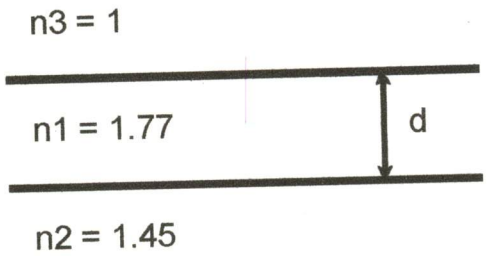
國 立 清 華 大 學 命 題 紙

一百學年度第二學期 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. Use the index profile, n1=1.77, n2=1.45, and n3=1 to design a single-mode asymmetric dielectric planar waveguide for l = 1 mm wavelength. If only one mode is allowed for the waveguide, is it TE or TM polarization? (5%) What is the range of thickness d for such a waveguide? (5%)



2. (10%) Suppose the propagation constant of the mp mode, where m,p = 0,1,2... , in a step-index fiber is

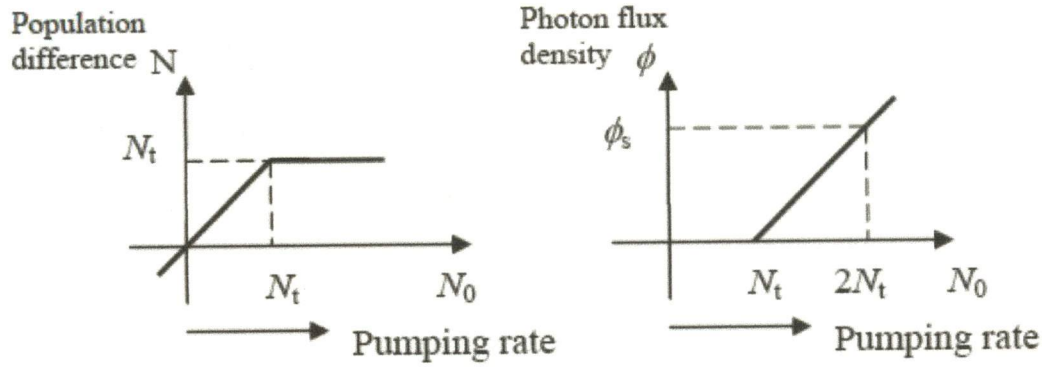
$$\beta_{mp} = n_1 k_0 \left[1 - \frac{(m+2p)^2}{M}\Delta\right] \quad \text{for} \quad V >> 1,$$

where V is the normalized frequency, n_1 is the refractive index of the core, k_0 is the free-space wave number, M is proportional to ω^2 and Δ is a constant independent of ω. Calculate the group velocity of each mode, i.e., the mp mode.

3. Consider transitions between two different energy levels:
(a) (6%) We can model the light-atom interaction using some absorption lineshape function: Sketch the typical lineshape function, write down it's mathematical form, and give the specific name for such profile.
(b) (4%) What are the origins for having the lineshape width?

4. (10 %) Please draw the energy levels and all the corresponding rates of decays, pumping, and emission according to the following rate equations. What is the steady-state population difference $N = N_1 - N_2$?

5. (a) Describe the gain and phase conditions for laser oscillation? (2%)
(b) What determines the pulse width of a Q-switched laser pulse? Explain how those parameters in your answer affect the laser pulse width. (3%)
(c) What determines the pulse width of a mode-locked laser? Prove your answer analytically. (2%)
(d) Propose at least two schemes to select a longitudinal mode of a laser having a linear-cavity length of 1.5 m. Specify the physical parameters of your schemes. (4%)
(e) Interpret the physical meaning of the following two plots for laser action. (4%)



6. (10%)

(1) THE SPECTRAL LINE SHAPE OF A LIGHT EMITTING DIODE: (5 POINTS)

a. Given the spectral line-shape function of LED function, $I(E)$,explain how this line-shape function is derived,

$$I(E) \sim \sqrt{E - Eg}\ e^{-E/KT}$$

b. Estimate where the maximum emission intensity occurs?
c. Draw a spectral line-shape for a GaAs LED emitting at 870nm and estimate the spectral linewidth.

(2) THE LIGHT EMITTING DIODE EFFICIENCY. (5 POINTS) –

Consider an LED with a threshold voltage of $V_{th} = E_g / e = 2.0$ V with a differential resistance of $R_s = 20\ \Omega$, so that the I–V characteristic in the forward direction is given by $V = V_{th} + I R_s$. When the device is operated at 20 mA it emits a light power of 4.0 mW of energy ($h\nu = E_g$), Assuming the light-extraction efficiency is 50%. Determine the device:

a. external quantum efficiency,
b. internal quantum efficiency, and
c. power efficiency,

7. (a) Both the light-emitting diode (LED) and laser diode (LD) can emit light by injecting current into the diodes, compare their differences between LED and LD. (5%)
(b) Explain why the materials with indirect band gap cannot be fabricated as the light sources. (2%)
(c) The light spot observed from far-field pattern for an edge-emitting laser is elliptic, not circular. Why? (3%)

8. A nematic liquid crystal (LC) cell is sandwiched between two glass plates coated with transparent electrodes at $z = 0$, and $z = d$ (Figure 1). Assume the LC is uniaxial with optic axis aligned with the molecular axis.

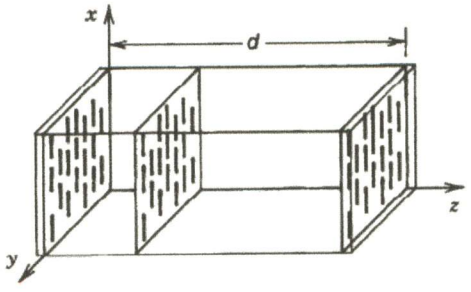


Figure 1.

(a) (5%) What will happen to the LC molecules (represented by vertical bars in Figure 1) when a voltage difference $V(0)-V(d)=V_0>0$ is applied to the electrodes? Justify your answer.

(b) (10%) Describe how to make a voltage-controlled intensity modulator by using the LC cell and some other components. Justify your anwer.

9. (a) Use index ellipsoids to explain type-I and type-II collinear phase matching for second harmonic generation in a positive uniaxial nonlinear optical material ($n_e > n_o$). (4%)
(b) Describe how quasi-phase-matching is achieved in a dispersive nonlinear optical material for laser wavelength conversion. List the advantages of this technique. (2%)
(c) Compare the frequency and threshold characteristics of SRO and DRO.(2%)
(d) Explain how the optical Kerr effect leads to self-focusing and spatial soliton of a laser beam. (2%)