Seat No. ______

King Monkut's University of Technology Thonburi

Midterm Examination 2/2014

EIE 423 Optical Communications — EIE Juniors/Seniors

Wednesday 25 February 2015 — 9:00p.m. – 12:00 p.m.

Instructions:

1. There are 5 problems and 6 pages (formula sheets included).
2. Please calculate your results to 4 significant figures. Each problem is worth 20 pts.
3. No textbooks or class notes are allowed into the examination room.
4. Students are allowed to bring a calculator to the examination.
5. Do all your work on the given working book.

Students have to raise his or her hand when they finish working on their examinations.
Otherwise, they will not be allowed to come out of the examination room.
Bringing exam papers with students outside the exam room are not allowed.

Academic dishonesty during the exam may result in expulsion or permanent dismissal from the university.

Name..

Student ID..**Seat No.**..

This exam is given by Apichai Bhatranand.

0-2470-9063

This examination has been approved by ENE department committees.

(Assoc. Prof. Rardchawadee Silapunt)

Head of Electronics and Telecommunication Engineering Department

Name...Seat No..................

1. (a) What level of ATM would be adequate for a digital radio broadcast if 8 bits/sample is used and a bandwidth per channel is 2MHz.

   (b) A receiver of sensitivity 1 μW. If 20 mW is transmitted at 100 MHz, what would be the maximum length of the link when an optical fiber with attenuation of 0.5 dB/km is used?

   (c) Light is incident on a dielectric interface between media of refractive indices 1.48 and 1.46 at an angle of θi relative to the normal. The incident wave propagates in the medium of higher refractive index. For what angles of incidence is the reflected power the same for both s- and p- polarizations? What is the reflectance for those angles of incidence?

2. For TE mode in symmetric slab waveguide of $n_1 = 1.50$ and $n_2 = 1.45$. A slab is 5 micron thick.
   a) What is the critical angle for the slab waveguide.
   b) How many angles of incidence are allowed if 1.3 micron light is launched in this waveguide?
   c) What happens to the number of angles as the wavelength is decreased?

3. (a) Find the core radius necessary for single-mode operation at 1,320 nm of a step-index fiber with $n_1 = 1.48$ and $n_2 = 1.47$.

   (b) What are the numerical aperture and maximum acceptance angle in degrees of this fiber?

   (c) If the optical fiber in (a) is used with 1550 nm light, could it be considered as a single-mode fiber? If not, how many modes does this fiber support?

   (d) Repeat (c) if the wavelength is 280 nm.

Name...Seat No..................

4. (a) The equilibrium length of a multimode SI fiber ($n_1 = 1.49$ $n_2 = 1.48$) is 1.5 km. The light source operating at 800 nm has a spectral width of 45 nm. Compute the maximum RZ data rate of a system with 5-km long silica optical fiber.

   (b) If the single-mode GRIN fiber is used, what would the maximum rate be?

5. An LED emits 2.33 mW with the drive current of 3.5 mA. The quantum efficiency is 0.7. What is the central wavelength of this LED? Compute the spectral width of this LED.

Name..Seat No..................

Constants

c = speed of light in free space = 3 x 10^8 m/s

e = q = 1.6 x 10^{-19} C

h = Planck's constant = 6.63 x 10^{-34} J.s

k = Boltzmann's constant = 1.38 x 10^{-23} J/K

Useful Formulas (1/2)

$R = m.f_s$ $\qquad n_1 \sin\theta_1 = n_2 \sin\theta_2$ $\qquad \lambda f = c$ $\qquad v = \frac{c}{n}$

$$\Delta\left(\frac{\tau}{l}\right) = -\left(\frac{\lambda}{c}\frac{d^2 n}{d\lambda^2}\right).\Delta\lambda = -M.\Delta\lambda \qquad M = \frac{\lambda}{c}\frac{d^2 n}{d\lambda^2}$$

$$M = \frac{-0.095}{4}\left(\lambda - \frac{\lambda_0^4}{\lambda^3}\right) \qquad \frac{\Delta f}{f} = \frac{\Delta v}{v} = \frac{\Delta\lambda}{\lambda}$$

$$(f_{3-dB})_{opt} \le \frac{1}{2\Delta\tau} \qquad (f_{3-dB})_{elec} \le \frac{0.35}{\Delta\tau}$$

$$R_{RZ} \times l = \frac{0.35}{\Delta(\tau / l)} \qquad R_{NRZ} \times l = \frac{0.7}{\Delta(\tau / l)}$$

$$L_f(dB) = -10\log_{10}\left[e^{-0.693\left(\frac{f}{f_{3-dB}}\right)^2}\right]$$

$$\rho = \frac{n_1 - n_2}{n_1 + n_2} \qquad R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2 \qquad E = hf$$

$$\rho_p = \frac{-n_2^2\cos\theta_i + n_1\sqrt{(n_2^2 - n_1^2\sin^2\theta_i)}}{n_2^2\cos\theta_i + n_1\sqrt{(n_2^2 - n_1^2\sin^2\theta_i)}} \qquad R = \rho^2$$

$$\rho_s = \frac{n_1\cos\theta_i - \sqrt{(n_2^2 - n_1^2\sin^2\theta_i)}}{n_1\cos\theta_i + \sqrt{(n_2^2 - n_1^2\sin^2\theta_i)}} \qquad T = 1 - R$$

$$\theta_B = \tan^{-1}\left(\frac{n_2}{n_1}\right) \qquad \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) \qquad \alpha = k_0\sqrt{n_1^2\sin^2\theta_i - n_2^2}$$

$$k = k_0 n_1 = \frac{2\pi}{\lambda_0}n_1 \qquad \beta = \frac{\omega}{v_g} \qquad n_{eff} = \frac{c}{v_g} = n_1\sin\theta$$

Name...Seat No..................

Useful Formulas (2/2)

$$E(y,z,t)=\begin{cases} E_2 e^{-\alpha\left(y-\frac{d}{2}\right)}\sin(\omega t-\beta z) & for\ y>d/2 \\ E_2 e^{\alpha\left(y+\frac{d}{2}\right)}\sin(\omega t-\beta z) & for\ y<-d/2 \end{cases}$$

$$\tan\left(\frac{hd}{2}\right)=\frac{\sqrt{n_1^2\sin\theta-n_2^2}}{n_1\cos\theta} \qquad \ldots for\ even\ solutions$$

$$\tan\left(\frac{d\pi n_1\cos\theta}{\lambda}\right)=\frac{\sqrt{n_1^2\sin^2\theta-n_2^2}}{n_1\cos\theta} \qquad \left(\frac{d}{\lambda}\right)_m=\left(\frac{d}{\lambda}\right)_0+\frac{m}{2n_1\cos\theta}$$

$$\left(\frac{d}{\lambda}\right)_{m,c}=\frac{m}{2\sqrt{n_1^2-n_2^2}} \qquad n_0\sin(\alpha_0)_{\max}=NA=\sqrt{n_1^2-n_2^2} \qquad \Delta=\frac{n_1-n_2}{n_1}$$

$$M_g=\frac{\lambda}{c}\frac{d^2n_{eff}}{d\lambda^2} \qquad \Delta\left(\frac{\tau}{l}\right)=\frac{n_1(n_1-n_2)}{cn_2} \qquad n(r)=\begin{cases} n_1\sqrt{1-2\left(\frac{r}{a}\right)^{\alpha}\Delta} & ;r\le a \\ n_1\sqrt{1-2\Delta} & ;r>a \end{cases}$$

$$NA(r)=\begin{cases} n_1\sqrt{2\Delta(1-(r/a)^{\alpha}} & ;for\ r\le a \\ 0 & ;for\ r>a \end{cases} \qquad V=\frac{2\pi a}{\lambda}\sqrt{n_1^2-n_2^2} \qquad N=\frac{V^2}{2}$$

$$\frac{a}{\lambda}\le\frac{2.405}{2\pi\sqrt{n_1^2-n_2^2}} \qquad n_{eff}=\frac{\beta_{pq}}{k_0}=n_1-(p+q+1)\frac{\sqrt{2\Delta}}{k_0 a} \qquad \frac{a}{\lambda}<\frac{1.2}{\pi\sqrt{n_1(n_1-n_2)}}$$

$$\Delta\tau=\sqrt{(\Delta\tau_m+\Delta\tau_g)^2+(\Delta\tau_{mm})^2} \qquad \Delta\tau_m=-M_m.\Delta\lambda.l$$

$$\Delta\tau_g=-M_g.\Delta\lambda.l \qquad P_0=\eta IE(eV)$$

$$\Delta\left(\frac{\tau}{l}\right)_{mm}=\frac{n_1\Delta^2}{2c} \qquad \Delta\left(\frac{\tau}{l}\right)_{mm}=\frac{n_1(n_1-n_2)}{cn_2}$$

$$(f_{3-dB})_{opt}=\frac{0.5}{\Delta\tau} \qquad (f_{3-dB})_{elec}=\frac{0.35}{\Delta\tau}=R_{RZ}$$

$$m_j=\frac{I_{sp}}{I_{dc}} \qquad m_p=\frac{P_{sp}}{P_{dc}}$$

$$\Delta\tau=\begin{cases} l.\Delta\left(\frac{\tau}{l}\right) & ;l\le l_e \\ \sqrt{l.l_e}.\Delta\left(\frac{\tau}{l}\right) & ;l\ge l_e \end{cases} \qquad i(t)=I_{dc}+I_{sp}\sin\omega_m t \qquad P_0(t)=P_{dc}+P_{sp}\sin\omega_m t$$

$$\Delta f=\Delta\nu=\frac{c}{2nL}$$

$$\Delta\lambda=\frac{\lambda_0^2}{c}\Delta\nu$$

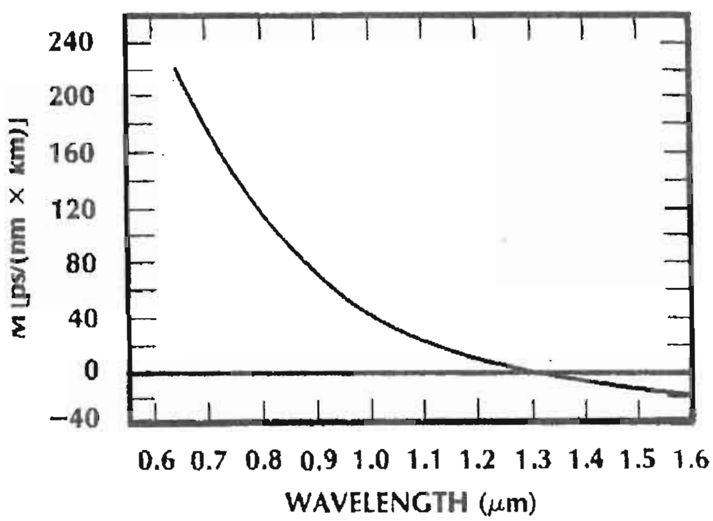
$$P_{sp}=\frac{a_1 I_{sp}}{\sqrt{1+\omega_m^2\tau^2}} \qquad (f_{3-dB})_{elec}=\frac{1}{2\pi\tau} \qquad \lambda_0=\frac{1.24}{E_g+kT} \qquad (E_{ph})_{\max}=E_g+kT$$

$$\phi=\tan^{-1}(\omega_m\tau) \qquad (f_{3-dB})_{elec}=\frac{0.35}{t_r} \qquad \frac{\Delta E}{(E_{ph})_{\max}}=\frac{3.3kT}{(E_{ph})_{\max}}=\frac{\Delta\lambda}{\lambda_0}$$

Name..Seat No..................

Digital transmission rates

Number of Voice channels	*Transmission Designation*	*Signaling Designation*	*Data Rate*
1	-	-	64 kb/s
24	T1	DS-1	1.544 Mb/s
48(2-T1 systems)	T1C	DS-1C	3.152 Mb/s
96(4-T1 systems)	T2	DS-2	6.312 Mb/s
672(7-T2 systems)	T3	DS-3	44.736 Mb/s
1344(2-T3 systems)	T3C	DS-3C	91.053 Mb/s
4032 (6-T3 systems)	T4	DS-4	274.175 Mb/s



Material dispersion for pure silica