Problem Set No. 5   *6.637 Optical Signals, Devices and Systems*   Issued Tues. 3/11/2003

Spring Term, 2003   Due Tues. 3/18/2003

Reading recommendation: 6.637 Class Notes, Chapters 1 - 5;

Problem 5.1 - The Hunt for Errors in Chapters 1 - 3

(a) Please list the errors that you have found (including typos) in first three chapters of the notes.

(b) Please identify sections of the notes (chapters 1-3 only) that are not clearly written or that are confusing. For each occurrence, state the source of the problem or the confusion.

Chapter 1 - Basic Properties of Electromagnetic Waves

Chapter 2 - Coherence and Interference

Chapter 3 - Diffraction and Propagation

It is acceptable (and preferred) that you to turn in a marked up copy of the pages of the notes that have your corrections. Please be sure to put your name on the pages you turn in.

Problem 5.2 - Lithium Niobate Modulators

Your goal is to design intensity and phase modulators for a collimated, **unpolarized** light beam of intensity, I_{in} , using the electro-optic effect in a given lithium niobate crystal. Lithium niobate is an uniaxial material ($n_x = n_y$) and its electro-optic tensor contains the following non-zero elements:

$$r_{22} = -r_{12} = -r_{61} \qquad r_{13} = r_{23} \qquad r_{42} = r_{51} \text{ and } r_{33}$$

The given crystal has transparent electrodes on the faces perpendicular to the c-axis as shown, and its dimensions are L_x, L_y and L_z. Thus, you can apply electric fields along the z-axis only. However, you can propagate the light beam to be modulated along either the x, y or z axes.
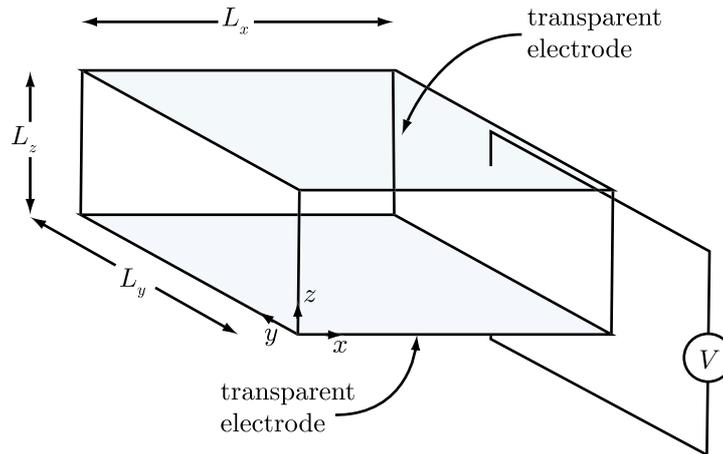
(a) First, I would like you to make a phase-only modulator but without the use of polarizers. Draw a diagram to show how you would operate the crystal to achieve this goal. For your chosen operation, what is your expression for $\Delta\Phi(V)$?

(b) I would like you to design an intensity modulator. Place the crystal between polarizers (not necessarily crossed), and for each of the three propagation directions, derive an expression for $I_{out}(V)/I_{in}$. Be sure to clearly specify your chosen orientation of the polarizers relative to the axes of the crystal (a diagram is required for each case).

(c) Suppose that the wavelength of the light to be modulated is $\lambda = 0.6\mu$m, and that $L_x = L_y = L_z$. Given that $n_O = 2.286, n_E = 2.200$ and that

$r_{22} = -r_{12} = -r_{61} = 6.8$ pm/V (pm=pico meter= 10^{-12}m)

$r_{13} = r_{23} = 9.6$pm/V

$r_{42} = r_{51} = 32.6$ pm/V

$r_{33} = 30.9$ pm/V

Which of the three cases makes the most efficient intensity light modulation system in terms of intensity change per volt? What is the half wave voltage for this system? How could you significantly lower the halfwave voltage?

Problem 5.3 - Acousto-optic Modulator

Two counter propagating acoustic pulses $g(t)$ and $h(t)$ are launched at $t = 0$ into a Bragg cell of length L and interaction width W (both transducers have width W) as shown. The acoustic material has a refractive index n and acoustic velocity v_a. It is read out with a plane wave of wavelength λ at the Bragg angle, θ_B, as shown.
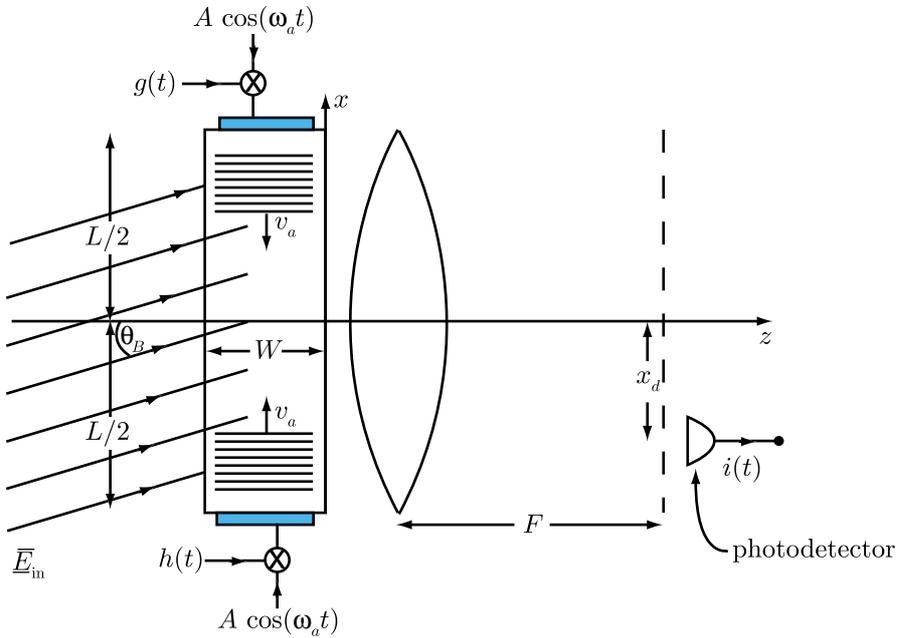
(a) Write an expression for the Bragg angle in terms of the device and operational parameters.

(b) (1) In the period before the two acoustic pulses meet each other, where (x_{d1}) in the back focal plane of the lens would you place a photodetector to receive first-order diffracted light owing to both pulses?

(2) Write an expression for the detector current $[i_1(t)]$ in terms of the signal and device parameters.

(c) (1) In the period during which the acoustic pulses partially or totally overlap, where (x_{d2}) in the back focal plane of the lens would you place a second photodetector to sense the occurrence of this overlap.

(2) Write an expression for this detector current $[i_2(t)]$ in terms of the signal and device parameters.

(d) The transducers are now changed so that the two acoustic signals are each of width $W/2$ (new transducer width), and the propagation paths of the acoustic signals are side by side (non-overlapping) as shown. Where (x_{d3}) in the back focal plane of the lens would you place a new photodetector to intercept the doubly diffracted first-order beams from this new cell?

(e) Write an expression $[i_3(t)]$ for the resulting photodetector current. What important mathematical operation is being performed by the system?