Çankaya University – ECE Department – ECE 572

Student Name :
Student Number :

Duration : 2 hours
Open book exam

Questions

1. (50 Points) Bearing in mind that in multimode graded index and step index fibres, the radial component of the wave vector is given by $k_r^2 = n^2(r)k_0^2 - \beta^2 - \frac{\ell^2}{r^2}$, where $n(r)$ is the refractive index profile in core or the cladding depending on the radial coordinate r, $k_0 = 2\pi/\lambda_0$, with λ_0 is the radiation wavelength of the source, β is the propagation constant, ℓ is the integer angular mode number.
By setting $k_r = 0$, we find two roots of r, called r_ℓ and R_ℓ. A wave propagates along the fibre axis within a radial area of r_ℓ to R_ℓ. For a wave to be guided, k_r must be positive between r_ℓ and R_ℓ. Furthermore, k_r must remain negative in the cladding region at least for $r >$ cladding radius.
The propagation constant, β is determined from the consistency condition that $2\int_{r_\ell}^{R_\ell} k_r dr = 2\pi m$, where m is an integer corresponding to mth root of the wave equation solution. Solving this integral yields β as $\beta = \frac{\left[ak_0^2 n_1^2 - 4k_0 n_1\sqrt{2\Delta}\left(m + \ell/2\right)\right]^{1/2}}{a^{1/2}}$, where a is the core radius.
By using the supplied Matlab code, calculate for a fibre of $n_1 = 1.49$, $n_2 = 1.47$ and $a = 25$ μm operating at $\lambda_0 = 1.31$ μm, which β parameters exist for guided modes, if this fibre has $q = 2$ (i.e. graded index fibre with quadratic grading profile in the core), and $q \to \infty$ (i.e. step index fibre). State in which fibre you find more β parameters, also examine the effect of wavelength changes by switching to $\lambda_0 = 1.55$ μm and $\lambda_0 = 0.85$ μm. Plot typical k_r curves on your exam paper.

Solution : By running the Matlab code at

$q = 2$, $\lambda = 1.31$ μm (see enclosed sheet)

A total of 51 modes is found, comparison to step index is not available from this code since β has to modified.

2. (25 Points) A laser has an emission wavelength of λ_0 = 1.06 μm with a spectral width of σ = 20 nm, (i.e. the width between the exp(-1) points from a peak of unity) and a peak gain of g(0) = 30 cm^{-1}. Using the Gaussian spectral form, plot $g(\lambda)$ against λ. If the laser cavity is 200 μm long, and refractive index, *n* is 3.2, calculate how many modes will be excited in this laser.

Solution: Using $g(\lambda) = g(0) \exp\left[-\frac{(\lambda-\lambda_0)^2}{2\sigma^2}\right]$

where $\lambda_0 = 1.06\ \mu m$, $\sigma = 20 nm$, $g(0) = 30\ cm^{-1}$

Plot is attached. (from ECE 474 FE 26.05.2008 - Q2)

According to formula for m (number of modes)

$m = \frac{L}{\lambda/2n}$ where L = cavity length

λ = central wavelength of operation

n = refractive index of lasing medium

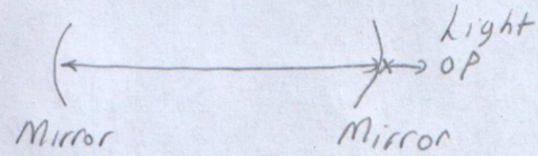
$m = \frac{200 \times 10^{-6}}{1.06 \times 10^{-6} / (2 \times 3.2)} \simeq 1207$ modes are

excited.

3. (25 Points) Answer the following questions as **True** or **False**. For the **False** ones give the correct answer or the reason. For the **True** ones justify your answer.

a) In a the physical construction of a laser resonator, there are two reflective mirrors : True

Since the physical construction of the laser is as follows



b) Dispersion in a single mode fibre is less than other fibres : True, since only HE_{11} propagates in fibre so intermodal dispersion is absent, only material and waveguide dispersions are present

c) Dispersion in a fibre increases with distance and wavelength: Dispersion increases with distance but measured against wavelength, for instance (according to Fig 2.10 of Agrawal) D_M increases with wavelength, whereas D_W is reduced with wavelength.

d) APD has a multiplication factor, M, larger than unity : True, M of APD is larger than unity

e) Responsivity of a PIN diode is the ratio of incident power to diode current : False

Responsivity is the reverse of that given above

i.e. $R = \frac{I_P}{P_0}$