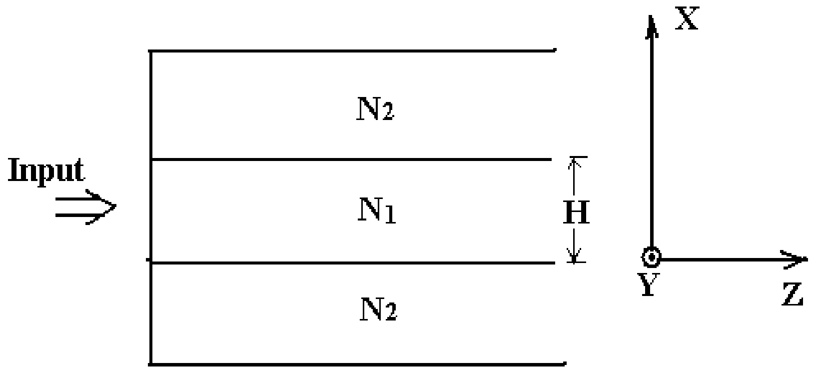
國 立 清 華 大 學 命 題 紙

九十七 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 科號________ 共_____頁第____頁 ＊請在試卷(答案卷)內作答

1. Consider a three-layer dielectric slab waveguide with refractive indices and thickness as indicated in the figure below.



(a) Explain why the propagation constant of every guided mode of this waveguide is larger than k_0N_2 but smaller than k_0N_1. (5%)

(b) Start with the second-order Helmholtz's equation and then solve it for this problem to find the distribution f(x) of TE modes in a general form. (9%)

2. Cutoff values of V (defined as $\frac{2\pi}{\lambda}a\sqrt{n_1^2 - n_2^2}$) for some lower-order LP modes of a step-index optical fiber are

LP_{01}: 0	LP_{11}: 2.405	LP_{21}: 3.832	LP_{31}: 5.136
LP_{02}: 3.832	LP_{12}: 5.520	LP_{22}: 7.016	LP_{32}: 8.417
LP_{03}: 7.016	LP_{13}: 8.654	LP_{23}: 10.173	LP_{33}: 11.620
LP_{04}: 10.173	LP_{14}: 11.792	LP_{24}: 13.323	Lp_{34}: 14.796

Now suppose you would use an input light with a wavelength of 1.55 μm for a step-index fiber with a core radius of 4.2 μm and a numerical aperture of 0.15.

How many LP modes exist in this fiber then? (6%)

At the wavelength above, certainly the fiber is not single-moded. How would you adjust your wavelength to get single-mode operation for the fiber? (5%)

3. For a two-level atomic system with populations N_1, N_2; life time τ_1, τ_2; spontaneous emission probability A_{21}; stimulated transition probability W_{12}; and pumping rates R_1, R_2,

   Write the rate equations. (8%)

   Determine the steady-state population inversion $N = N_2 - N_1$. (6%)

   Find the saturation time constant $\ _s$ for this system. (6%)

   Calculate the parameter N when $W_{12} = 2/\ _s$. (5%)

4. (10 %) Several mechanisms can lead to the absorption and emission of photons in a semiconductor. For example, band-to-band (interband) transitions. Please write down 5 mechanisms and briefly describe each of them.

5. (6 %) For an InGaAsP diode laser amplifier that has a junction thickness of 2 μm, the current density that just make the semiconductor transparent is $J_T = 3.2 \times 10^4$ A/cm^2. (a) If the thickness of the junction is reduced from 2 μm to 0.1 μm, what would the J_T be? (b) What could be the problem of having such a small thickness? (c) What kind of structure can be used to overcome the problem? How?

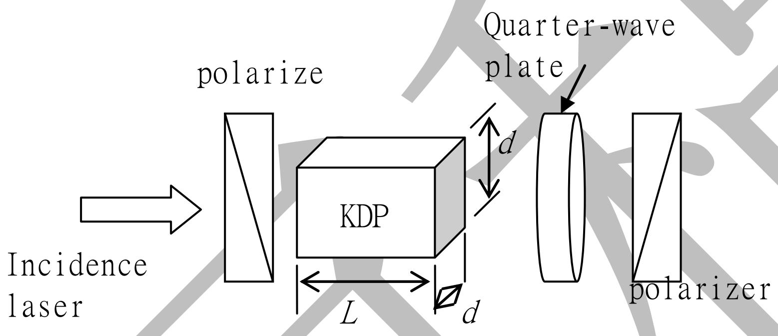
6. (9 %) For an InGaAsP (n = 3.5) laser with center wavelength $\lambda_o = 1.3$ μm of length d = 400 μm, (a) what is the resonator mode spacing in frequency and in wavelength? (b) If the spectral width B = 1.2 THz, how many longitudinal modes may oscillate? (c) To reduce the number of modes to one, how much the resonator length d has to be reduced? (d) Without reducing the resonator length, what kind of structures can be utilized for single mode oscillation?

7. (2%) Describe the functioning principle of a traveling-wave electro-optic modulator. In particular,

comment on the purpose of the "traveling-wave" design of the modulator.

8. (8%) A longitudinal electro-optic amplitude modulator consists of a KDP crystal and a quarter wave plate in a pair of cross polarizers, as shown below.

The electric field E is applied to the crystallographic z direction of the KDP crystal, resulting in an index ellipsoid of $\frac{x_1^2+x_2^2}{n_o^2}+\frac{x_3^2}{n_e^2}+2r_{63}Ex_1x_2=1$. The intensity transmittance of the amplitude modulator is given by $\Im=\sin^2(\frac{\Gamma}{2})$, where Γ is the total phase retardation between the two incidence polarizations through out the KDP crystal and the quarter-wave plate.



a. What is the switching voltage of this amplitude modulator? Assume the incidence laser wavelength is λ_0. (4%)

b. Describe the difference in its performance with and without the quarter-wave plate. (4%)

9. (6%) In a three-wave parametric down-conversion process, if the three waves have the frequency relationship $\omega_3 > \omega_1, \omega_2$ and $\omega_1 = \omega_3/3$.

a. What is the frequency of ω_2 in terms of ω_3? Provide the reason of your answer. (2%)

b. If you measure power consumption (pump depletion) of 3 W from Wave 3, what could be the maximum power increases for Waves 1 and 2 at the output? (4%)

10. (4%) In a second harmonic generation process, given material dispersion and the phase matched fundamental wavelength, how do you determine the phase matching bandwidth of (of the

fundamental wave of) the second harmonic generation? Don't just write down a formula. Please provide the derivation or the thinking path of the formula.

11. (5%) Prove that the optical Kerr effect results from the third-order optical nonlinearity.