BIRLA INSTITUE OF TECHNOLOGY AND SCIENCE, PILANI
FIRST SEMESTER 2016-2017
EEE F426 FIBER OPTICS AND OPTOELECTRONICS

MID-SEMESTER TEST {Open-Book} **October 7, 2016**

Note: TEST Duration is 90 minutes. Each question carry 10 {~ 5 + 5} marks. Use blue/black ink only.

1. (a) (i) What are energies in eV of light at wavelengths 810, 1300, and 1565 nm? (ii) Consider a 1 ps pulse with 100 pW amplitude at each of these wavelengths. How many photons are in such a pulse at each wavelength?

(b) Light traveling in air strikes a glass plate at an angle, θ_1 = 36°, where θ_1 is measured between the glass surface and the incoming ray. Upon striking the glass, beam is refracted and part of it is reflected. If the refracted and reflected beams make an angle of 90° with each other, what is the refractive index of glass? What is the critical angle for this glass?

2. (a) (i) Consider a multimode step index optical fiber that has a core diameter of 50 μm, a core index of 1.46, and a relative refractive index difference of 1.5 %. Calculate V-number and total number of modes at 1310 nm. (ii) Repeat (i) for graded index fiber with parabolic index profile with a 25 μm core radius.

(b) Consider a step index fiber that has a 8 μm core radius, a relative refractive index difference of 0.2%, and a core index of 1.49. Is the fiber single mode at 1310 nm, and 810 nm? Find LP modes that exist at both wavelengths.

3. (a) The optical power loss resulting from Rayleigh scattering in a fiber can be calculated from equation as follows,

$$\alpha_{scat} = (4.343)\frac{8\pi^3}{3\lambda^4} n^8 p^2 k_B T_f \beta_T \text{ dB/km},$$

where, n = 1.46 is refractive index, k_B is Boltzmann's constant, $\beta_T = 6.8 \times 10^{-12}$ cm^2/dyn, is the isothermal compressibility of the material and the fictive temperature, T_f = 1400 K, is the temperature at which density fluctuations are frozen into glass as it solidifies, p = 0.286, is the photo-elastic coefficient. Is 1550 nm, the wavelength with lowest attenuation compared to 850 nm and 1310 nm? Show calculations to justify your answer.

(b) Consider GI fibers with parabolic refractive index profiles, with n_2 = 1.48, and relative refractive index difference of 1%. Calculate *Meff*, effective number of modes that are guided by a curved multimode fiber of radius, a at 1550 nm for R = 2.5 cm when a = 62.5 μm. *Meff* is expressed as follows,

$$M_{eff} = M_{\infty}\left\{1 - \frac{\alpha+2}{2\alpha\Delta}\left[\frac{2a}{R} + \left(\frac{3}{2n_2 kR}\right)^{2/3}\right]\right\}$$

where, α defines graded index profile, Δ is core cladding relative refractive index difference, n_2 is cladding index, $k = 2\pi/\lambda$ is wave propagation constant, and M_∞ is total number of modes in a straight fiber. Compare when a = 30 μm.

4. (a) Assume a step-index fiber that has a V-number of 5.0. (i) Estimate fractional power traveling in cladding in lowest order modes. (ii) Estimate attenuations for all lower modes, if 0.42 and 0.48 dB/km is core and cladding attenuation respectively.

(b) A 8 km transmission link consists of a step-index multimode fiber that has a core index n_1 = 1.475 and a core-cladding refractive index difference of 1.5 %. (i) Find the delay difference between faster and slowest mode. (ii) Find the rms pulse broadening resulting from intermodal delay and maximum bit rate-distance product.

5. (a) A LED is operating at 810 nm has a spectral width of 36 nm. What is the pulse broadening in ns/km due to material dispersion? What is the pulse broadening if a laser with spectral width of 3.6 nm is used?

(b) Calculate the waveguide dispersion (in ps/nm.km) at 1290 nm for a single mode fiber with core and cladding diameters of 8 μm and 127 μm, respectively. The core index is 1.474 and relative refractive index difference is 0.24 %.

6. (a) A double hetero-junction InGaAsP LED emitting at a peak wavelength of 1300 nm has radiative and non-radiative recombination times of 22 and 88 ns, respectively. The drive current is 36 mA. (i) Find the internal quantum efficiency and internal power level. (ii) if the refractive index of light source material is 3.48, find the power emitted by the device.

(b) Find the external quantum efficiency for a $Ga_{1-x}Al_xAs$ laser diode (with x = 0.03) with band gap energy of 1.798 eV that has an optical-power-versus-drive-current relationship of 0.454 mW/mA.