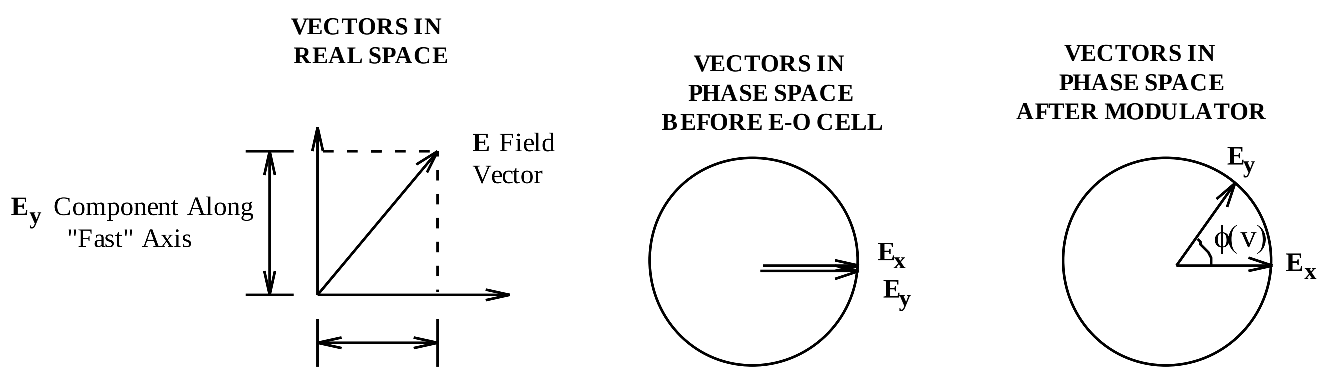
LAB 09 – ELECTRO- AND ACOUSTO-OPTICS
FALL 2016

Objective To learn how to use voltage controlled waveplates to measure and actively change the polarization state of light. We will also study acousto-optic modulators.

PART I ELECTRO-OPTIC MODULATORS (voltage controlled waveplates)

Discussion $\lambda/4$ and $\lambda/2$ waveplates produce a fixed phase delay between the two orthogonal components of the electric field vector. An electro-optic modulator can be thought of as a **voltage controlled** waveplate or a dynamic wave retarder. By applying a voltage across an electro optic crystal the indices of refraction along the fast and the slow axis change. This is the electro-optic effect. The refractive index changes are not the same along each axis.

The resultant vector sum of field components has a phase term $\phi(v)$ (see the figure below) that is a function of the applied voltage. Thus the phase shift between $\mathbf{E_x}$ and $\mathbf{E_y}$ can be set through changing the voltage. If an output polarizer is set crossed to the initial laser polarization (blocks the laser light), a voltage, V_π can be applied to create a π phase shift. At this setting, the output is passed by the polarizer. Thus, the whole system can act as an intensity modulator.



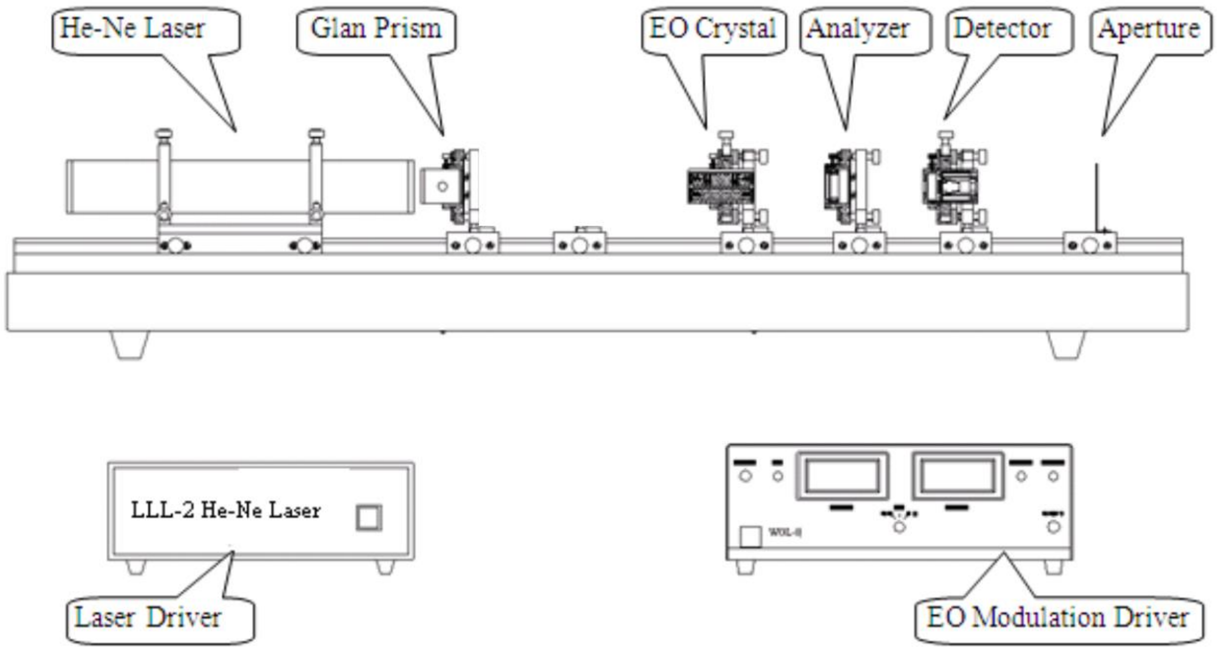
$$\mathbf{E} = \mathbf{E_x} \exp(\omega t)\,\hat{\mathbf{i}} + \mathbf{E_y} \exp(\omega t)\,\hat{\mathbf{j}}$$

$$\mathbf{E} = \mathbf{E_x} \exp(\omega t)\,\hat{\mathbf{i}} + \mathbf{E_y} \exp(\omega t + \phi(v))\,\hat{\mathbf{j}}$$

Phase shift depends on applied voltage V

Experiment

1) Set up as in the figure below with the output polarizer axis crossed with that of the Glan prism.



2) Connect the detector to “Receiving Light Intensity” port at the back of the EO Modulation Driver.

3) Connect the modulator to the “Modulation Voltage” port at the back of the EO Modulation Driver.

4) Rotate the EO cell to find the fast and the slow axis. Once you have found these, rotate the EO cell so that the polarization of the input light is 45^{o} with respect to the crystal axes.

5) Set the voltage mode to “Extremum”.

6) Increase the DC voltage in steps of ~ 10 *V* and record the output light intensity vs. voltage up to a maximum of 400 *V*. Estimate V_{π} within ± 5 volts. ENTER YOUR DATA DIRECTLY WITH EXCEL FOR YOUR LAB REPORT (SEE ‘QUESTIONS FOR WRITEUP’ AT THE END).

(5 points)

PART II HALF WAVE VOLTAGE USING MODULATION FREQUENCY DOUBLING

Discussion We know that if the modulator is biased at the peak or minimum transmittance, the AM modulation on the output light will be frequency doubled. This yields a very accurate way of determining V_{π}.

Experiment

1) Using the same setup as in Part I, set the voltage mode to “Modulation”. Increase the ac modulation signal to maximum.

2) Connect the BNC output of the EO Modulation Driver to an oscilloscope.

3) From the data obtained in Part I, roughly locate the DC voltage where the minimum EO modulator output intensity is located. Starting at this DC voltage, tune to find the minimum more precisely by locating the point at which the modulated signal frequency doubles. Label the applied DC voltage at this point V_{min}.

4) Repeat the same process to precisely find the DC voltage at maximum intensity, V_{max}. Use V_{max} and V_{min} to find V_{π}

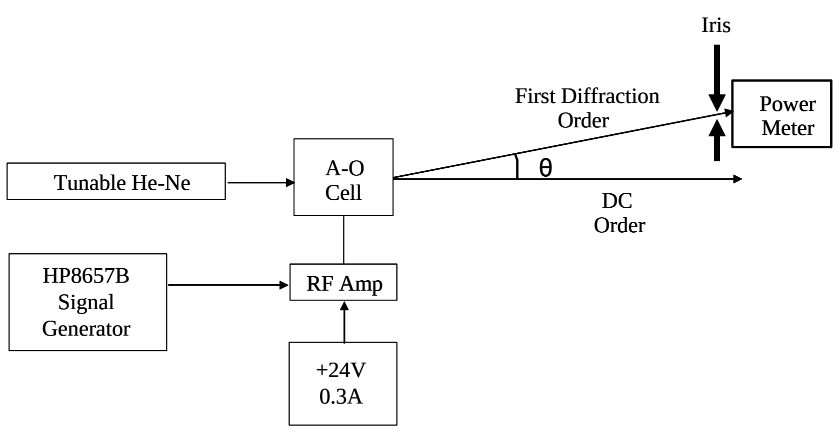
(5 points)

PART III ACOUSTO-OPTICS

Discussion The design carrier modulation frequency of the AO cell in lab is 80 *MHz*. If the carrier frequency is changed from this center frequency, the diffraction efficiency will decrease due to Bragg mismatch. The diffraction efficiency is also a function of the RF power applied to the cell through the dependence of I_s (the acoustic intensity) on the applied RF power.

Experiment

1) Set up the figure below using the 6328 (red) line of the HeNe. The AO cell handles a maximum of 1 Watt of RF power (+30 dBm)…do not connect the RF power to it yet. Set the power on the signal generator to - 10 dBm. The RF amp provides 20 dB power gain. Provide the amp with +24 Volts. The center pin is positive. Set the frequency of the signal generator to 80 *MHz*. The RF amplifier is the small black box with the heat dissipation fins on top. You can now provide the resulting +10dBm of RF power to the AO cell.



2) Coarsely align the AO cell by adjusting the magnetic base until some light gets through and can be seen in the first diffraction order. The AO cell should be roughly normal to the beam. Then use the knob on the side of the mount for fine-tuning and maximize the amount of light into the first diffraction order. If you have trouble locating the input/output ports, see the TA. You should see multiple diffraction orders, but you should maximize the *first* order.

3) Now record the diffraction efficiency (ratio of diffracted power to total power) as a function of frequency in ~4 *MHz* steps starting at 60 *MHz* and ending at 100 *MHz*. Plot the data directly into Excel for your writeup. You may use an iris to assist you in isolating the power on the first diffraction order. Be sure to subtract the detector background signal.

(4 points)

4) Set the AO cell to operate at 80 *MHz.* Record the diffraction efficiency with the tunable HeNe set to each of the 5 available laser lines (don't worry if you can't get green). **ONLY TURN THE COLOR KNOB. DO NOT ADJUST THE TRANSVERSE ADJUSTMENT.** The TA will provide you with all the wavelengths. Plot the diffraction efficiency vs. wavelength directly into Excel for your writeup.

(4 points)

5) Repeat step 3 with λ at 6328 µm and f = 80 *MHz*, but now vary the total amplified RF power (dBm) into the AO cell. Start at -15 dBm and increase in steps of 5 dBm to a maximum of +30 dBm. *This is the power out of the RF amp (total RF power), and not the signal generator.* **DO NOT EXCEED +10DBM OUT OF THE SIGNAL GENERATOR, I.E. +30DBM FROM THE AMPLIFIER *SINCE THE AMPLIFIER PROVIDES A FIXED 20 DB OF GAIN*.** Plot the data directly into Excel for your writeup.

(4 points)

QUESTIONS/PROBLEMS FOR WRITE-UP

Plot out and print the data you accumulated as a part of this lab