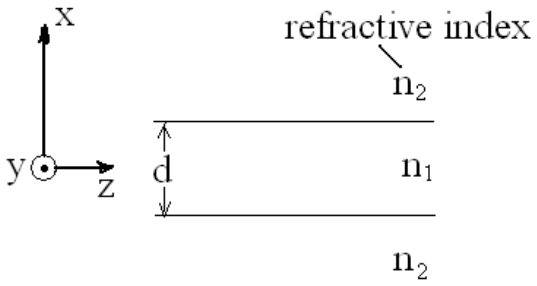
國 立 清 華 大 學 命 題 紙

九十九學年度第二學期 光電工程研究所 博士班研究生資格考試

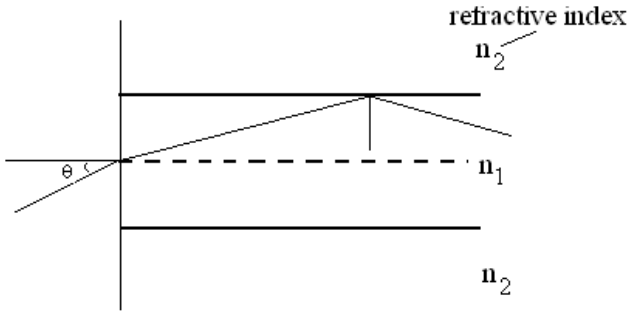
科目 光電子學二 共 頁第 頁 ＊請在試卷(答案卷)內作答

1. Consider the following dielectric slab waveguide problem, wherein you treat a one-dimensional waveguide structure in the transverse domain.



(a) (8%) Derive the electric field distributions of TE modes.
(b) (7%) Show how you would derive the dispersion relations for TE modes.

2. (10%) Derive the numerical aperture of an optical fiber by referring to the following figure.



3. (15 %) Please answer the following questions briefly:
(a) What are the main differences between laser amplifiers and lasers?
(b) Under what circumstances can hole burning occur?
(c) What are the origins of gain saturation of a laser medium?
(d) What are the characteristics of amplified spontaneous emission noise?
(e) Is there any two-level pumping schemes? If any, how does it work? If no, why not?
(f) What factors determines the number of possible laser modes?
(g) What determines the pulsewidth of a mode-locked laser? Can a mode-locked laser have a homogeneously broadened gain medium? Why?

4. (10 %) Gain switching and Q-switching are two common techniques for generating short pulses.
(a) To describe and compare the mechanisms of these two techniques, please carefully draw the detailed evolutions of the pump, the loss, the gain (population difference), and the photon number density for at least an entire cycle. Please mark and show all the critical timings clearly.
(b) What are the shortest possible pulsewidths for these techniques? Under what conditions?

5. (15%) Specify and briefly explain the factors that determine the probability densities of a photon being absorbed in a direct band-to-band transition.

6. (10%) Brief describe the structure and the working principles of quantum-well lasers and the quantum-cascade lasers.

7. (a) (7%) Describe, using your own words, assisted by equations and diagrams, the operation principle of a liquid crystal modulator. What is the function of each major component of such a modulator?
(b) (2%) Describe the difference in design configurations of a liquid crystal phase modulator and a liquid crystal amplitude modulator?
(c) (3%) Discuss the pros and cons of a liquid crystal modulator.

8. Consider the simple harmonic motion of an electron under the influence of an applied field *E*. The motion can be described by an equation of the form

$$m\frac{d^2x}{dt^2} + kx = -qE$$

where *m* is mass of the electron, *k* is the interatomic restoring force constant, *q* is electronic charge. The resonance frequency of the harmonic motion is $\omega_0 = \sqrt{k/m}$.

(a) (5 points) What is the displacement *x*(*t*) if the applied field is of the form $E = E_0 \cos\omega t$ where $\omega \neq \omega_0$.
(b) (8 points) Suppose there is a slight nonlinearity so that

$$m\frac{d^2x}{dt^2} + kx + \alpha x^3 = -qE$$

where $\alpha x^3 << kx$, calculate the third harmonic polarization $P^{(3)}(\omega)$ produced by the electron. (hint: let $x(t) = A\cos\omega t + B\cos 3\omega t$)