UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2004/2005

October 2004

ZSC 549/4 - Physics of Optical Communications
[Fizik Komunikasi Optik]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of **FIVE** pages of printed material before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **LIMA** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

Instructions: Answer all **FIVE** (5) questions. Students are allowed to answer all questions in Bahasa Malaysia or in English.

*[**Arahan:** Jawab kesemua **LIMA** (5) soalan. Pelajar dibenarkan menjawab semua soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]*

1. (a) Write down a complete expression for the x-polarized wave propagating $\vec{k}$ along the z direction, the electric field is confined to x-y plane.

[(a) Tuliskan ungkapan gelombang tertutup-x yang merambat sepanjang z, medan elektrik terbatas pada satah x-y.]

(50/100)

(b) A laser beam is almost perfectly parallel, it can be focused to a spot of radius of a few wavelengths. A beam of 1 mW at 0.633 μm is focused by a lens to a spot of radius 6 μm, then find the resultant intensity and corresponding electric field.

[(b) Alur laser yang hampir selari boleh difokuskan kepada titik berjejari beberapa panjang gelombang. Suatu alur 1 mW dengan panjang gelombang 0.633 μm difokus oleh kanta ke suatu titik berjejari 6 μm, tentu jumlah keamatan dan medan elektrik alur laser tersebut.]

$\mu_o = 4\pi \times 10^{-7}$ Hm^{-1}
$c = 3 \times 10^8$ m/s
$n = 1$ (air)

(25/100)

(c) (i) Write Maxwell's equations for an isotropic, linear, nonconducting, and nonmagnetic medium.

[(c) (i) Tuliskan persamaan Maxwell untuk medium isotropik, linear, bukan pengkonduk dan bukan magnet.

(ii) Explain Maxwell's contribution toward optical communication.

(ii) Terangkan sumbangan Maxwell terhadap komunikasi optik.]

(25/20)

2. (a) A transverse plane electromagnetic wave propagating in vacuum. The electric field is given by $\vec{E} = \vec{E}_o \cos[\omega t - 3x + 4y]$, where x and y are measured in meter and ω in rad.sec^{-1}, vector $\vec{E}$ is assumed to lie in the x-y plane.

[(a) Gelombang elektromagnet satah melintang merambat dalam vakum. Medan elektrik diberi oleh $\vec{E} = \vec{E}_o \cos[\omega t - 3x + 4y]$, dengan x dan y diukur dalam meter dan ω dalam rad.saat^{-1}, vektor $\vec{E}$ dianggap terletak dalam satah x-y.]

Find the values of
[Dapatkan nilai]

(i) $\vec{k}$
(ii) ω
(iii) $\vec{E}$ and *[dan]*
(iv) λ

(20/100)

(b) Explain the loss mechanism in an optical fiber. (40/100)

[(b) Explain mekanisme kehilangan di dalam gentian optik.]

(c) Write down the expression for pulse dispersion in a square law medium, and show whether it is valid for parabolic index and step index optical fibers.

[(c) Tuliskan ungkapan untuk sebaran denyut di dalam medium hukum kuasadua, dan tunjukkan samada ia sah untuk gantian optik indek parabolik dan indek bertangga.]

(40/100)

3. (a) Explain the broadening of a Gaussian pulse.
A wave packet is given by

$$\Psi(z,t) = \int_{\Delta\omega} |A(\omega)| \exp[i\{\omega t - kz + \phi(\omega)\}] d\omega .$$

Show that the wave packet remain undistorted for $z << Z_d$ where

$$Z_d = \frac{2}{\alpha(\Delta\omega)^2}, \text{ (assume } \phi(\omega) = O, \quad \alpha = \left.\frac{d^2k}{d\omega^2}\right|_{\omega=\omega_o} \text{).}$$

[(a) Terangkan pelebaran denyut Gaussian.
Paket gelombang diberi oleh

$$\Psi(z,t) = \int_{\Delta\omega} |A(\omega)| \exp[i\{\omega t - kz + \phi(\omega)\}] d\omega .$$

Tunjukkan paket gelombang tersebut tidak herot untuk $z << Z_d$ apabila

$$Z_d = \frac{2}{\alpha(\Delta\omega)^2}, \text{ (andaikan } \phi(\omega) = O, \quad \alpha = \left.\frac{d^2k}{d\omega^2}\right|_{\omega=\omega_o} \text{).]}$$

(50/100)

(b) In an optical pulse propagation through a fiber by a Gaussian temporal distribution, if there exist 1ns pulse at $\lambda_o \approx 0.834$ μm find the

[(b) Di dalam perambatan denyut optik melalui gentian taburan ruang Gaussian, jika wujud denyut lns pada $\lambda_o \approx 0.834$ μm tentukan]

(i) spectral width and
[(i) lebar spektrum]
(ii) calculate spectral purity of the pulse for $\omega_o \approx 2.4 \times 10^{15}$ s^{-1}.
[(ii) kirakan ketulenan spektrum denyut dengan $\omega_o \approx 2.4 \times 10^{15}$ s^{-1}.]

(25/100)

(c) (i) Explain Transverse Electric (TE) modes and transverse magnetic (TM) modes in a planar wave guide.

[(i) Terangkan mod elektrik melintang (TE) dan mod magnet melintang di dalam pandu gelombang satah.]

(ii) What are symmetric and antisymmetric modes?

[(ii) Apakah simetri dan antisimetri?

(25/100)

4. (a) (i) Explain the principle of optical detections system.

[(i) Terangkan prinsip sistem pengesanan optik.]

(ii) A photomultiplier is used to detect light from a HeNe laser. Assume the converting efficiency η is 10% and the band width $\Delta\nu$ is 1 kHz. Calculate the minimum detectable power, if the wavelength of HeNe laser light is 633 nm. ($h = 6.626 \times 10^{-34}$ Js)

[(ii) Suatu fotomultiplier digunakan untuk mengesan cahaya daripada laser HeNe. Anggap kecekapan penukaran η adalah 10% dan lebar jalur $\Delta\nu$ ialah 1 kHz. Kirakan kuasa terkesan minimum jika panjang gelombang cahaya laser HeNe ialah 633 nm. ($h = 6.626 \times 10^{-34}$ Js .)

(iii) An argon laser beam (λ = 514.5 nm) passing through the aperture window of a photo-multiplier is 1W. How many photons will hit the cathode of the photomultiplier in every second?

[(iii) Alur laser argon (λ = 514.5 nm) 1W melintasi bukaan tetingkap fotomultiplier, berapa banyakkah foton yang akan mengenai katod fotomultiplier setiap saat?

(50/100)

(b) (i) Write types of optical fiber and draw a schematic diagram of optical fibers.

[(i) Tuliskan jenis gentian optik dan lakarkan gambarajah skematik gentian optik tersebut.]

(ii) The ratio of the cladding and core refractive indices of a 2 km long fiber is 0.98. Calculate the dispersion of the fiber.

[(ii) Nisbah indek biasan pelapisan dan teras gentian optik sepanjang 2 km ialah 0.98. Kirakan sebaran gentian tersebut.]

(50/100)

5. (a) Explain the principle of optical amplification. Can an optical amplifier become a source of radiation?

[(a) Terangkan prinsip penguat optik. Bolehkah amplifier optik menjadi sumber sinaran?]

(25/100)

(b) (i) Using WDM schemes, can a huge band width be exploited?

[(i) Bolehkah lebar jalur yang besar diterokai melalui skema WDM?]

(ii) Calculate the gain band width in frequency domain corresponding to a gain band width of 30 nm in wavelength domain centered around 1550 nm.

[(ii) Kirakan lebar jalur gandaan domain frekuensi pada lebar jalur gandaan domain panjang gelombang 30 nm berpusat di 1550 nm.]

(25/100)

(c) (i) What is free electron laser (FEL) and the difference between conventional laser and FEL?

[(i) Apakah laser elektron bebas (FEL) dan apakah perbezaannya dengan laser biasa?]

(ii) Explain phase Coherence and Bunching mechanism for FEL.

[(ii) Terangkan koheren fasa dan mekanisme gugusan dalam FEL.]

(50/100)

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