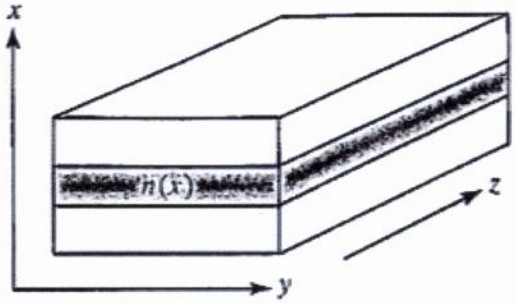
國 立 清 華 大 學 命 題 紙

一百零二學年度第二學期 光電工程研究所 博士班研究生資格考試

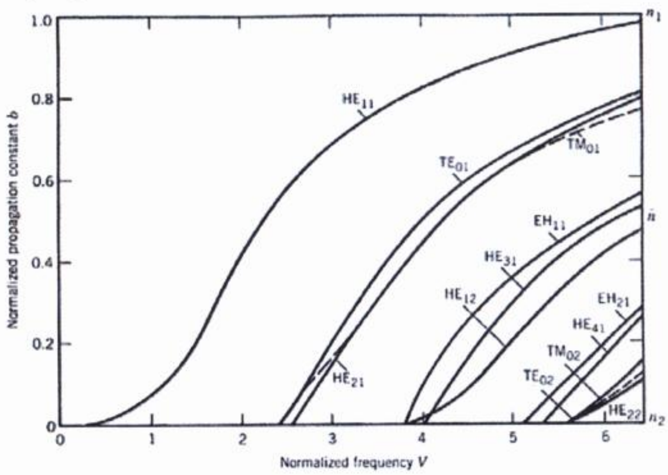
科目 光電子學二 共 3 頁第 1 頁 ＊請在試卷(答案卷)內作答

1. (10 %) For a planar dielectric waveguide shown below, there are totally 6 components (E_x, E_y, E_z, H_x, H_y, H_z) to formulate the electromagnetic wave. Please answer the following questions.
   (a). Among these 6 components, which components vanish for the TE wave? Please give an explanation. (5%)
   (b). Among these 6 components, which components vanish for the TM wave? Please give an explanation. (5%)



2. (10 %) (a) Numerical aperture, *NA*, of an optical fiber defines the maximum acceptable incident angle from air to the optical fiber that ensures total internal reflection exists at the core/cladding interface. Assume the indices of refraction of core and cladding in an optical fiber are n_1 and n_2, respectively. Please derive the numerical aperture, *NA*, as a function of n_1 and n_2. (5%)

   (b) In the figure shown below, each curve represents a surviving mode in an optical fiber as a function of the normalized frequency. The normalized frequency, *V*, is defined as $V = 2\pi \frac{a}{\lambda} NA$, where *a* is the core radius of the optical fiber. If Δ= 0.36%, where $\Delta \equiv \frac{n_1 - n_2}{n_1} \times 100\%$, please describe how you can design a single-mode fiber which allows only one mode that can propagate in an optical fiber at wavelength of 1.55 μm. (5%)



3. (10%) $\rho(\upsilon)$ is the spectral energy density due to photons with energy $h\upsilon=E_2-E_1$. Suppose that there are N photons per unit volume and the frequency range of emission is $\Delta\upsilon$, $\rho(\upsilon)$ can then be expressed as $(N h\upsilon)/\Delta\upsilon$. Consider an Ar-ion laser with the emission wavelength at 488nm. The linewidth in the output spectrum is $6*10^9$ Hz.

(a) Please estimate the photon concentration necessary to achieve more simulated emission than spontaneous emission.

(b) Once the photon concentration exceeds the number obtained in (a), does it guarantee laser operation? Why?

4. (10 %) Please answer the following questions briefly:

(a) What are the main differences between laser amplifiers and lasers?

(b) Under what conditions can hole burning occur?

(c) Is it possible to achieve population inversion in a two-level pumping scheme? If any, how does it work? If not, why not?

(d) Please draw the energy levels and all the corresponding routes of decays, pumping, absorption, and emission according to the following rate equations. Mark the rate or the time constant for each route.

$$\frac{dN_2}{dt} = R_2 - \frac{N_2}{\tau_2} - (N_2 - N_1)W_i$$

$$\frac{dN_1}{dt} = -R_1 - \frac{N_1}{\tau_1} + \frac{N_2}{\tau_{21}} + (N_2 - N_1)W_i$$

5. (10%) (a) What does laser mode-locking mean? (5%)

(b) Discuss in details, what analyses could you experimentally perform to ensure a laser is mode-locked? (5%)

6. (10%) Consider a PN junction, and assume the p-doped area has a Fermi level aligning with the valence band edge, and the n-doped area has a Fermi level aligning with the conduction band edge:

(a) Plot the band diagram when there is no bias applied to the PN junction; please outline the conduction band edge, the valence band edge, and the equilibrium Fermi-level (4%)

(b) Plot the band diagrams for forward bias (3%) and reverse bias (3%) scenarios; please outline the conduction band edge, the valence band edge, and the (quasi) Fermi-levels.

6. (10%) Both light-emitting diode (LED) and laser diode (LD) can emit light through injecting current into the diodes, what is the difference between LED and LD?

7. (10%) Is the Pockels effect (index change Δn is proportional to the applied e-field E) due to linear optics, $\chi^{(2)}$ nonlinearity, or $\chi^{(3)}$ nonlinearity? Justify your answer.

8. (5%) A lossless difference frequency generation process is pumped with 10 W power at 1 μm and seeded with 1 W signal at 1.5 μm. At the output, the pump is left with 9 W. (a) What is the idler wavelength? (1%) (b) Use the Manley-Rowe relation to estimate the output signal and idler powers. (4%)

9 (5%) explain how one would achieve phase matching for second harmonic generation in a birefringence nonlinear optical material.

10. (10%) If you were a R&D leader in your future employing company, and you are asked by your boss to assess the technical maturity of "high power semiconductor light source integrated on a semiconductor chip" that you have never had any substantial experience on. You start to feel nervous and panic about how to approach the problem. Then some vague memories come up in you mind about what you have learned in your Photonics II class back in IPT of NTHU: waveguide, semiconductor optics, semiconductor light sources, nonlinear optics.....etc. Please write down in free style some preliminary thoughts about the fundamental technical concerns that can guide you to go further into technical assessment of the problem. This may save your future job or even reward you with a promotion and good profit sharing.