PREFACE

Motivation and objectives of the thesis.

The main applications of Liquid Crystals are electro-optic display devices used in electronic watches, calculators, T.V Screens etc. The fast response with low electric fields and wide range of operating temperatures are the essential parameters. There are several other electro-optic applications mentioned below. This motivated us to study the various properties of available Liquid Crystals ultimately leading to the design of the applications mentioned below.

Liquid Crystals are thermo tropic exhibiting various phase transitions under the influence of electric field. The molecules behave differently at each phase. The parameters like refractive index, optical polarization, dielectric constant and other physical parameters are different in different Liquid Crystal Phases.

Hence it is essential to determine the Phase transitions of Liquid Crystal samples which are suitable for different electro-optic applications. In this endeavor, a systematic study of seven Liquid Crystal samples of different varieties is undertaken. Based on these studies different electro-optic devices were developed.

List of Electro-Optic Devices Developed.

1. Electro-optic shutter to completely turn on/off a beam of light.
2. Electro-optic beam attenuator to vary the intensity of a beam of light.
3. Electro-optic Polarization Rotator to rotate the polarization state of a beam of light either clockwise or anti-clockwise.
4. Electro-optic variable wave plate to delay the time of flight of a beam of light. It can be designed to be a quarter wave or half wave plate.

5. Electro-optic modulator with 2.8MHz Sine Wave switching was developed.

The Liquid Crystals used for the investigations of electro-optic studies are

1. MBBA (Methoxy benzilidene Butyl aniline) ----- room temperature LC.

2. \( p-n \)-alkoxy benzoic acids( nOBA)

3. \( p-(p'-ethoxy benzylidene)-p \)-cyano aniline (EBCA)

4. \( p-n \)-alkoxy benzoic acids: \( p-(p'-ethoxy benzylidene)-p \)-cyano aniline (nOBA: EBCA) --- mixtures

5. Nano doped \( p-n \)-alkoxy benzoic acids (nOBA-n) ----- nano ferro mixtures

6. Ferro electric liquid crystal-12bpa

7. Bent liquid crystal-Bent-7

**Salient features of the present work:**

1. Design and fabrication of rotating polarizing spectrometer.

   Rotating polarizing spectrometer (RPS) has two optical channels. One channel is sample channel and the other channel is reference channel. For both the channels light from the two diode lasers passes through a polarizer, rotating analyzer and finally falls on a photo transistor. The output from the two photo transistors is sine wave. The sine wave from the reference channel is given to the reference input of the lock in amplifier. Another sine wave from the sample channel is given to the input of the Lock in Amplifier. In the path of the sample beam, Liquid Crystal sample is placed which will change the polarization with change in temperature, electric field. The phase change between sample and reference channel is measured on the lock in amplifier. There are
many methods to determine phase transitions but this rotating polarizing technique is found to be relatively simple and more accurate. In this method, the accuracy is independent of the variations of source intensity and detector parameters.

The thesis deals with two aspects of Liquid crystals.

1. **Theoretical aspects**

i) Design and fabrication of Rotating Polarizer Spectrometer, thin Liquid Crystal sample holder with heating elements, thyristor temperature controller, measurement of electro-optic properties of liquid crystal material with electric field and temperature.

ii) Calibration of instrument by studying the variation of optical polarizing angle of Glucose and Fructose with concentration.

iii) Resolving the peaks of Phase Transitions of Liquid Crystal samples with temperature. We have determined the phase transitions of the liquid crystals for the compounds mentioned above.

2. **Application aspects.**

This part deals with the applications and evaluation of certain important properties of Liquid crystals pertinent to electro-optic modulators, electro optic switches, optical polarizability of Nematic and Banana or bent liquid crystals.

- Study of optical polarization properties of liquid crystals.
- The studies of electronically tunable optical polarization and birefringence.
- Development of electro-optic modulator and study of switching characteristics and frequency response.
The birefringence of a Liquid Crystal is dependent on applied voltage, wavelength, and temperature. In these experiments, the temperature and voltage dependence was studied. Measurements were studied at different temperatures. An optical polarization plot was studied with different applied voltages.

These technologies can be extended from single, large apertures to segmented, or pixelated, apertures – also known as spatial light modulators (SLMs). With an SLM one can spatially vary the amount of modulation to create a variety of optical functions. For instance computer generated holograms can be implemented, wavefront errors can be corrected, atmospheric turbulence can be simulated, beams can be steered, pulses can be shaped, or coherent images can be implemented for optical processing.

Polarization Rotators offers the maximum switching speed between two orthogonal output states. Depending on drive voltage and wavelength the switching frequencies can be as high as 2MHz. Even higher frequencies can be utilized if rotation angles of less than 90° can be accommodated. Response times are approximately equal in both directions (positive polarity to negative polarity and vice versa) at <100 us typically, but can be as short as 15 us with higher drive voltages.

This device behaves optically like a zero-order half-wave retarder mounted in a mechanical rotation stage. Varying the electric field is identical to rotating the mechanical stage. The rotation angle varies with both drive amplitude and polarity. The positive maximum voltage will give the maximum rotation in one direction, while the
negative maximum voltage will give the maximum rotation in the opposite direction. Therefore both positive and negative drive voltages are required to achieve the full 90° rotation range. In addition, the drive signal must have a zero dc offset, implying with a typical square-wave drive the output will have a 50:50 duty cycle between the 0° and 90° states. However, pulsed drives with varying voltage levels can be utilized to change the duty cycle as long as the signal has no net dc offset, and as long as the threshold voltage of the device is not exceeded.

A stable output rotation angle can be held indefinitely, but will vary with changes in drive voltage or operating temperature. Usually the drive signal must be ac, with zero dc offset to prevent damaging the device. Typically a 2 kHz square-wave is suitable. Varying the amplitude of the square-wave (while maintaining a zero dc offset) results in changing the rotation angle. A voltage of 0 V yields the maximum rotation of 90°, while the maximum voltage (typically ±10 V) yields 0° of rotation.

In the experiment, practically a D.C voltage is applied to the LC cell without considerable damage due to electrical polarizing effects to study the property of beam attenuator. For this purpose highly pure sample was prepared to avoid electrical conduction and polarization.

**Tunable Liquid Crystal Cell:**

For the purpose of studying the electro-optic properties of Liquid Crystals, a specially fabricated surface stabilized glass cell was imported from USA with 5 micrometers separation and a pre tilt angle. One of the critical components for studying the electro-optic properties of liquid crystals is the sample cell. A small separation of 5.0μm±0.2μm will provide a very high electric field with lower voltages. The
specification of the cell is given below.

Transparent conductive tracks are on the small projection of one of the glass plates. Teflon wires are soldered to the tracks by a special ultrasonic soldering machine. A small pin hole is provided to the cell for filling up the sample. Specialized techniques for filling the cell with solid and liquid samples were adopted.

3. OPTICAL MODULATION

A 2 MHz Sine wave with a maximum, Control voltage of 20v p-p is applied to the LC Cell. The voltage was varied between 0-20V. The Laser beam made passing through the LC Cell electro-optic modulator falls on to a photo transistor. The output of the photo transistor was observed on a digital storage oscilloscope. Based on the studies of various electro-optic properties of different types of Liquid Crystals, the electro-optic devices mentioned above were developed. In the following five Chapters the results of the conducted research are presented in detail.

Chapter 1.

The introductory part presents a short overview of electrically-controlled director reorientation effect, which is at the core of all electro-optical applications of LCs, clarifies the motivation behind the choice of the dissertation topic and explains the objectives of the thesis.

Chapter 2.

It presents the introductory part of theory of different types of liquid crystals with its structures and properties.
Chapter 3.

It explains the possibility of refraction in regular birefringent materials in the certain range of angles of the light incidence and for the first time presents the experimental observation of electrically tunable refraction in nematic LC.

Chapter 4.

This chapter deals with Design of Rotating Polarizing Spectrometer, temperature controlled sample chamber, LASER driver, and relevant electronic circuits.

Chapter 5.

This chapter deals with the Calibration of instrument by studying the variation of optical polarizing angle of Glucose and Fructose with concentration. It summarizes the results of the research presented in the dissertation and discusses the development of electrooptic devices.