國 立 清 華 大 學 命 題 紙

一百學年度第一學期 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 頁 ＊請在試卷(答案卷)內作答

I.. (9%) When a voltage V is applied to a lithium niobate crystal along the crystallographic z direction, the ordinary and extraordinary refractive indices are expressed by

$n_0(E) = n_0 - \frac{1}{2} n_o^3 r_{13} E$ and $n_e(E) = n_e - \frac{1}{2} n_e^3 r_{33} E$, respectively, where $E = V/L_z$ is the electric field along z with L_z being the thickness of the crystal in z. Assume the other dimensions of the crystal are L_x and L_y along the crystallographic x and y directions.

(1) Design and draw an optical intensity modulator using such a crystal for an incident laser with wavelength λ. Specify the directions of the laser propagation and polarization with respect to the crystallographic directions. (3%)

(2) What is the half-wave voltage of your intensity modulator? (3%)

(3) Propose a scheme or design to guarantee linear modulation of your modulator? (3%)

II. (9%) A laser pulse is sent into a piece of lithium niobate crystal to create an intensity of 1 GW/cm^2 inside the crystal. A DC electric field follows the laser pulse envelope is induced in the crystal. Assume the ordinary and extraordinary refractive indices of lithium niobate are about 2. The relevant nonlinear coefficients for lithium niobate are d_{31} = 5 pm/V×ε_0 and d_{33} = 30 pm/V×ε_0, where ε_0 is the vacuum permittivity. Let the laser propagate along the crystallographic y direction.

(1) Explain and model this phenomenon? (3%)

(2) Assume the laser polarization is along z. What is the peak DC electric field induced in the crystal? What is the direction of the induced DC electric field? (3%)

(3) Assume the laser polarization is along x. What is the peak DC electric field induced in the crystal? What is the direction of the induced DC electric field? (3%)

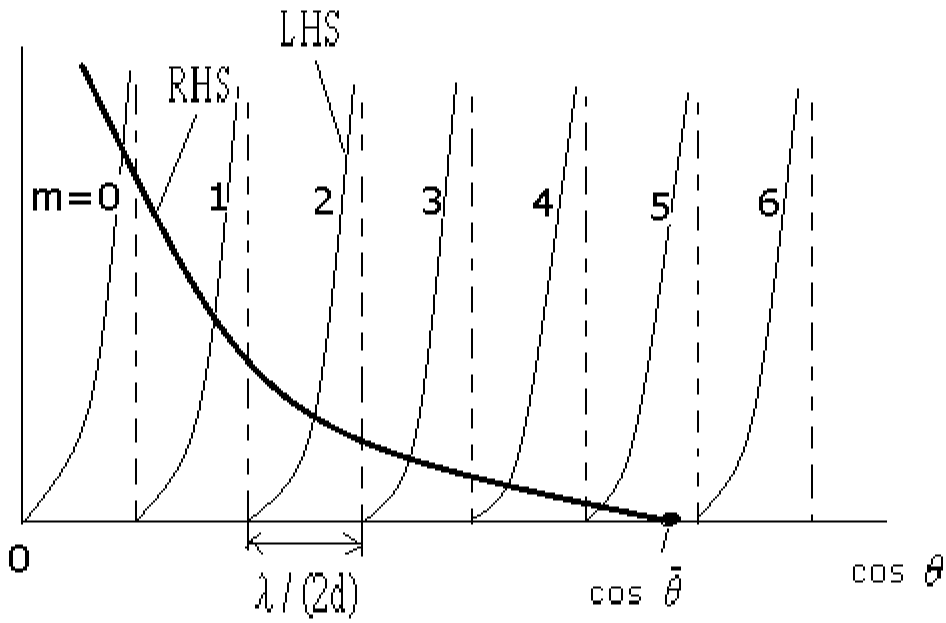
III. (7%)Suppose you have a convenient Nd laser emitting at 1064 nm. Devise a few nonlinear laser wavelength converters to obtain red (600-650 nm), green (520-540 nm), blue lasers (450-480 nm) by using the Nd laser as a pump. Assume that your crystal is transparent for laser wavelengths between 400 and 4000 nm. Also, assume perfect phase matching for all your processes. Please specify the details of your laser wavelength converters (SHG, SFG, OPO, Raman etc.).

IV. (15%)The self-consistency condition for TE modes in a symmetrical slab waveguide (which is composed of a guiding layer with the index n1 clad by two layers with the index n2) is

$$\tan(\pi \cos\theta \; d/\lambda - m\pi/2) = \sqrt{\frac{\cos^2\bar{\theta}}{\cos^2\theta} - 1}$$

where λ is the optical wavelength, d is the thickness of the guiding layer, θ is the incidence angle, and $\cos^2\bar{\theta}$ is a constant equal to (n1^2－ n2^2)／n1^2.

A graphical solution to the equation above is shown below, where LHS and RHS refer to the left-hand side and the right-hand side of the equation, respectively.



From the figure above, find the condition for single-mode operation, and also find the cutoff frequency of the second-order mode (i.e., TE_1 mode, the next higher order mode than TE_0 mode, the lowest order mode).

V. (10%) An optical fiber with a core radius of 5 μm has the core refractive index 1.5 and the cladding index 1.45. Assume the light launched into the fiber has a free-space wavelength of 1.55 μm. Is this fiber a single-mode fiber? Explain your answer.

VI. (6%) (a) Explain in detail why photon emission is unlikely in an indirect bandgap semiconductor.
(6%) (b) Explain in detail why all the semiconductor materials are opaque (not transparent) in the visible range.
(13%) (c) Explain the basic working principles of the light emitting diode and the diode laser.

VII. (15 %) Please answer the following questions briefly:

(a) What are the main differences between laser amplifiers and lasers?
(b) In what kind of gain media can hole burning occur?
(c) What are the characteristics of amplified spontaneous emission noise (bandwidth, coherence, polarization, etc.)?
(d) Is there any real two-level pumping schemes? If any, how does it work? If no, why not?
(e) What factors determines the number of possible laser modes (longitudinal, transverse, etc.)?
(f) How a mode-locked laser generates short pulses? What determines the pulsewidth?
(g) The laser modes occupy a large gain bandwidth in a mode-locked laser. Instead of the inhomogeneously broadended gain medium, can a mode-locked laser have a homogeneously broadened gain medium? Why?

VIII.. (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 (starting of the pulse, peak of the pulse, peak of the gain, and relations between the pump, loss, gain, and photon density, etc.).

(b) Under what conditions one can get the shortest pulse from these techniques? What are the shortest possible pulsewidths?