UNIVERSITI SAINS MALAYSIA

First Semester Examination
2003/2004 Academic Session

September - October 2003

ZSC 549/4 - Physics of Optical Communications

Time : 3 hours

Please check that the examination paper consists of **THREE** printed pages before you commence this examination.

Answer all FIVE questions. Students are allowed to answer all questions in English.

1. (a) (i) What is the concept of coherence?

(ii) An LED at 850 nm has a typical $\Delta\lambda$ of 30 nm. The corresponding coherence length is 24 μm. Find the coherence time.

(5/20)

(b) The output from a single-mode fiber operating at 1320 nm is approximately a Gaussian beam with ω_o = 5.5 μm. Find the corresponding divergence angle for the above given parameters.

(5/20)

(c) A planar wave guide with n_1 = 1.503, n_2 = 1.500, d = 4 μm at λ_o = 1μm. Find the value of the wave guide parameter.

(5/20)

(d) (i) Draw a schematic of Mach-Zehnder interferometic arrangement for sensing.

(ii) A sensor can detect phase change of 10^{-6} rad with a laser source of wave length λ_o = 0.6338 μm and an index for silica doped fiber is 1.456. Find the corresponding change in fiber length.

(5/20)

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2. (a) (i) Explain TE modes and TM modes in a planar wave guide.

(ii) What are Symmetric and Antisymmetric modes?

(5/20)

(b) In an optical pulse propagation through a fiber by a Gaussian temporal distribution, if there exist 1 ns pulse at $\lambda_o \approx 0.833$ μm, find

(i) spectral width and
(ii) calculate spectral purity of the pulse for $\omega_o \approx 2.3 \times 10^{15}$ s^{-1}.

(5/20)

(c) (i) Write down the expression for group velocity in material dispersion for frequency-dependent refractive index (n) with a pulse of transverse length L and dependent wave length λ_o.

(ii) Show that the resultant temporal broadening of the pulse is

$$\Delta\tau = -\frac{L}{c}\left(\lambda_o^2 \frac{d^2n}{d\lambda_o^2}\right)\left(\frac{\Delta\lambda_o}{\lambda_o}\right)$$

(10/20)

3. (a) Explain the requirements of high speed communication. When a laser diode is modulated, the refractive index of the cavity also changes due to carrier injection. If the fraction change in refractive index is 10^{-7}, what are the corresponding fraction change in wave length and frequency shift for wave length $\lambda_o = 1300$ nm.

(10/20)

(b) (i) Explain in brief the principle of optical detection and why semiconductor photodiodes are the most commonly used in optical fiber systems.

(ii) Explain what is a PIN photodetector with the help of a suitable figure.

(5/20)

(c) A Si PIN detector has $\rho = 0.5$ A/W. Assuming a reverse bias of 20 V and a load resistance of 100 Ω calculate maximum power and sensitivity before and after increasing load resistor to 10 kΩ.

(5/20)

4. (a) (i) What is Fermi energy or the Fermi level?

(ii) Explain frequency chirping. Can chirping increase spectral bandwidth that leads to an increased pulse broadening? Can chirping be avoided by employing CW laser diode?

(5/20)

(b) A laser cavity has a decay time $t_c = 10^{-8}$ sec. When an active medium is filled in it (assume refractive index = 1) one obtains growth rate of photon energy density, $\gamma = 4 \times 10^8\ s^{-1}$. If the length of the cavity, along with the active medium, is doubled, what would be the new growth rate? Neglect diffraction and scattering losses.

(10/20)

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

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

(5/20)

5. (a) Draw a schematic diagram of an optical fiber cable.

(2/20)

(b) Explain the principle of optical amplifier and also give a brief idea of EDFAs for WDM Transmission.

(8/20)

(c) (i) An erbium-doped silica, medium has concentration $5 \times 10^{24}\ m^{-3}\ E_r^{3+}$ ion. If the absorption cross section $\sigma_a = 4.644 \times 10^{-25}\ m^2$ and emission cross section $\sigma_e = 4 \times 10^{-25}\ m^2$ for $\lambda = 1535.9$ nm, obtain the absorption coefficient assuming the excited state occupancy (N_2) is zero.

(ii) Determine the rate of absorption per unit volume if the power of light is 1 mW with a cross sectional area 1 mm^2 and $\lambda = 1535.9$ nm, $\sigma_a = \sigma_e = 4.644 \times 10^{-25}\ m^2$.

(10/20)