BIRLA INSTITUE OF TECHNOLOGY AND SCIENCE, PILANI
FIRST SEMESTER 2023-2024
EEE F426 FIBER OPTICS AND OPTOELECTRONICS
COMPREHENSIVE EXAMINATION (OB) December 20, 2023

DURATION: 180 min **Max. Marks: 80**

Note: *All questions equal marks. State valid assumptions and consider typical values wherever necessary.*

[1] The separation of spectral lines $\Delta\lambda$ is 1 μm for a GaAs (n = 3.65) laser. Find the laser cavity length and estimate the number of longitudinal modes emitted by the laser at 850 nm. Also, determine the threshold gain coefficient when effective loss coefficient is 1.5/mm at a confinement factor of 0.8.

[2] Calculate half-wave voltage for a $LiNbO_3$ longitudinal electro-optic modulator assuming that $r_{33} = 30.8 \times 10^{-12}$ m/V is the relevant electro-optic coefficient at 850 nm. Estimate the range of transmittance (in dB) that can be achieved at this half wave voltage if applied for intensity modulation when V_0 = 10V and f_m = 2.5 GHz.

[3] Estimate the source to fiber coupling efficiency and the optical loss (in dB) for a laser diode forward biased with a current of 300 mA and a voltage of 3 V. Assume the fiber has a numerical aperture of 0.244 while the laser has an internal quantum efficiency of 0.8. Use the wavelength assumed and threshold gain coefficient calculated in problem [1].

[4] Two step-index single mode fibers with 8 μm diameter and a core index of 1.488 are spliced without any extrinsic misalignments but due to distinct relative refractive index differences, Δ_1=0.0019; Δ_2=0.0021, both fibers suffer from connection losses due to intrinsic parameters i.e. NA and MFD (w_P). Estimate the total loss (in dB) at the splice. Assume λ = 1050nm.

[5] Estimate the critical radius of curvature of the step-index single mode fibers mentioned in problem [4]. Estimate the bending loss (in dB) when the loss can generally be represented by a radiation attenuation coefficient, $\alpha_R = c_1 \exp(-c_2 R_{cs})$ where R_{cs} is the radius of curvature of the fiber bend and c_1, c_2 are constants which are independent of R_{cs}. Assume c_1, c_2 are unity.

[6] Confirm if both step-index single mode fibers mentioned in problem [4], behaves as multimode fibers when their relative refractive index differences are scaled up by a factor of 10. Determine the overall dispersion in the multimode fiber with largest number of modes propagating through it. Assume typical values needed for your calculation but at 1050 nm.

[7] Is it possible to compensate the losses calculated in problem [4] and [5] considering magnitude of losses (in dB) together, using a Raman amplifier? If yes, then determine the input pump power required for such amplification considering physical length of fiber amplifier do not exceed 5 km. Assume typical values needed for your calculation but at 1050 nm.

[8] An InGaAs avalanche photodiode (M~50, x~0.4) is operating at room temperature (300 K) at a wavelength of 1050 nm. Its quantum efficiency is 40% and the incident optical power is 300 nW. Assume that the primary dark current of the device is 2 nA, and the load resistor is 1000 ohms. Estimate the effective bandwidth required to achieve S/N ≥ 30 dB at the input end of an amplifier of the receiver.

[9] Use the effective bandwidth estimated in problem [8] to calculate required CNR in the same case. Consider modulation index of 0.5, noise factor of 2 and RIN of -144 dBm/Hz to support your calculations.

[10] (a) Calculate the line width of source when SBS threshold power for the best possible case is 15 mW. Consider Brillioun gain of 6×10^{-11} m/W, effective area of 55×10^{-12} m^2, and effective length of 20 km at a pump wavelength of 1550 nm. (b) A light of wavelength 1550 nm is propagating through a FBG based sensor with Λ = 500 nm. Due to change in pressure, the effective index of FBG changes at the rate of 10^{-6} KPa^{-1}. The effective index of the core is n = 1.488 and the change in the periodicity of gratings with change in pressure 10^{-9} KPa^{-1}. Find the corresponding shift in Bragg's wavelength for a pressure change of 25 KPa.