UNIVERSITI TUN HUSSEIN ONN MALAYSIA

PEPERIKSAAN AKHIR
SEMESTER II
SESSION 2008/2009

SUBJECT NAME	:	OPTICAL COMMUNICATION SYSTEM
SUBJECT CODE	:	BEP 4253
COURSE	:	4BEE
EXAMINATION DATE	:	APRIL 2009
DURATION	:	3 HOURS
INSTRUCTION	:	JAWAB LIMA (5) SOALAN SAHAJA DARIPADA TUJUH (7) SOALAN

KERTAS SOALAN INI MENGANDUNGI SEMBILAN (9) MUKA SURAT

Q1 (a) Describe with the aid of simple ray diagram how an optical signal propagate inside :

(i) the multimode step index fiber

(ii) the single-mode step index fiber

Compare the advantages and disadvantages of these two types of fiber for the use as an optical channel.

(10 marks)

(b) Consider a piece of step-index optical fiber with a refractive index at the fiber core and cladding of 1.48 and 1.46, respectively.

(i) Calculate the refractive index change, Δ

(ii) What should be the maximum fiber core diameter if this fiber is designed to be single-mode for wavelength starting from 1100nm? Assume V = 2.405.

(iii) Estimate the number of modes if the fiber is used for 850nm laser.

(10 marks)

Q2 (a) Describe the mechanism of intermodal dispersion in a multimode step index fiber. Formulate and derive the total broadening of a light pulse δT_s due to intermodal dispersion in a multimode step index fiber may be given by :

$$\delta T_s \approx \frac{L(NA)^2}{2n_1 c}$$

where L is the fiber length, NA is the numerical aperture of the fiber, n_1 is the core refractive index and c is the velocity of light in a vacuum.

(12 marks)

(b) A multimode step index fiber has a numerical aperture of 0.3 and a core refractive index of 1.45. The material dispersion parameter for the fiber is 250ps nm^{-1} km^{-1} which makes material dispersion the totally dominating chromatic dispersion mechanism. Calculate :

(i) the total rms pulse broadening per kilometer when the fiber is used with an LED source of rms spectral width 50nm, and

(ii) the corresponding bandwidth-length product for the fiber.

(8 marks)

Q3 (a) Briefly describe the processes by which light can be emitted from an atom for an **LED** and **LASER** source. Illustrate the answer with an energy-level diagram.

(11 marks)

(b) A 10km optical fiber transmission link is built using standard single mode fiber at a transmission wavelength of 1550nm. A GaAs planar LED is used as a source. Estimate the external power efficiency of the source when the transmission factor of the GaAs-air interface is 0.68 and the internally generated optical power is 30% of the electrical power supplied. The refractive index of GaAs may be taken as 3.6.

(3 marks)

(c) Considering GaAs LED in Q3 (b), predict :

(i) The coupling efficiency of coupling the emitted light into a step index fiber with an NA of 0.15 when the device is close proximity to the fiber and is smaller than the fiber core.

(ii) The optical loss relative to the optical power generated internally if the device emits into a thin air gap before light is coupled into the fiber.

(6 marks)

Q4 (a) For an analog receiver using p-i-n diode, discuss the effects of the following parameters on the signal-to-noise ratio (SNR) :

(i) modulation index,

(ii) received optical power, and

(iii) receiver bandwidth

(6 marks)

(b) A p-i-n photodiode has a quantum efficiency of 85% at a wavelength of 1.55μm. Calculate :

(i) its responsivity at 1.55μm,

(ii) the received optical power if the mean photocurrent is 10^{-6}A, and

(iii) the corresponding number of received photons at this wavelength

(9 marks)

(c) Consider the p-i-n diode of Q4 (b) as a high impedance front-end receiver with an equivalent resistance R_{eq} = 2030Ω and amplifier noise figure F_t = 5dB. Given that η = 85%. The dark current I_D = 1.5nA, T = 27°C and Bit rate = 50Mb/s. Assume non-return-to-zero (NRZ) encoding is used, therefore the $B = \frac{1}{2 \times Bitperiod}$.

(i) Determine the incident power to the receiver that will give a SNR = 15.6dB

(ii) For the above incident power, what are the effect(s) on bandwidth and SNR of the receiver if R_{eq} is increased by a factor of 2?

(5 marks)

Q5 (a) Assume that the following power values were measured in the component shown in Figure Q5(a). The output power from laser diode (LD) is 2mW. The received power measured at PD1 and PD2 are 1.4mW and 0.4mW, respectively. Assume connector has a 0.15dB loss.

(i) Deduce the splitting ratio, excess loss and insertion loss for port 1 to port 2 and for port 1 to port 3.

(ii) Discuss how to measure the return loss at port 1. You may need an additional component.

(12 marks)

(b) A component known as optical Add-Drop is an important device in Wavelength Division Multiplexing (WDM) system.

(i) Explain the operation of an optical Add-Drop

(ii) Demonstrate and describe with an aid of a schematic diagram how to make a multi-channel, e.g : 2-channel, OADM by using a three port circulator, Fiber Bragg Grating (FBG) and coupler.

(8 marks)

Q6 (a) Discuss the pros and cons of using optical amplifier, compared to Optical – Electronic – Optical (O/E/O) regenerator for long haul transmission.

(5 marks)

(b) With the help of illustration aid compare the major elements of fiber amplifiers for Erbium Doped Fiber Amplifier (EDFA) and Fiber Raman Amplifier (FRA) in terms of their operation of the device, pump power, wavelength and amplifier gain.

(10 marks)

(c) An optical system having a SNR = 10.8dB for a thermal-limited constant power. The bandwidth of the system is 10MHz. The detected signal power at the receiver is 2×10^{-12}W and the thermal-noise power is 1.66×10^{-13}W at 300K. Suppose that the photodetector is followed by an amplifier with a power gain of 10dB and a noise temperature 454K. Deduce the noise figure of the amplifier in dB.

(5 marks)

Q7 (a) An optical fiber system is to be designed to operate over a 6 km length without repeaters. The rise times of the chosen components are as follows: Source (Laser) = 4ns, Fiber intermodal = 5ns/km, Pulse broadening intramodal = 2ns/km, Detector (APD photodiode) = 3ns.

(i) Determine the system rise time.

(ii) Estimate the maximum bit rate that may be achieved on the link when using an NRZ format.

(8 marks)

(b) A GPON system will be developed. One company agreed to provide the OLT and two ONU transceiver modules. Design a two way PON system for FTTH application for a residential building with 32 floors and one flat on each floor. Each floor is about 4 meter high. The center office (CO) is 10km away from the building. Use the assume parameters given in Table Q7(b).

(i) Show your system design graphically (include the components used and fiber length).

(ii) Provide a power budget calculation for downstream and upstream to show that your design has sufficient power to reach the most remote flat and with some power margin left.

(12 marks)

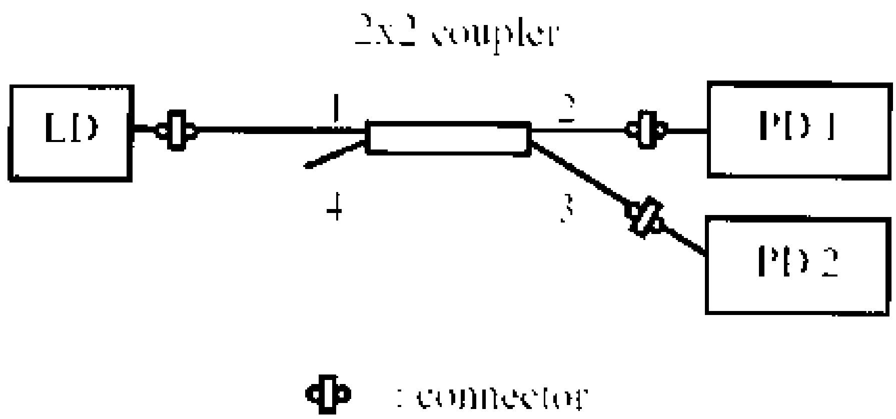

Figure Q5 (a)

Table Q7 (b)

Upstream	
Attenuation coefficient	0.2dB/km
Mean power launched from transmitter	-1dBm
Mean power required at receiver	-28dBm
Downstream	
Attenuation coefficient	0.34dB/km
Mean power launched from transmitter	-1.5dBm
Mean power required at receiver	-27dBm
Components	
Connector loss	0.2dB/ connector
Splitter loss	17.5dB

Constants

Planck's constant, h=6.626 x 10^{-34} J.s

Boltzmann's constant, K=1.381 x 10^{-23} J.K^{-1}

Electron charge, e=1.602 x 10^{-19} Coulomb

Velocity of light in vacuum, c=2.998 x 10^{8} m/s

Formula

$$V = \frac{2\pi}{\lambda} a n_1 (2\Delta)^{\frac{1}{2}}, \tau_g = \frac{1}{c}\left(n_1 - \lambda\frac{dn_1}{d\lambda}\right), \tau_m = \frac{L}{c}\left(n_1 - \lambda\frac{dn_1}{d\lambda}\right), \sigma_m = \frac{\sigma_\lambda L}{c}\left(\lambda\frac{d^2 n_1}{d\lambda^2}\right)$$

$$\tau_s = \frac{(NA)^2}{2cn_1}, \tau_s = \frac{n_1\Delta^2}{8c}, \sigma_s = \frac{Ln_1\Delta}{2\sqrt{3}c}, \sigma_s = \frac{L(NA)^2}{4\sqrt{3}n_1 c}, \sigma_t = (\sigma_m^2 + \sigma_s^2)^{\frac{1}{2}}$$

$$B_t = \frac{0.2}{\sigma} bits/sec, B_t = \frac{1}{2\tau} bits/sec, BW = B_T(RZ), BW = \frac{1}{2}B_t(NRZ),$$

$$\eta_{int} = \frac{1}{1+\tau_r/\tau_{nr}} = \frac{\tau}{\tau_r}, P_{int} = \eta_{int}\frac{I_p}{e}h\upsilon = \eta_{int}\frac{hcI_p}{e\lambda}, \eta_{ep} = \frac{P_e}{P}, where\ P = IV$$

$$P_e = \frac{P_{int}Fn^2}{4n_x^2}, r_e = \frac{I_p}{e}, r_p = \frac{P_o}{hf}, L = \frac{\lambda}{2n}q, \Delta\lambda = \frac{\lambda^2}{2nL}, \Delta f = \frac{c}{2nL}$$

$$i_{th}^2 = \frac{4KTB}{R}(A^2), i_{shot}^2 = 2eB(I_p + I_d)(A^2)$$

$$SNR = \frac{S}{N} = \frac{I_p^2}{i_{shot}^2 + i_{th}^2 + i_{amp}^2}, SNR = \frac{S}{N} = \frac{M^2 I_p^2}{i_{shot}^2 M^{2+x} + i_{th}^2 + i_{amp}^2}$$