

Molecular Materials and Devices, Incorporated

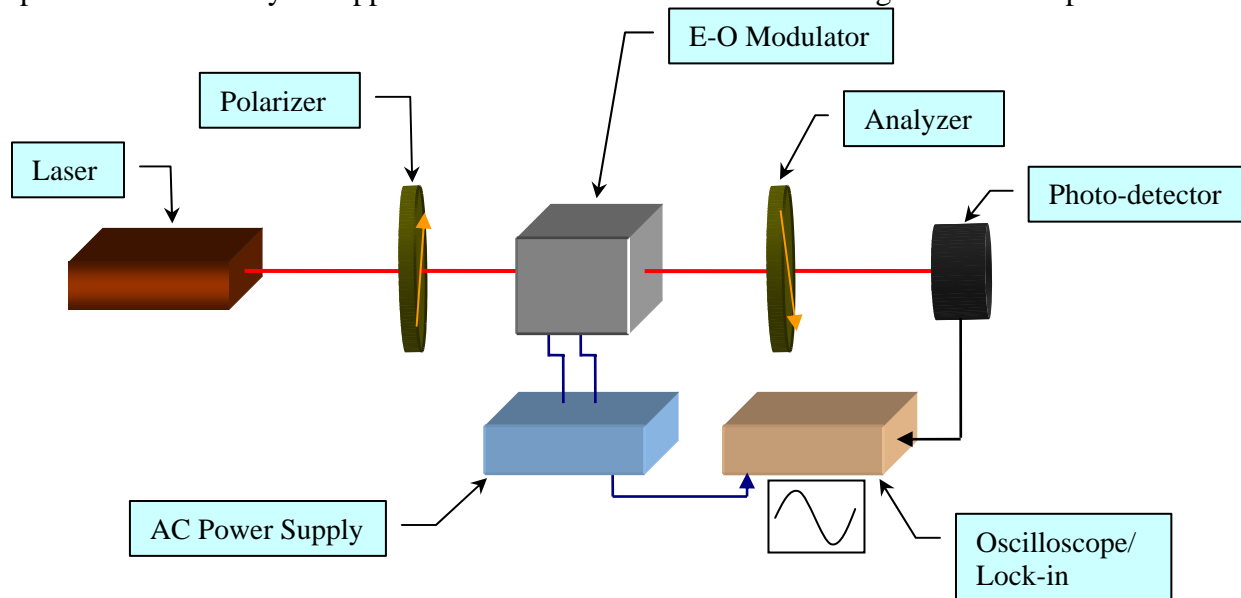
Electro-Optic Modulator Tutorial

Introduction:

This tutorial examines the working principles of an Electro-optic modulator for use as a demonstrative tool for graduate and undergraduate students. The electro-optic material used is a single-crystal film of DAST approximately 5 microns thick. This film is prepared by a special method (modified shear method, US patent issued). An electric field is applied across the sample such that the direction of the field is along the dipole axis of the material. Electro-optic modulation is observed for a light beam passing through the film when an electric field is applied. The reason for using the DAST film is that its electro-optic coefficient is exceptionally large (770 pm/V at 633 nm) that produces significant electro-optic modulation even for a single-pass through a thin film and for a low electric field.¹⁻³

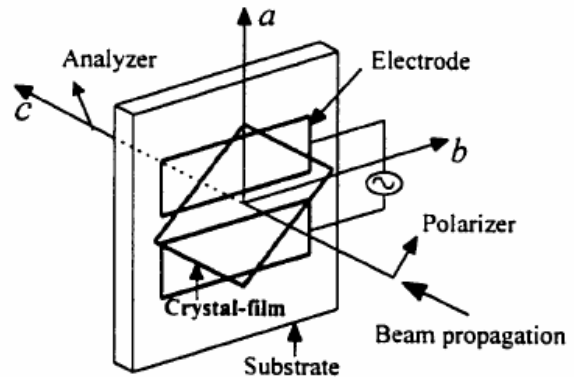
Experimental setup:

The modulator comprises of a focusing lens, a collecting lens, a single-crystal film of an organic electro-optic material on a micro-positioner and electrical leads attached to the electrodes applied on the electro-optic film. The overall setup for an experimental demonstration involves a laser, a polarizer, an analyzer, an ac power supply, a photodiode, an oscilloscope and the electro-optic modulator. The incident laser beam passes through the polarizer which provides a 45 degree angle of polarization with respect to the vertical axis (dipole axis). The beam is then focused on the DAST sample within the electro-optic modulator. The beam passes through the analyzer and is collected into the photodiode. The modulation signal produced by the electro-optic effect caused by the applied electric field is then recorded using an oscilloscope.

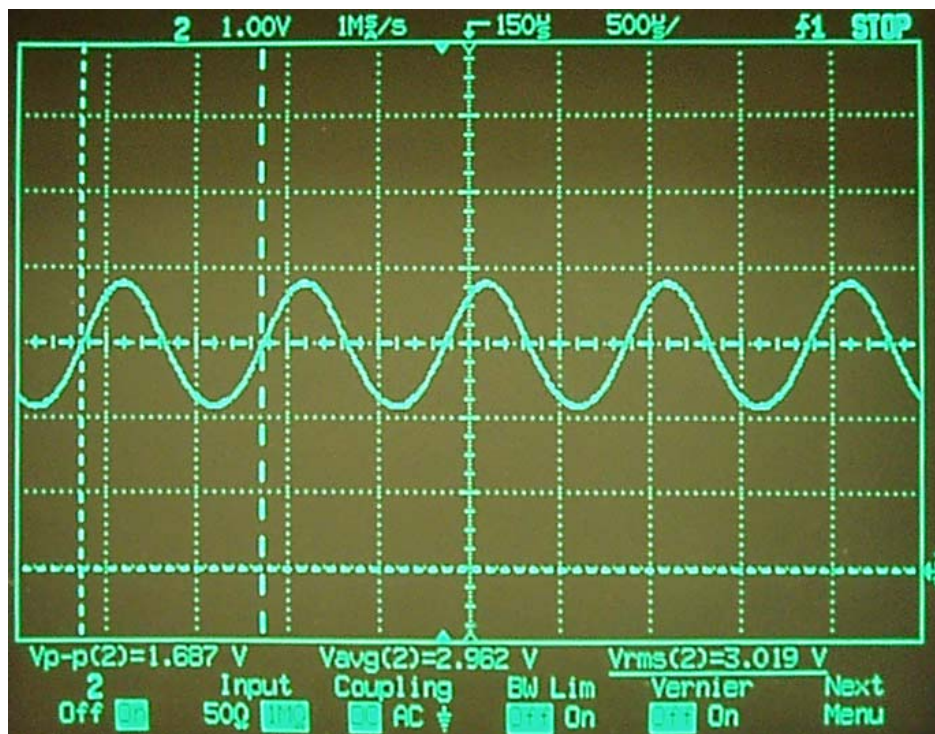


Principle of Operation:

The active electro-optic material used is a thin single-crystal film of DAST. Gold electrodes are deposited such that the ac field is applied along the dipole axis of the crystal. The gap between the electrodes is around 70 microns. On applying the electric field along the dipole-axis of the sample, a birefringence is induced. Without an electric field there is no induced birefringence and therefore the set-up allows only very low transmission of light. As a field is applied more light passes through the analyzer resulting in the modulation.



The modulated signal is collected using a photodetector and can be studied using either an oscilloscope or a lock-in amplifier. A reference signal from the voltage driver is fed to the oscilloscope/lock-in to filter out the noise. The modulation observed is directly proportional to the magnitude of the voltage applied. Below is an oscilloscope trace showing a modulation of about 28 percent for an applied field of about 125 volts.



Instructions for aligning the system:

A typical setup to observe electro-optic modulation would include the following components: 1) Laser source, 2) A polarizer and an analyzer, 3) Photodetector to collect the modulated signal, 4) An oscilloscope or a lock-in amplifier to analyze the modulated signal, 5) AC power source to drive the electro-optic modulator and the electro-optic modulator.

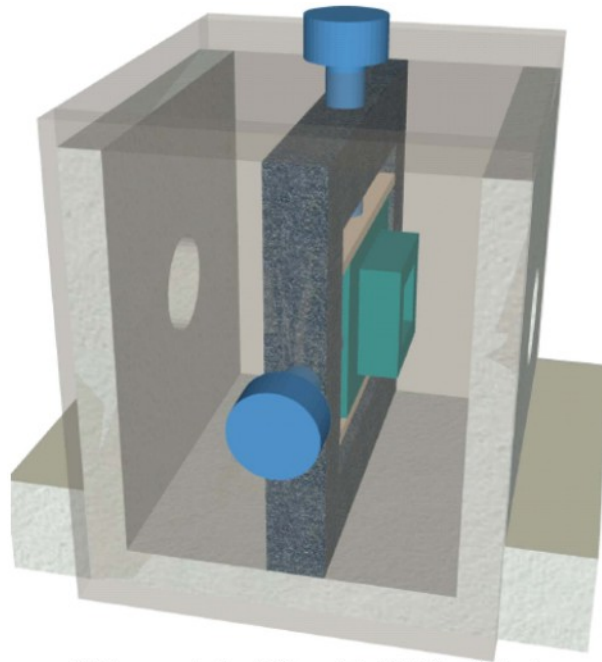
STEP 1: Install the laser and the photodetector with sufficient space between them so as to accommodate the polarizer, analyzer and the E-O Modulator. The laser's polarization is to be orthogonal to the dipole axis of the DAST crystal, which is parallel to the horizontal.

STEP 2: Then the polarizer and the analyzer are to be installed. Initially, the angle of polarization of the polarizer and analyzer is to be set parallel to each other and to the laser's polarization.

STEP 3: Next the E-O modulator is to be introduced between the polarizer and the analyzer while constantly monitoring and maximizing the DC power available at the photodetector.

STEP 4: The E-O modulator is then to be connected to the voltage driver by means of the alligator clips. The photodetector is then to be connected to an oscilloscope or a lock-in amplifier. A reference signal from the voltage driver is fed to the oscilloscope/lock-in amplifier.

Now that all the components are installed and aligned, the polarizer is to be set at an angle of 45 degrees to the dipole axis of the DAST sample. And the analyzer is to be orthogonal to the polarizer. This can be done by monitoring and minimizing the DC power available at the photodetector by rotating the analyzer. The DAST sample in the E-O modulator is usually centered so that the beam is focused between the electrodes and on the DAST sample. Once the electric field is applied, the modulated signal should be detected immediately. In the case where the modulated signal is low or absent, the DAST sample can be translated in the x-y plane by means of the fine pitch screws on the stage, in order to maximize the modulation depth. Once the maximum modulation depth is attained, the analyzer can be rotated to peak the modulated signal. This is done because DAST has an inherent birefringence which can be compensated by rotating the analyzer.



3D model of the E-O Modulator



Photo of E-O Modulator Tutorial,
Pockels cell

Advantages of using DAST Single-crystal film as an electro-optic material for the present application:

1. DAST single-crystal film has the largest known ¹ electro-optic coefficient of electronic origin (770 pm/V at 633 nm).
2. High modulation-depth (more than 20%) can be readily produced for a single-pass through such a single-crystal film operating at a low field.
3. This modulator structure involves insignificant insertion and propagation losses.
4. Besides its use as a tutorial for underlying principles of electro-optic modulation, the modulator discussed is useful as a Pockels cell for various applications.
5. Modification of the structure for high-speed (GHz) applications is viable.
6. The films have a high melting point of 256°C.
7. The films have high optical quality, good mechanical stability and are environmentally stable.

References:

1. "Single-pass Thin-film Electro-optic Modulator based on an Organic Molecular salt", Applied Physics Letters, M. Thakur, J. Xu, A. Bhowmik and L. Zhou, 74 635 (1999).
2. "Electro-optic Modulation at 1.5 GHz using Single-crystal Film of an Organic Molecular Salt", M. Thakur, A. Mishra, J. Titus and A.C. Ahyi, Appl. Phys. Lett., 81 3738 (2002).
3. "Electroabsorption in Single-crystal Film of a Second Order Optical Material", R.K. Swamy, S.P. Kutty, J. Titus, S. Khatavkar and M. Thakur, Appl. Phys. Lett., 85 4025 (2004).