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Universiti Tun Hussein Onn Malaysia

# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER I
## SESSION 2019/2020

| | | |
|---|---|---|
| COURSE NAME | : | FIBER OPTICS |
| COURSE CODE | : | BWC 40703 |
| PROGRAMME CODE | : | BWC |
| EXAMINATION DATE | : | DECEMBER 2019 / JANUARY 2020 |
| DURATION | : | 3 HOURS |
| INSTRUCTION | : | ANSWER **ALL** QUESTIONS |

TERBUKA

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

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**Q1** (a) Differentiate the single mode and multimode fiber.

(4 marks)

(b) Discuss the differences between meridional and skew ray paths in step index fibers with the aid of suitable diagrams.

(4 marks)

(c) Sketch the electric field distribution pattern of the fundamental mode LP01, LP11 and LP21.

(6 marks)

(d) A multimode graded index fiber has an acceptance angle in air of 8°. If the refractive index at the core axis is 1.52, calculate the relative refractive index difference between the core axis and the cladding.

(6 marks)

**Q2** (a) List the types of losses in optical fiber.

(4 marks)

(b) Discuss the absorption, the intrinsic absorption and extrinsic absorption mechanisms in optical fibers.

(6 marks)

(c) A 6 km optical link consists of multimode step index fiber with a core refractive index of 1.5 and a relative refractive index difference of 1%. Calculate:

(i) the delay difference between the slowest and fastest modes at the fiber output.
(ii) the rms pulse broadening due to intermodal dispersion on the link.
(iii) the maximum bit rate that may be obtained without substantial errors on the link assuming only intermodal dispersion.
(iv) the bandwidth–length product corresponding to **Q2 (c) (iii)**.

(8 marks)

(d) Make suggestion to reduce material dispersion in optical fiber system.



(2 marks)

**Q3** **Figure Q3** shows the configuration of the dual-wavelength fiber laser in linear cavity configuration which is used for communication system.

(a) List **THREE (3)** optical fiber connections from the system.

(3 marks)

(b) Explain briefly the principle operation for the WDM fiber coupler.

(6 marks)

(c) A four-port multimode fiber FBT coupler has 60 $\mu$W optical power launched into port 1. The measured output powers at ports 2, 3 and 4 are 0.004 $\mu$W, 26.0 $\mu$W and 27.5 $\mu$W, respectively. Determine the insertion losses between the input and output ports and the split ratio for the device.

(6 marks)

(d) Describe the structure of the fiber Bragg grating. Explain how it can effectively block a specific optical signal at a particular wavelength.

(5 marks)

**Q4** **Figure Q4** shows the erbium-doped fiber amplifier (EDFA) which is most commonly used to compensate the loss of an optical fiber in long-distance optical communication.

(a) List **TWO (2)** types of gain media with their optical bands.

(2 marks)

(b) Describe the function of optical spectrum analyzer and laser diode in the **Figure Q4**.

(4 marks)

(c) Explain briefly the working principle of erbium doped fiber amplifier with the aid of a suitable energy band diagram.

(10 marks)

(d) Propose an EDFA design incorporating both with a co- and counter-propagating pump.

(4 marks)

**Q5** A long haul single mode optical fiber system is designed to operate at a wavelength of 1300 nm. Parameters established for the system are as follow:

| | |
|---|---|
| Mean power launched for the laser transmitter | -3 dBm |
| Cabled fiber loss | 0.4 dB $km^{-1}$ |
| Splice loss | 0.1 dB $km^{-1}$ |
| Connector losses at the transmitter and receiver | 1 dB each |
| Mean power required at the APD receiver when operating at 35 Mbit $s^{-1}$ (BER $10^{-9}$) | − 55 dBm |
| Required safety margin | 7 dB |

(a) Illustrate the possible backscatter plot for the optical link provided by Optical Time Domain Reflectometry (OTDR).



(4 marks)

(b) In this system, assume a 40 km single mode link with 2 connector pairs and 5 slices. Calculate the total link loss of the system.

(8 marks)

(c) Calculate the maximum possible link length without repeaters when operating at 35 $Mbits^{-1}$ (BER $10^{-9}$). It may be assumed that there is no dispersion–equalization penalty at this bit rate.

(5 marks)

(d) Recommend a way to improve the sensitivity performance of OTDR measurement technique.

(3 marks)

– **END OF QUESTIONS** –

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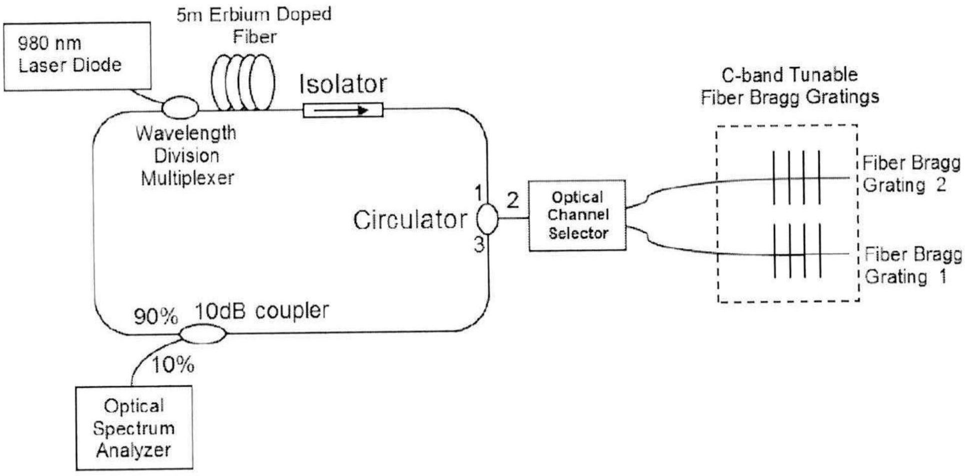


**Figure Q3**

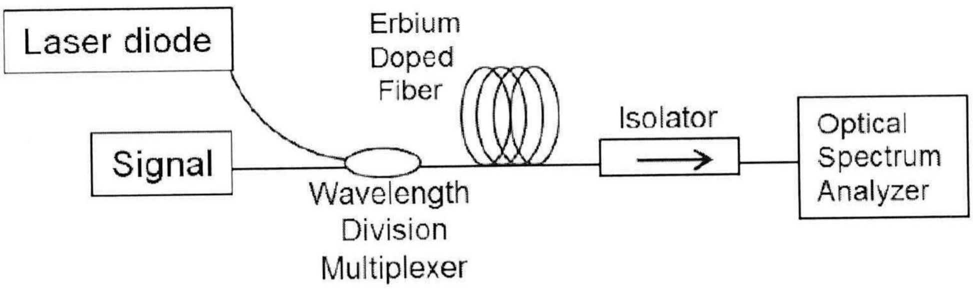


**Figure Q4**

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## CONSTANT

Boltzmann's constant, K=1.381 x $10^{-23}$ J.K$^{-1}$
Velocity of light in vacuum, c = 2.998 x $10^{8}$ m/s

## FORMULAE

| | | | |
|---|---|---|---|
| $V=\frac{2\pi}{\lambda}an_1(2\Delta)^{\frac{1}{2}}$ | $M_s \simeq \frac{V^2}{2}$ | $\sigma_m = \frac{\sigma_\lambda L}{c}\left(\lambda\frac{d^2n_1}{d\lambda}\right)$ | $M=\frac{\lambda}{c}\left(\frac{d^2n_1}{d\lambda}\right)$ |
| $\sigma_s=\frac{Ln_1\Delta}{2\sqrt{3}c}$ | $\sigma_s=\frac{L(NA)^2}{4\sqrt{3}n_1c}$ | $\sigma_T=(\sigma_m^2+\sigma_s^2)^{\frac{1}{2}}$ | $B_T=\frac{0.2}{\sigma}\ bits/sec$ |
| $B_T=\frac{1}{2\tau}\ bits/sec$ | $BW=B_T(RZ)$ | $V=\frac{2\pi a}{\lambda}\sqrt{n_1^2-n_2^2}$ | $n_1 sin\theta_1=n_2 sin\theta_2$ |
| $\alpha_{dB}=10log_{10}\frac{P_{out}}{P_{in}}$ | $P_{Ra}(t)=\frac{1}{2}P_{in}S\gamma_R W_o v_g$ | | $S\simeq\frac{\pi(NA)^2}{4\pi n_1^2}$ |
| $v_g=\frac{c}{N_g}\cong\frac{c}{n_1}$ | $P_1=P_0+C_L+M_a dB$ | $P_1=P_0+(\alpha_{fc}+\alpha_j)L+\alpha_{cr}+M_a dB$ | |
| $C_L=(\alpha_{fc}+\alpha_j)L+\alpha_{cr}+D_L$ | | $D_L=2(2\sigma B_T\sqrt{2})^4 dB$ | $C_L=(\alpha_{fc}+\alpha_j)L+\alpha_{cr}$ |