) SLD

5. Briefly describe all the characteristics of LED’s.

6. What is meant by the direct modulation of an optical source? Give reasons for the current use of direct intensity modulation of semiconductor optical sources and comment on possible alternatives.

Numerical Problems(PART 2)
1. The external power efficiency of an InGaAsP/InP planar LED is 0.75% when the internally generated optical power is 30 mW. Determine the transmission factor for the InP-air interface if the drive current is 37 mA and the potential difference across the device is 1.6 V. The refractive index of InP may be taken as 3.46.

2. A GaAs planar LED emitting at a wavelength of 0.85 μm has an internal quantum efficiency of 60% when passing a forward current of 20 mA s⁻¹. Estimate the optical power emitted by the device into air, and hence determine the external power efficiency if the potential difference across the device is 1 V. It may be assumed that the transmission factor at the GaAs-air interface is 0.68 and that the refractive index of GaAs is 3.6. Comment on any approximations made.
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ASSIGNMENT 6
Theory Questions (PART A)

1. Briefly discuss the possible sources of noise in optical fiber receivers. Describe in detail what is meant by quantum noise. Consider this phenomenon with regard to:
   (a) Digital signalling;
   (b) Analog transmission.
   giving any relevant mathematical formulae.
2. Explain receiver structures.

Numerical Problems (PART B)
1. A silicon photodiode has a responsivity of 0.5 A W$^{-1}$ at a wavelength of 0.85$\mu$m. Determine the minimum incident optical power required, at the photodiode at this wavelength in order to maintain a bit error rate of $10^{-7}$, when utilizing ideal binary signalling at a rate of 35 Mbits s$^{-1}$.
2. An analog optical fiber communication system requires an SNR of 40 dB at the detector with a post detection bandwidth of 30 MHz. Calculate the minimum optical power required at the detector if it is operating at a wavelength of 0.9 $\mu$m with a quantum efficiency of 70%. State any assumptions made.
3. A germanium photodiode incorporated into an optical fiber receiver working at a wavelength of 1.55 $\mu$m has a dark current of 500 nA at the operating temperature. When the incident optical power at this wavelength is 10$^{-7}$ W and the responsivity of the device is 0.6 A W$^{-1}$, shot noise dominates in the receiver. Determine the SNR in dB at the receiver when the post detection bandwidth is 100 MHz.
ASSIGNMENT 1

Theory Questions (PART A)
1. Draw and explain block diagram of optical communication system.
2. What are the advantages of optical fiber communication?
3. What is the structure of an optical fiber?
4. Explain the following terms:
   a. Critical angle
   b. Numerical aperture
   c. Step index fiber
   d. Graded index fiber
   e. Multimode fiber
   f. Acceptance angle
5. What do you mean by normalized frequency $V$ of the fiber? On the basis of this, differentiate between single and multimode fibers.
6. Explain what is meant by graded index optical fiber giving an expression for the possible refractive index profile. Indicate major advantage of this type of fiber with regard to multimode propagation.

Numerical Problems (PART B)
1. A step index fiber has a solid acceptance angle in air of 0.115 radians and a relative refractive index difference of 0.9%. Estimate the speed of light in the fiber core.

2. The velocity of light in the core of a step index fiber is $2.01 \times 10^8$ m S$^{-1}$, and the critical angle at the core-cladding interface is $80^\circ$. Determine the numerical aperture and the acceptance angle for the fiber in air, assuming it has a core diameter suitable for consideration by ray analysis. The velocity of light in a vacuum is $2.998 \times 10^2$ m S$^{-1}$.

3. A single mode step index fiber has a core diameter of 4 µm and a core refractive index of 1.49. Estimate the shortest wavelength of
light which allows single mode operation when the relative refractive index difference of the fiber is 2%.

4. A graded index fiber with a core axis refractive index of 1.5 has a characteristic index profile of 1.90, a relative refractive index difference of 1.3% and a core diameter of 40 µm. Estimate the number of guided modes propagating in the fiber when the transmitted light has a wavelength of 1.55 µm and determine the cutoff value of the normalized frequency for single mode transmission in the fiber.

5. What are skew rays? Skew rays are accepted into a large core diameter (compared to the wavelength of the transmitted light) step index fiber in air at a maximum axial angle of 42°. Within the fiber they change direction by 90° at each reflection. Determine the acceptance angle for meridional rays for the fiber in air.

6. An optical fiber has numerical aperture of 0.20 and a cladding refractive index of 1.59. Determine:
   1. the acceptance angle for the fiber in water which has a refractive index of 1.33;
   2. the critical angle at the core-cladding interface.

7. A step index fiber in air has a numerical aperture of 0.16, a core refractive index of 1.45 and a core diameter of 60µm. Determine the normalized frequency for the fiber when light a wavelength of 0.9 µm is transmitted. Further, estimate the number of guided modes propagating in the fiber.

8. A single mode step index fiber which is designed for operation at a wavelength of 1.3µm has core and cladding refractive indices of 1.447 and 1.442 respectively. If the core diameter is 7.2µm, check that the fiber will permit single mode transmission.
ASSIGNMENT 6
Theory Questions (PART A)

1. Discuss and draw optical transmitter Circuit. Explain how the signal modulated and launched in the optical fiber.
2. Draw and explain block diagram and detection principle of coherent optical fiber system.
3. Discuss and draw optical Receiver Circuit. Briefly describe equalizer.
4. What are various modulation techniques used in optical communication System?
5. Write short notes:
   a) Power budgeting
   b) Sub carrier intensity Modulation
   c) Sub carrier phase Modulation
   d) LED drive circuits
   e) LASER drive circuits
   f) Regenerative receiver
6. What is meant by intensity modulation of an optical source?
7. Write note on Line coding.
8. What is the use of preamplifier in optical receiver system?

Numerical Problems (PART B)

1. An optical fiber system uses fiber cable which exhibits a losses dB/km-1. Average splice losses for the system are 1.5 dB km-1, and connector losses at the source and detector are 4 dB each. After safety margin been allowed. the total permitted channel loss is 37 dB. Assuming the link be attenuation limited, determine the maximum possible transmission distance without a repeater.
2. A digital single mode optical fiber is stem is designed for operation at a wavelength of 1.5 μm and a transmission rate of 560 Mbits/s over a distance of 50 km without repeaters. The single mode injection laser is capable of launching optical power of -3 dBm into the fiber cable and exhibits a loss of 0.35 dB km-1. In addition splice losses are 0.1 dB km-1. connector loss: the receiver is 0.5 dB and the receiver sensitivity is -1 dBm. Finally) an extinction ratio penalty of 1 dB is predicted for the system. Perform an ortleal power budget for the system and determine the margin.