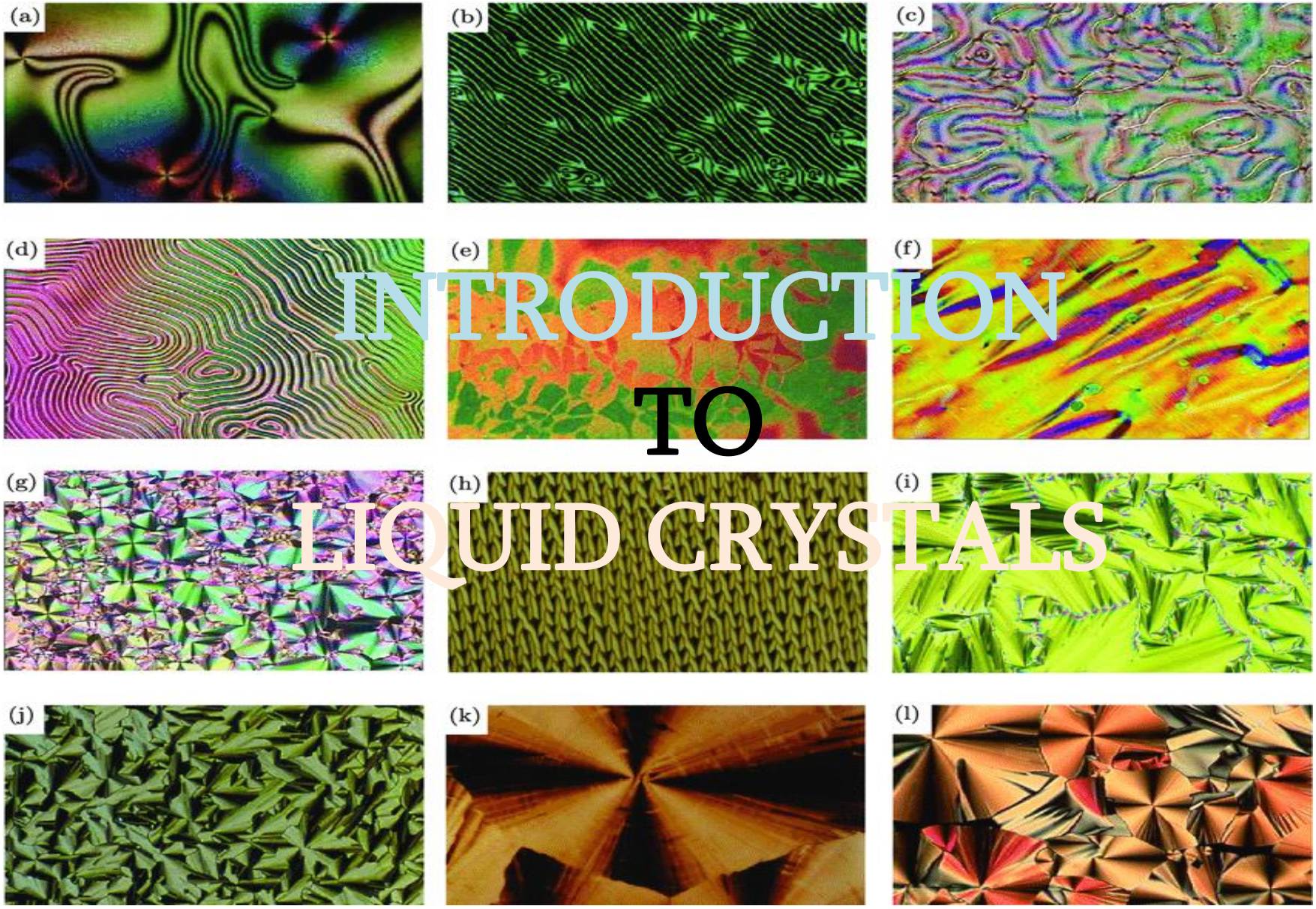
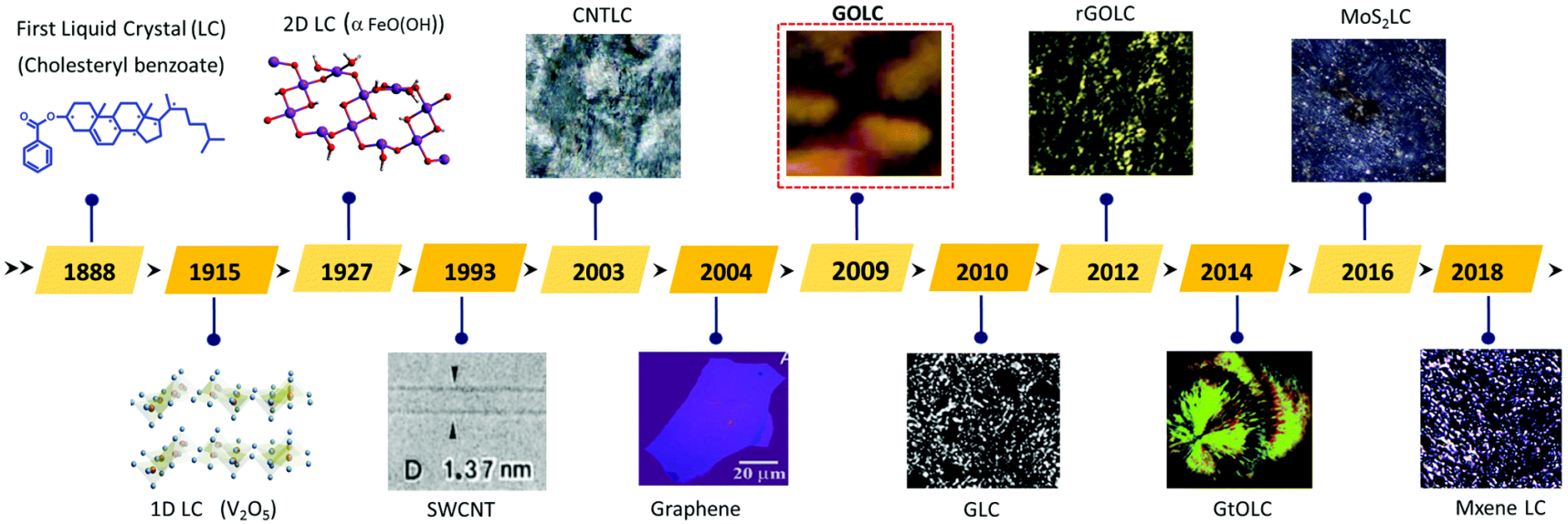
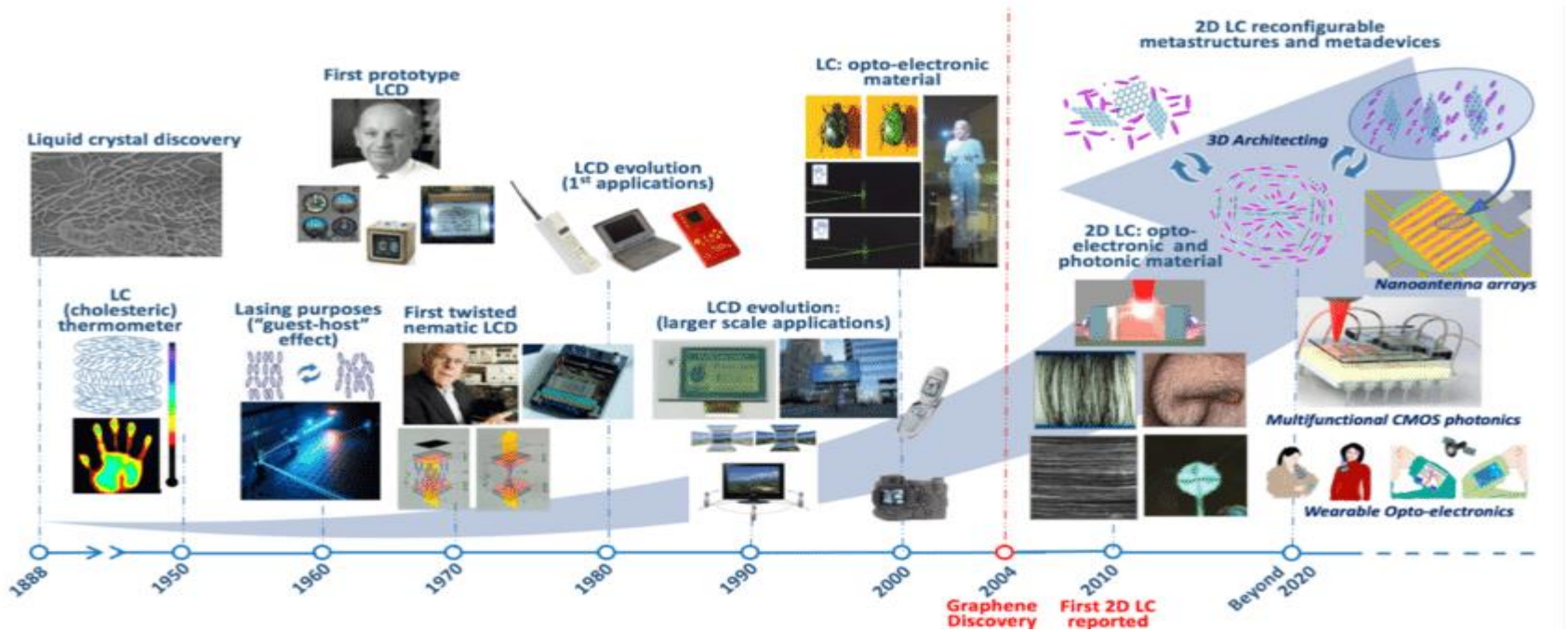


INTRODUCTION TO LIQUID CRYSTALS


First Liquid Crystal (LC)
(Cholesteryl benzoate)
2D LC (α FeO(OH))
CNTLC
GOLC
rGOLC
MoS2LC
1888
1915
1927
1993
2003
2004
2009
2010
2012
2014
2016
2018
1D LC (V2O5)
D 1.37 nm
SWCNT
20 μm
Graphene
GLC
GtOLC
Mxene LC


Liquid crystal discovery
First prototype LCD
LCD evolution (1st applications)
LC: opto-electronic material
2D LC reconfigurable metastructures and metadevices
3D Architecting
2D LC: opto-electronic and photonic material
Nanoantenna arrays
LC (cholesteric) thermometer
Lasing purposes ("guest-host" effect)
First twisted nematic LCD
LCD evolution: (larger scale applications)
Multifunctional CMOS photonics
Wearable Opto-electronics
1888
1950
1960
1970
1980
1990
2000
2004
Graphene Discovery
2010
First 2D LC reported
Beyond 2020

What different phases

- **Solid Phase**

  Molecules with both orientation and positional orders, and are held to each other strongly.

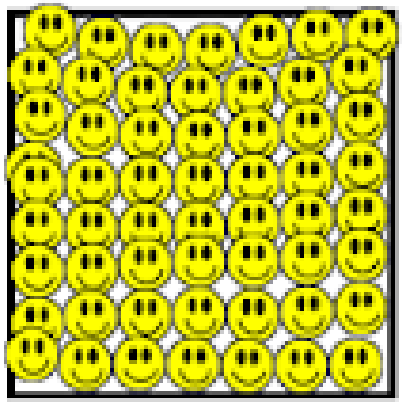
- **Liquid Phase**

  Molecules with no orientation and positional orders, but are held together by weak intermolecular forces.

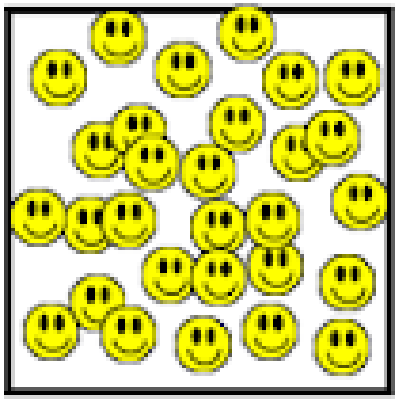
- **Gas Phase**

  No ordering, no intermolecular attraction

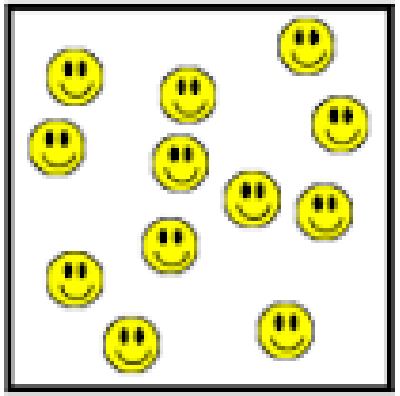
Pictorial Representation



Solid



Liquid



Gas

Introduction to Liquid Crystals

In 1988, Austrian Botanist Friedrich Reinitzer

⇨ **to study the role of cholesterol in plants**

⇨ **Found two melting point 145.5 ºC and at 178.5 ºC.**

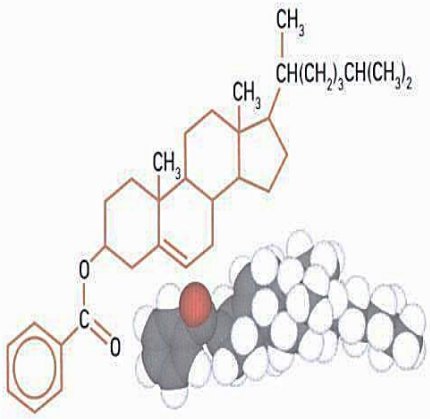
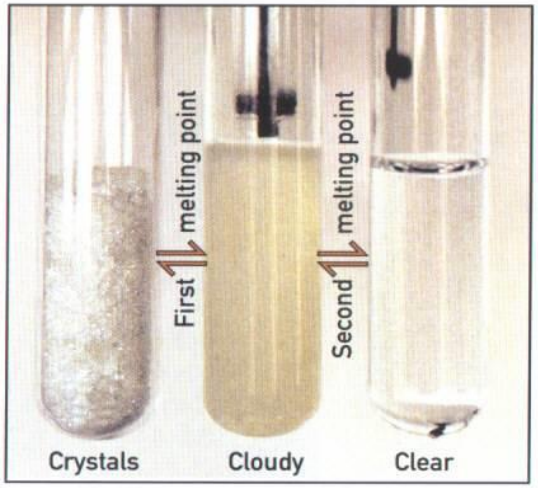


Figure 3. The rod-like molecular structure of cholesteryl benzoate.



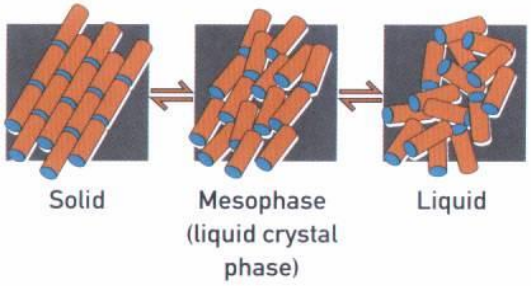


Figure 1. In the liquid crystal state, rod-shaped molecules can move about but still point in the same general direction.

Otto Lehmann, examined the cloudy ‘in-between phase’

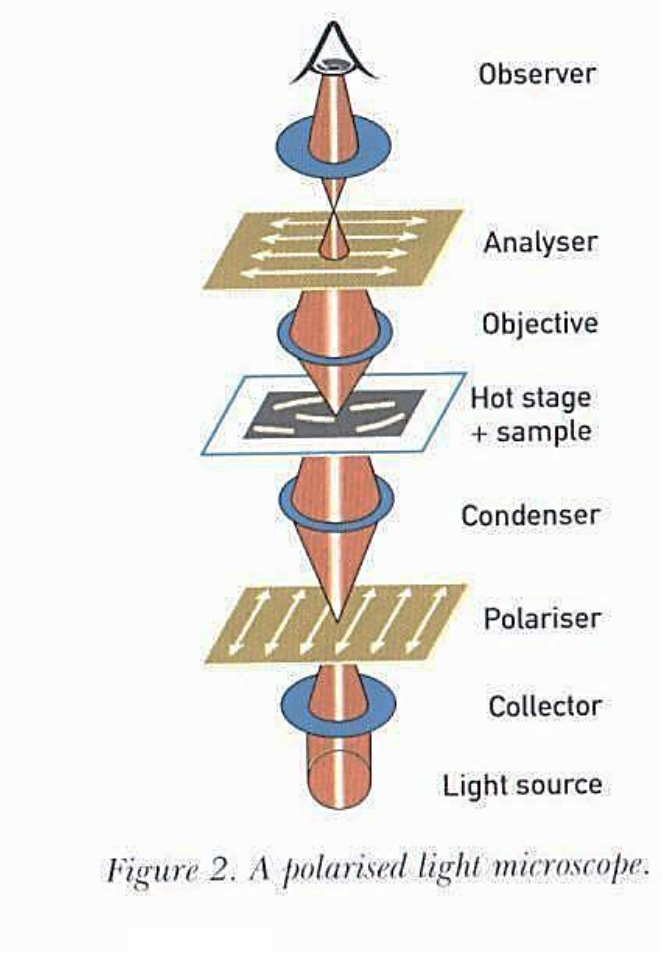
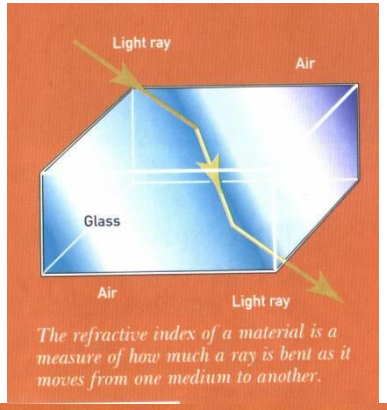
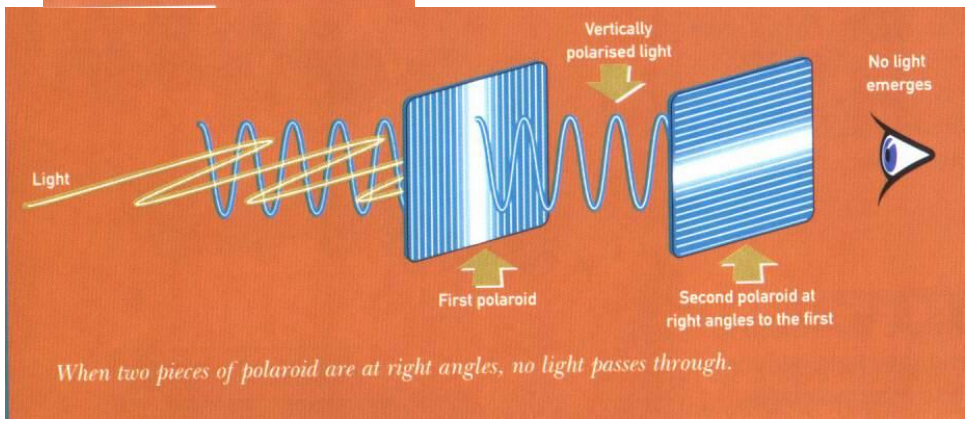


Figure 2. A polarised light microscope.

“*mesophase*”



The refractive index of a material is a measure of how much a ray is bent as it moves from one medium to another.

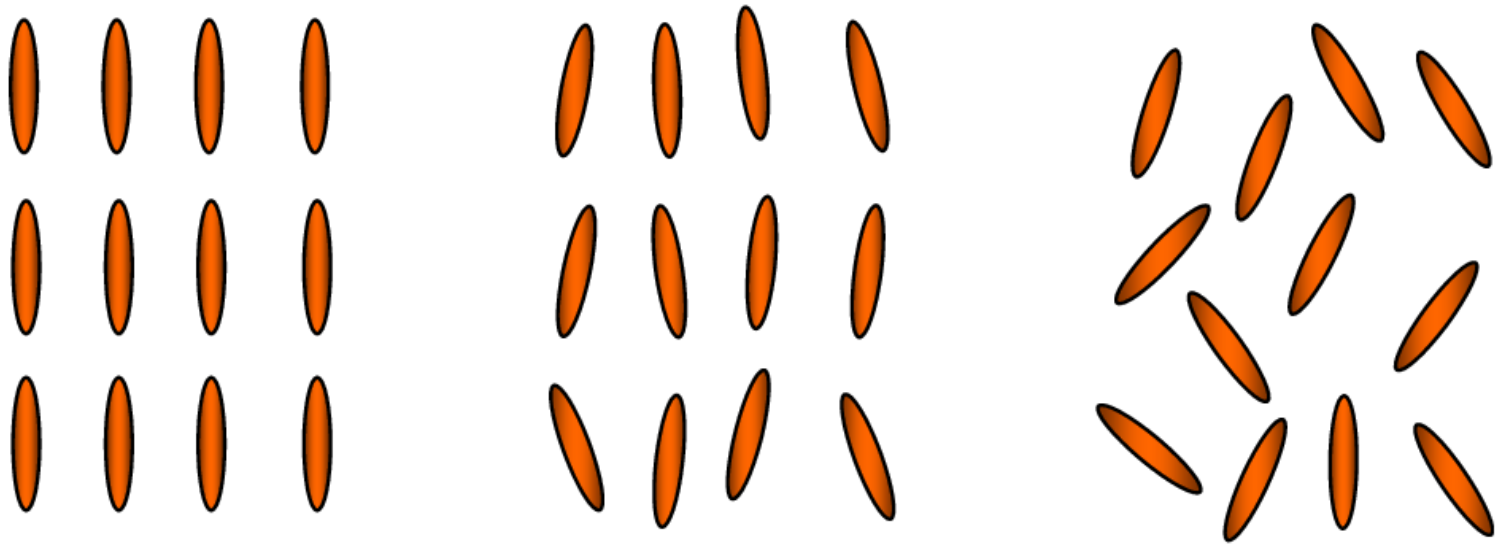


When two pieces of polaroid are at right angles, no light passes through.

- Liquid Crystals are soft condensed matters discovered in 1888 by Physicist Otto Lehmann.

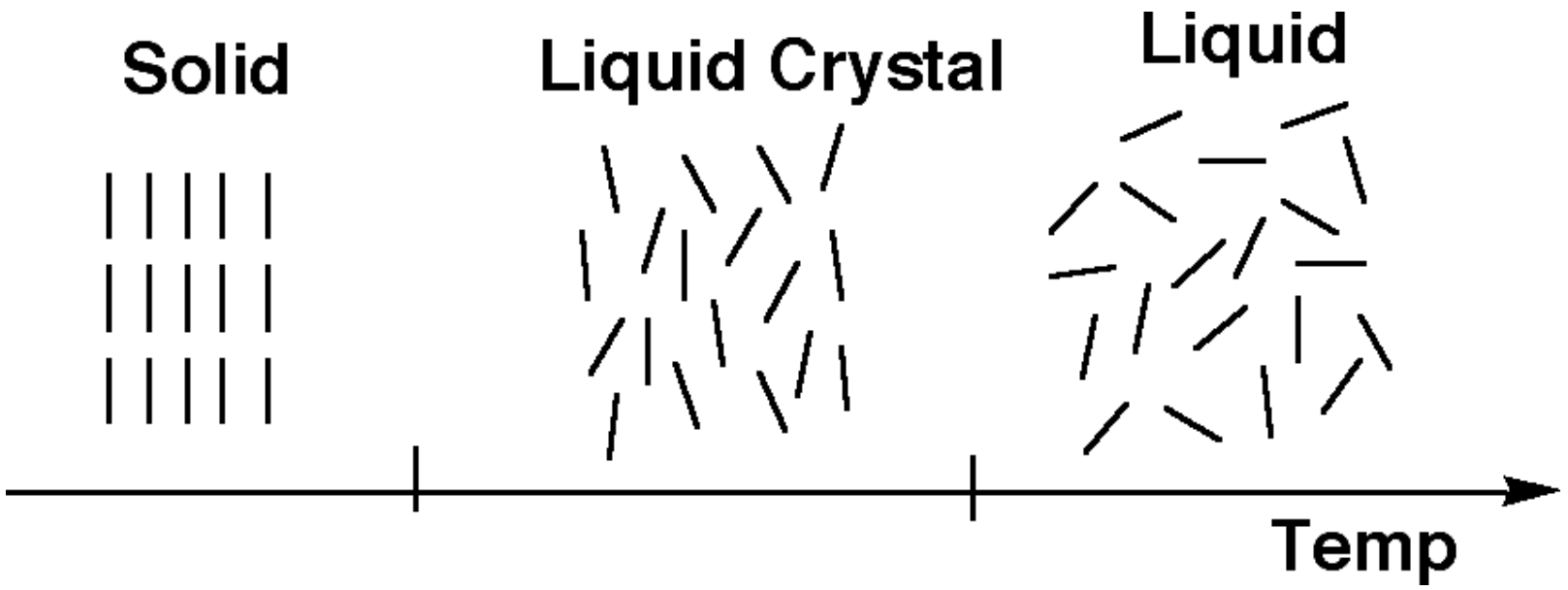
- Positional order may be lost, but some of orientational order remains.

- Also referred as *mesophase.*


Solid
Liquid crystal
Liquid

Liquid Crystal Phase

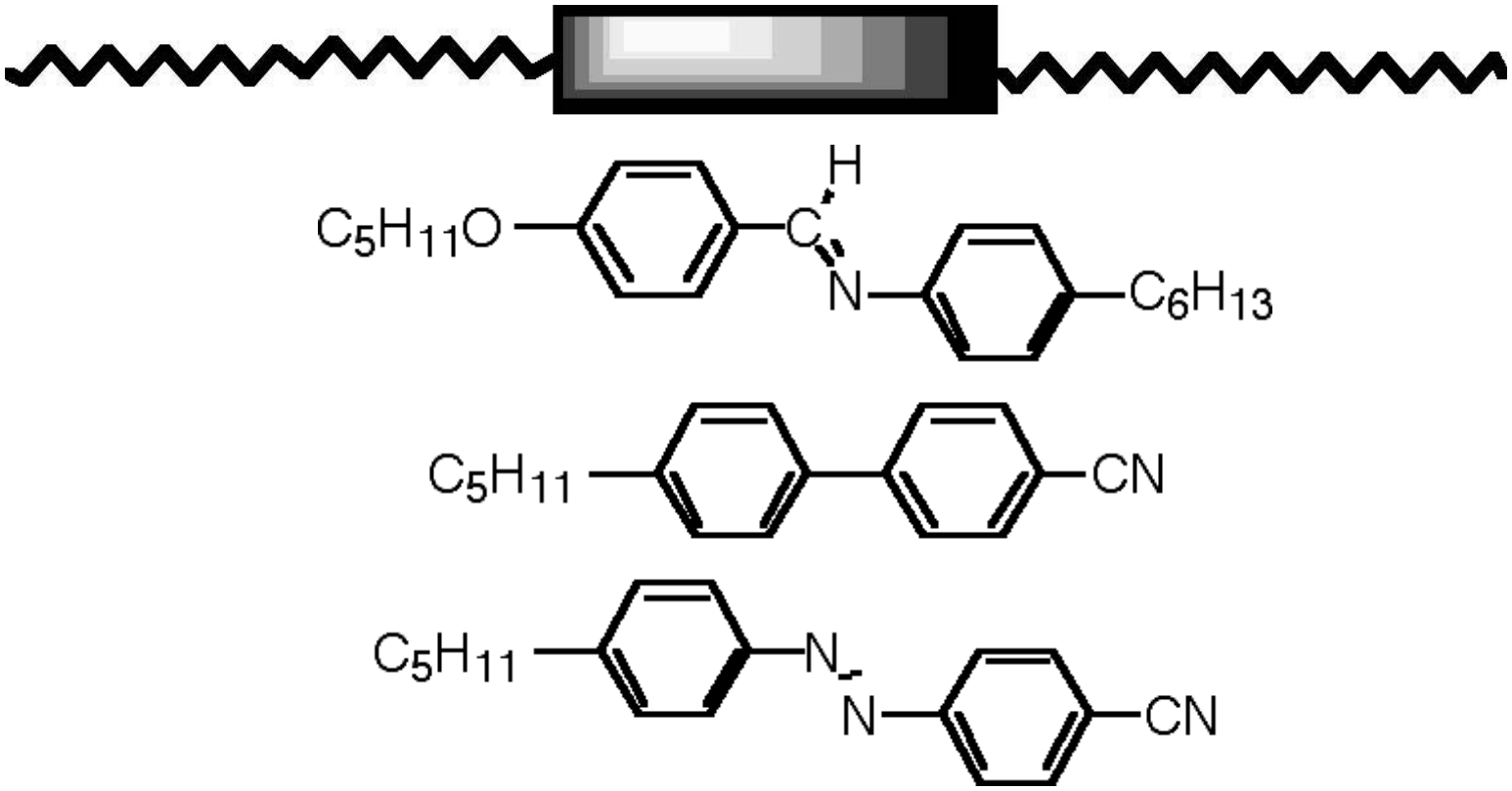
- A fluid phase in which a molecule flows and will take the shape of its container.
- It differs from liquid that there are still some orientational order possessed by the molecules.



Criteria for a molecule being liquid crystal

- The molecule must be elongated in shape- length should be significantly greater than its width.
- Molecule must have some rigidity in its central region.
- The ends of the molecule are somewhat flexible.

Typical representation of a LC molecule

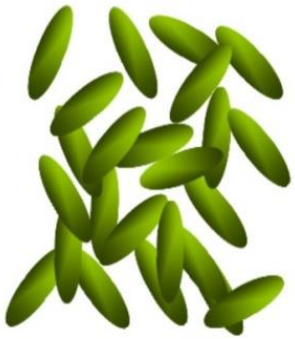


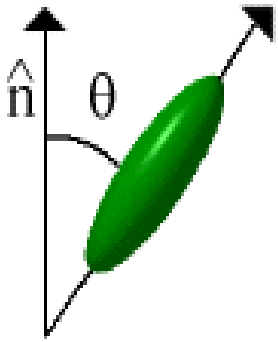
Mesogens

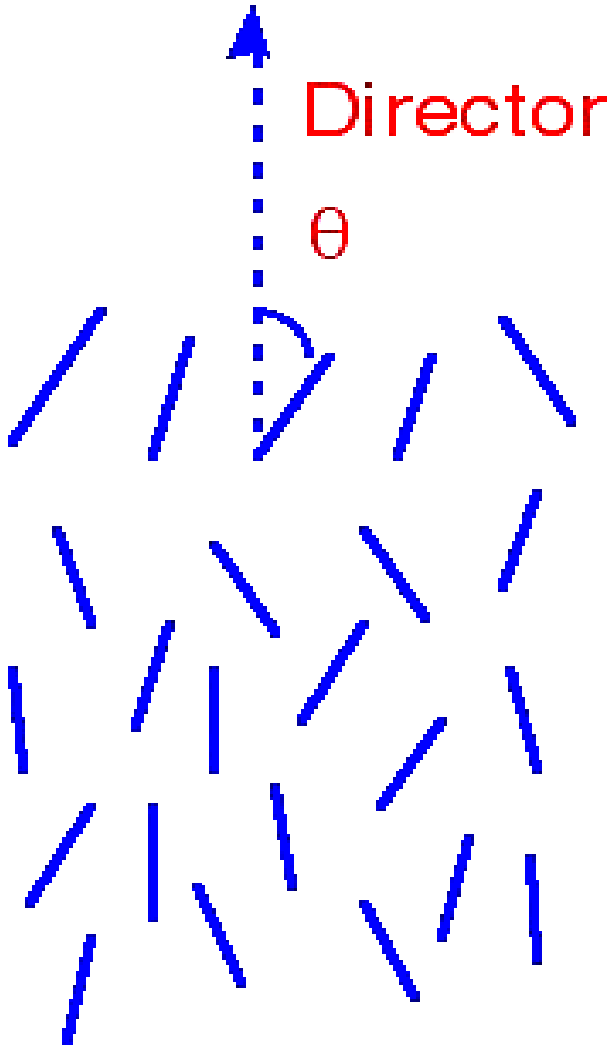
Note: these molecules possess very strong dipole moment

Director

Assuming that the direction of preferred orientation in a liquid crystal (LC) is ↑, this direction can be represented by an arrow, called the *director* of the LC.







Order Parameter

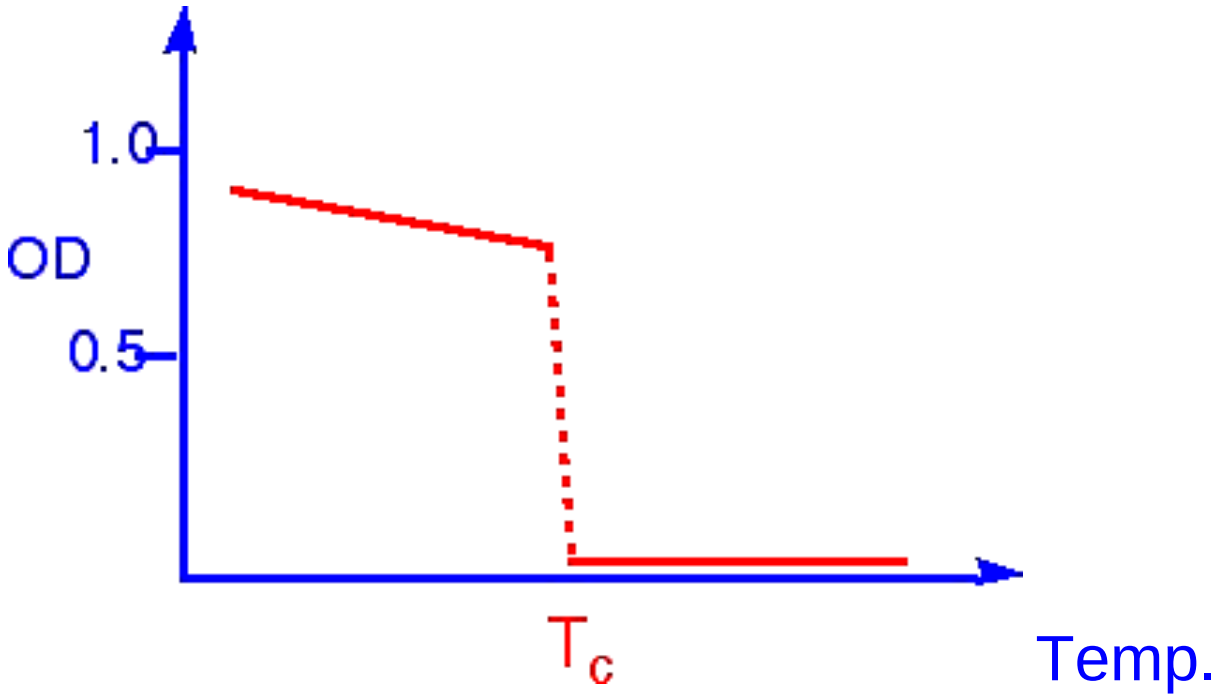
- Each molecule is orientated at some angle to the director
- Measure the angle of all the molecule with the director and obtain the average angle as a measure of the degree of orientational order as θ.

$$\textbf{Order parameter (S)} = \frac{[(3cos^2\theta)-1]}{2}$$

For perfect orientation: θ for all molecules = 0° and S = 1

For completely random orientation: S = 0

- The order parameter decreases as the temperature is increased
- Typical values of order parameter (S) are ~ 0.3 to 0.9



T_c: transition temperature from LC to liquid state

Types of Liquid Crystals

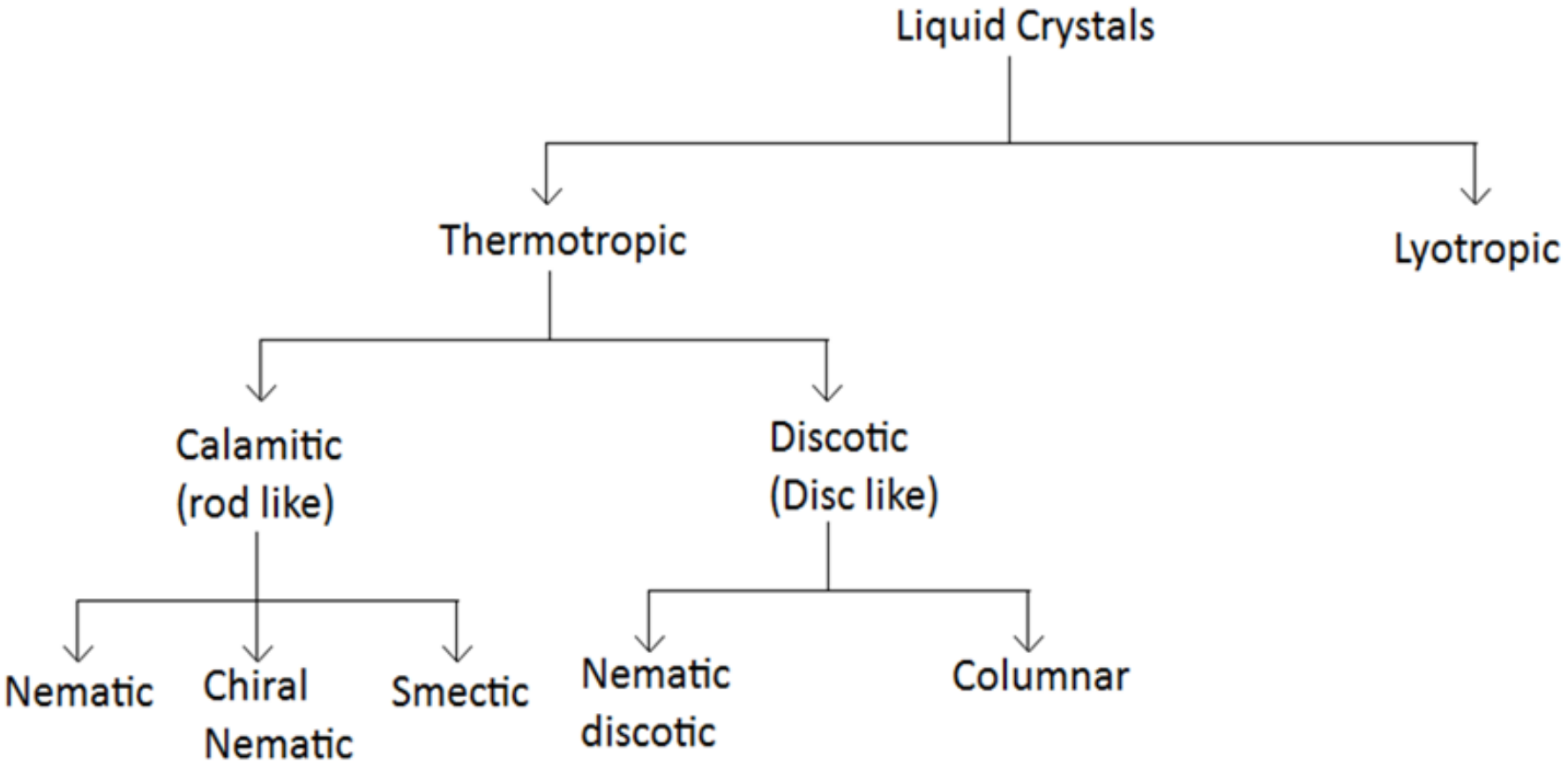
Thermotropic Liquid Crystals

- LC phase transitions resulted from temperature changes

Lytropic Liquid Crystals

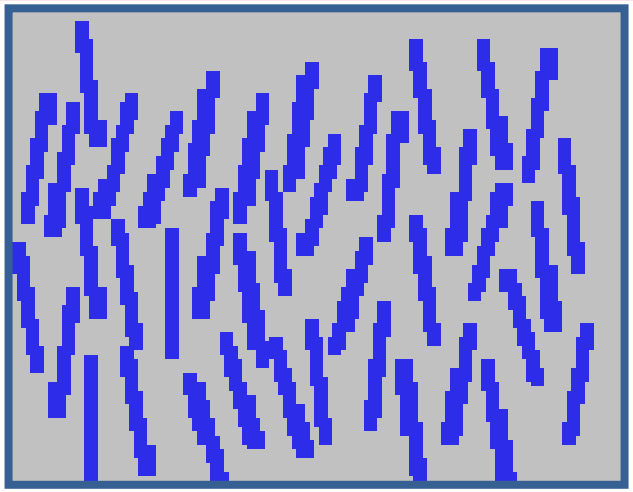
- LC phase is formed when a molecule is dissolved in a suitable solvent (with specific concentration at a particular temperature)

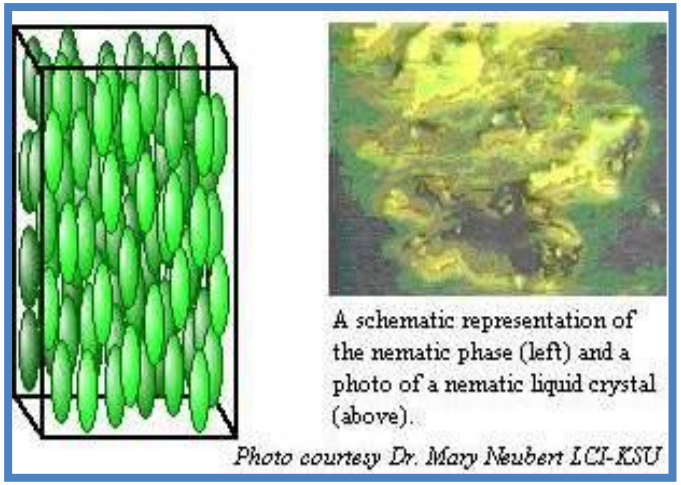
CLASSIFICATION OF LIQUID CRYSTALS



NEMATIC LIQUID CRYSTALS

- Simplest form of a liquid crystal
- Molecules are arranged in one layer
- Long-range orientational order but no positional order
- Molecules in this phase are long and rod-like in shape. They are free to move in space.



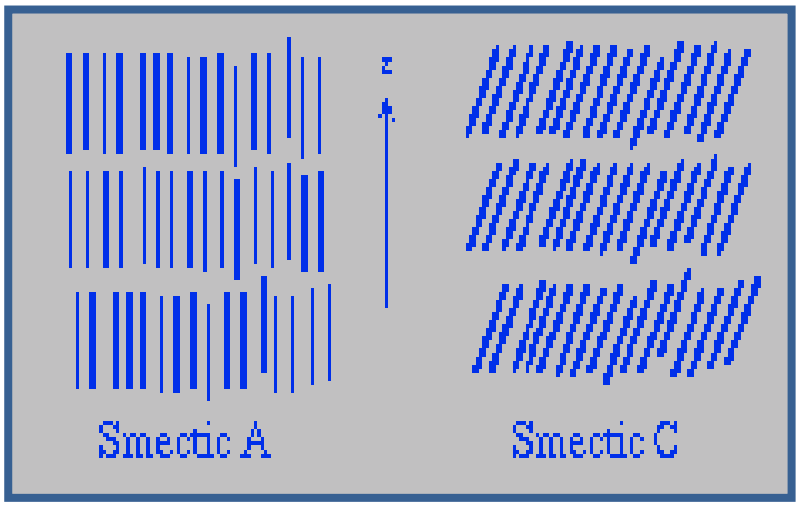


PROPERTIES OF NEMATIC CRYSTALS

- Despite the high degree of orientational order, nematic phase as a whole is in disorder i.e. NO MACROSCOPIC ORDER (orientation within a group is similar but not from one group to another).
- Structure of nematic phase can be altered in a number of ways. E.g. electric or magnetic field or treatment of surfaces of the sample container.
- They changes plane of vibration becomes perpendicular when small potential difference is applied
- Thus, possible to have microscopic order & macroscopic order.
- Nematic liquid crystals are widely used in electro-optic display devices .

SMECTIC LIQUID CRYSTALS

- It occurs at a temperature below nematic and cholesteric.
- Molecules align themselves parallel & tend to arrange in layers.
- All positional order is not destroyed when a crystal melts to form this liquid crystal.
- Chiral Smectic C liquid crystals are useful in LCDS.
- They are also known as soap like as the layers slide over the other.

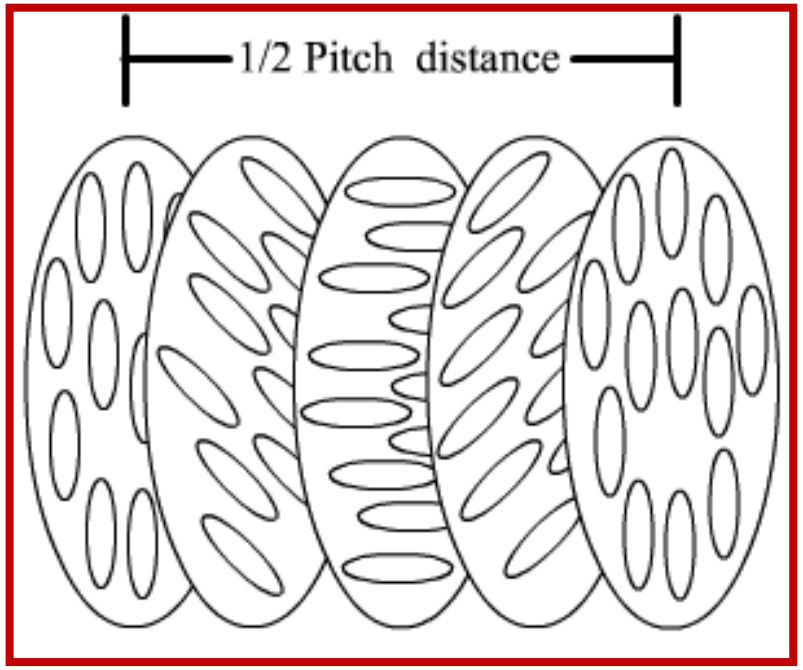


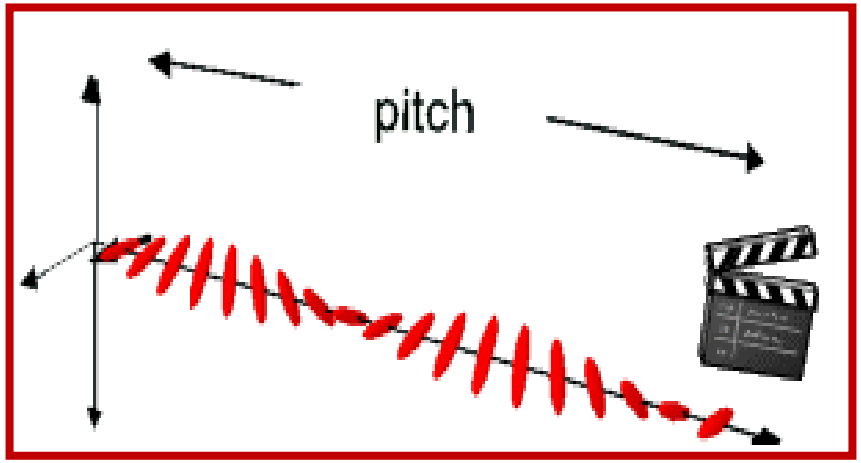
CHOLESTERIC LIQUID CRYSTALS

- The first liquid crystal that was observed through a polarizing microscope is cholesteryl benzoate. Thus, CHOLESTERIC liquid crystal OR chiral nematic liquid crystal.
- Cholesteric liquid crystals have great potential uses as
  - Sensors
  - Thermometer
  - Fashion fabrics that change colour with temperature
  - Display devices

PROPERTIES OF CHOLESTERIC CRYSTALS

- In CHOLESTERIC phase, there is orientational order & no positional order, but, director is in HELICAL ORDER.
- The structure of cholesteric depends on the PITCH, the distance over which the director makes one complete turn i.e. 360°.
- One pitch - several hundred nanometers (170 nm-200 nm)
- Pitch is affected by:-
  - Temperature
  - Pressure
  - Electric & magnetic fields



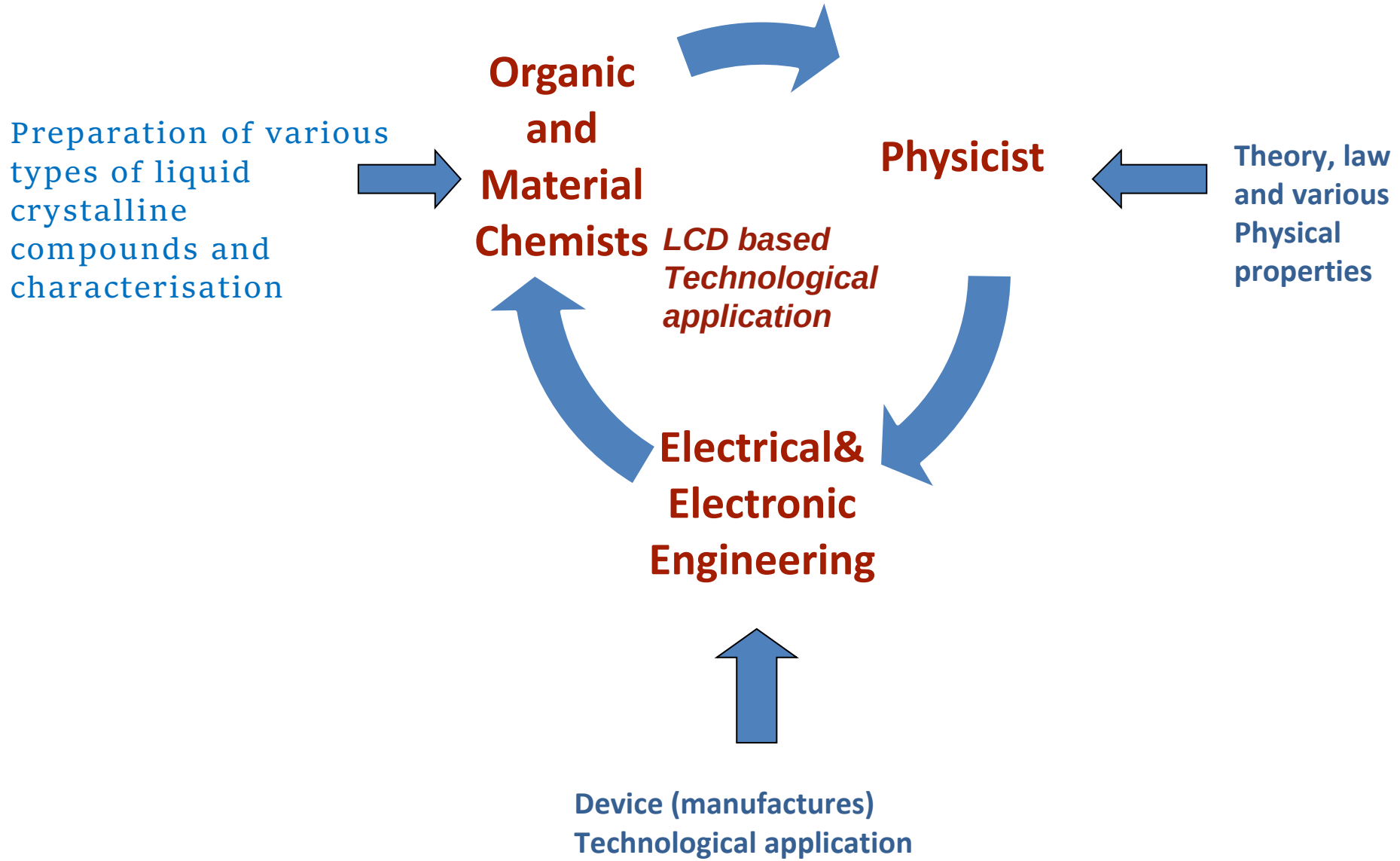


Applications of liquid Crystals

Applications of Liquid Crystals

- LCD (Liquid crystal display)
- Liquid crystal thermometer
- Liquid crystal lenses
- Liquid crystal laser
- Optical Images
- Medicinal Uses
- Helmets and bullet proof Jackets
- Optical memories

LCD: MULTIDISCIPLINARY AREA



WORKING OF LCD'S

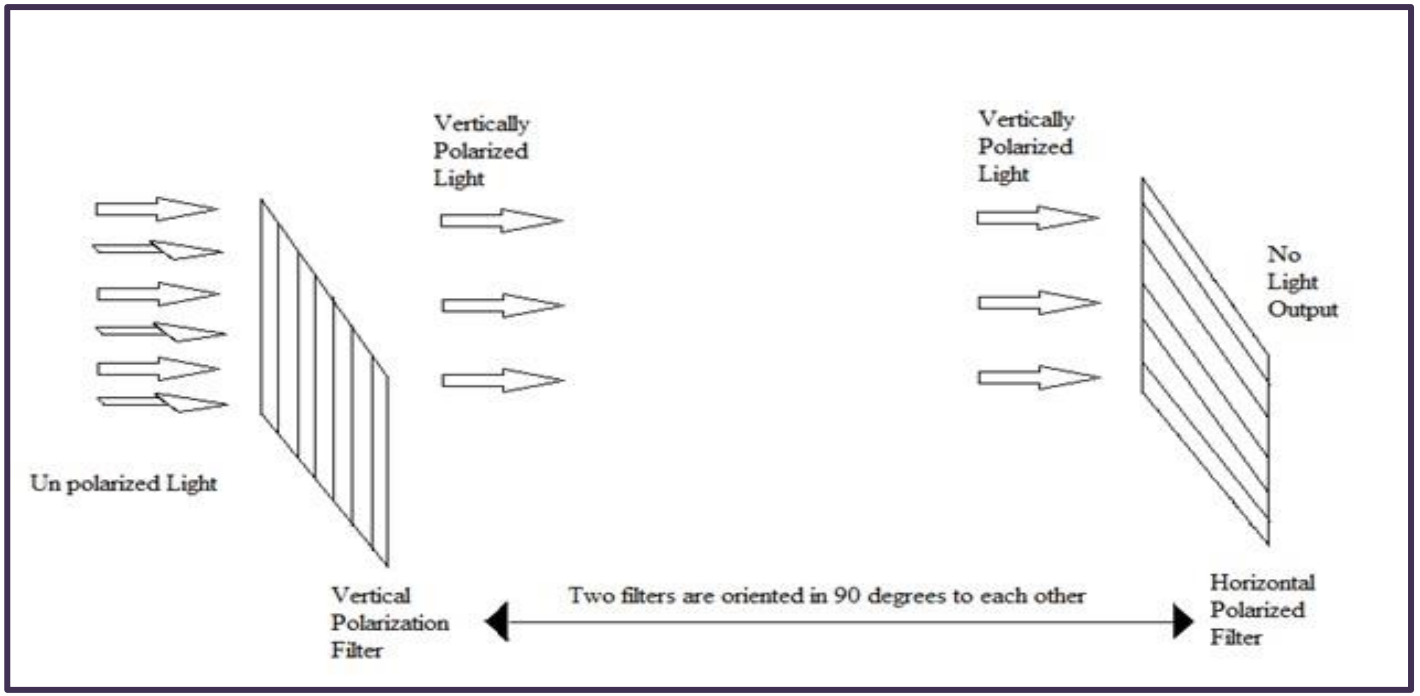
LCD's work using the four main concepts:

1. Light can be polarized.
2. Liquid crystals can transmit and change polarized light.
3. The structure of liquid crystals can be changed by electric currents.
4. These are transparent substances that can conduct electricity.

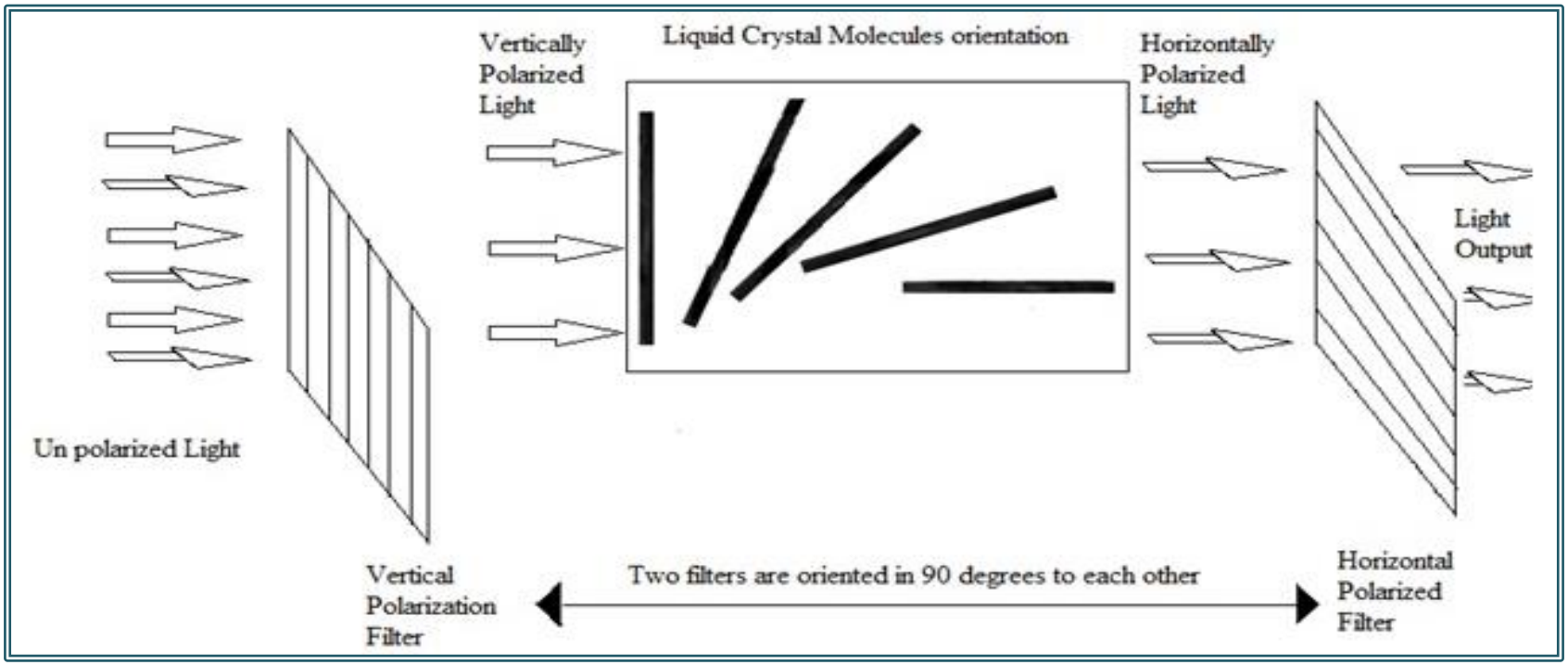
CONSTRUCTION OF LED

•**There are two polarization filters oriented at 90° angle to each other. These filters are used to polarize the Unpolarized light.**

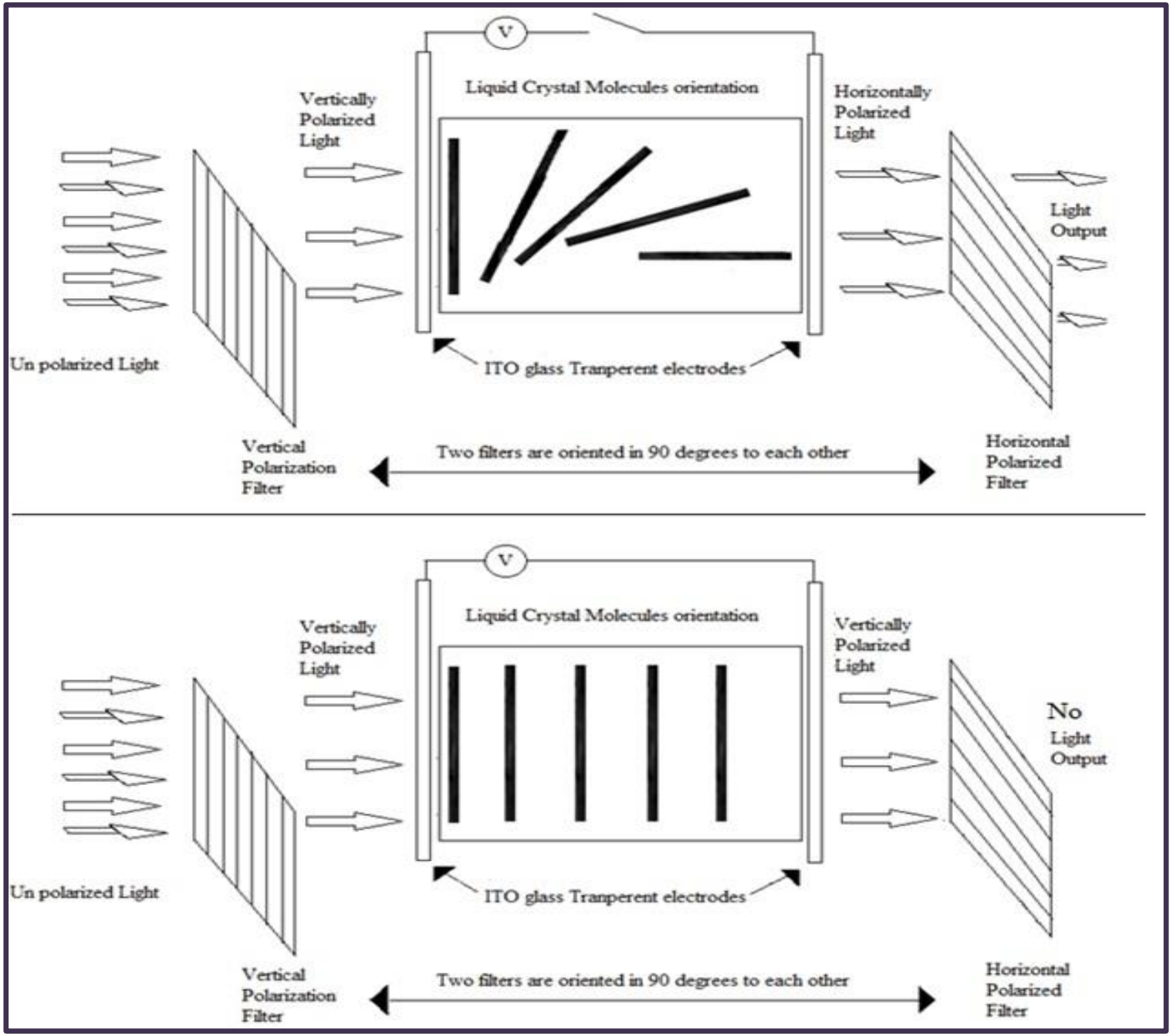
•**The first filter (Vertical polarized filter) polarizes the light with one polarization plane (Vertical). When the vertically polarized light passes through the second filter (Horizontal polarized filter) no light is produced at the o/p.**



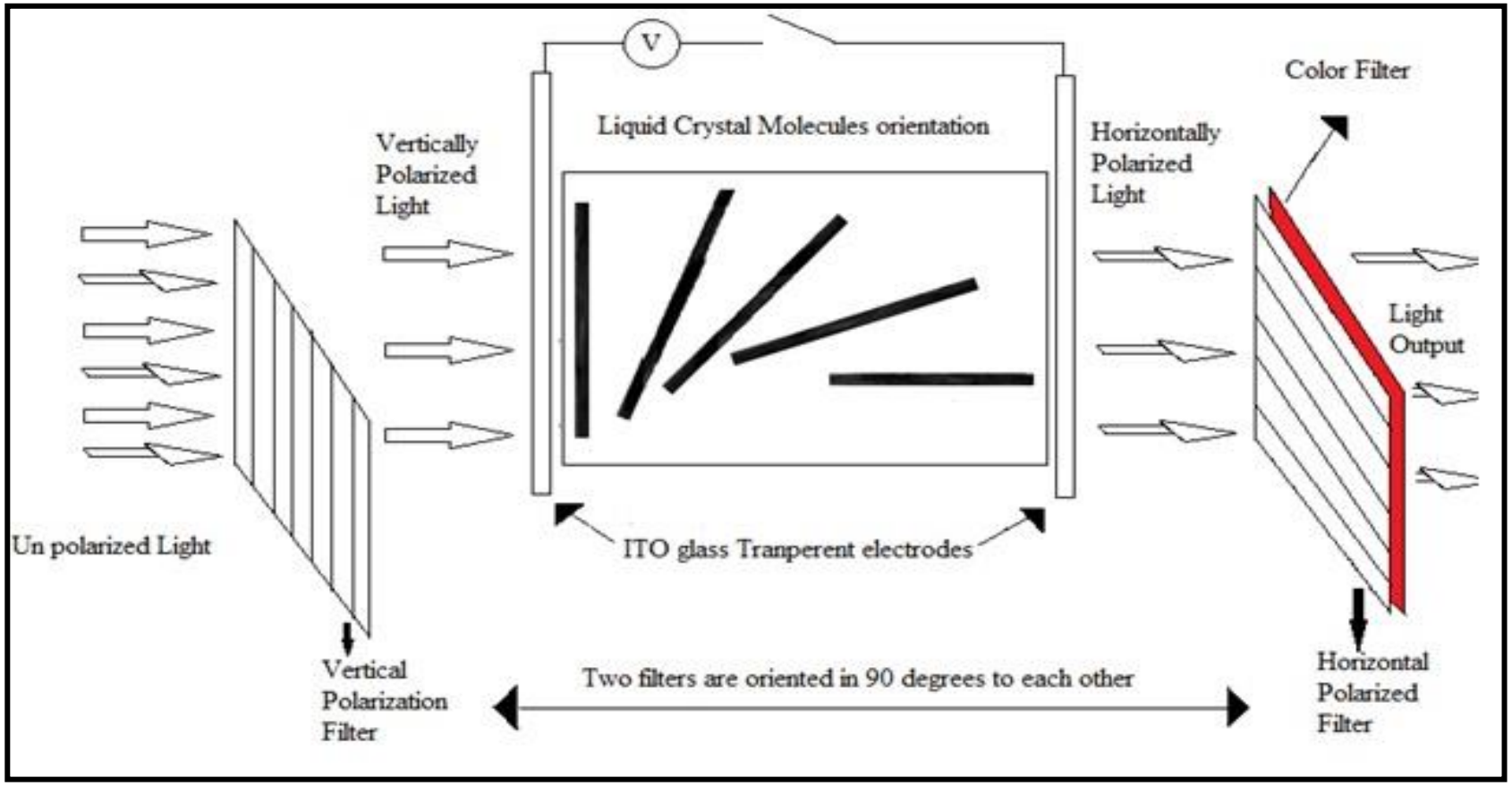
- **The vertically polarized light should rotate at 90° in order to pass the horizontally polarized light. This can be achieved by embedding liquid crystal layer between two polarization filters.**
- **The liquid crystal layer consists of rod shaped tiny molecules and ordering of these molecules creates directional orientation property.**
- **These molecules in the liquid crystal are twisted at 90° degrees. The vertically polarized light passes through the rotated molecules and gets twisted to 90°. When the orientation of light matches with the outer polarization filter, light passes and brightens the screen.**



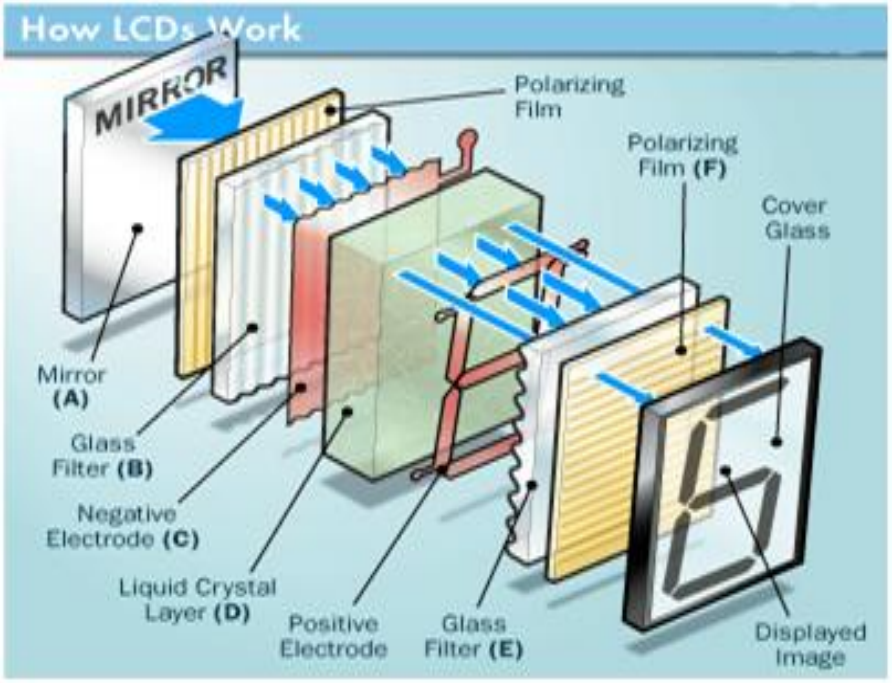
- If the Liquid crystal molecules are twisted at 90° more precisely, then more light will pass through it.
- Two electrodes are aligned in the front and back of the liquid crystal in order to change the orientation of the crystal molecules by applying voltage between them.
- If no voltage is applied b/w the electrodes, the orientation remains twisted at 90 °, the light passes through the outer filter and thus the pixel appears white.
- If a voltage is applied, the molecules in the liquid crystal layer changes its orientation, changing the orientation of light that gets blocked by the outer filter, and thus the pixel appears black.
- In this way, black and white images or characters are produced.
- By controlling the voltage applied between liquid crystal layers in each pixel, light can be allowed to pass through outer polarization filter in various amounts, so that it becomes possible to produce different gray levels on the LCD screen.

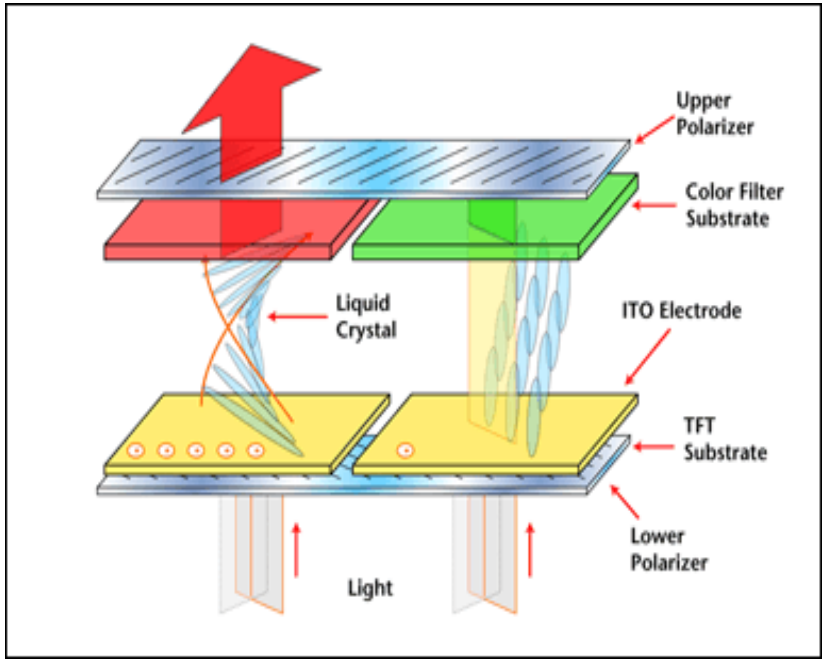

V
Liquid Crystal Molecules orientation
Vertically Polarized Light
Horizontally Polarized Light
Light Output
Un polarized Light
ITO glass Tranperent electrodes
Vertical Polarization Filter
Two filters are oriented in 90 degrees to each other
Horizontal Polarized Filter
V
Liquid Crystal Molecules orientation
Vertically Polarized Light
Vertically Polarized Light
No Light Output
Un polarized Light
ITO glass Tranperent electrodes
Vertical Polarization Filter
Two filters are oriented in 90 degrees to each other
Horizontal Polarized Filter

In order to produce color images a color filter is placed in front of the outer polarization plate. The red, green and blue are the three standard colors filters are placed for every three pixels to produce different color images by varying the intensity of each color.



Liquid Crystal Display(LCD)

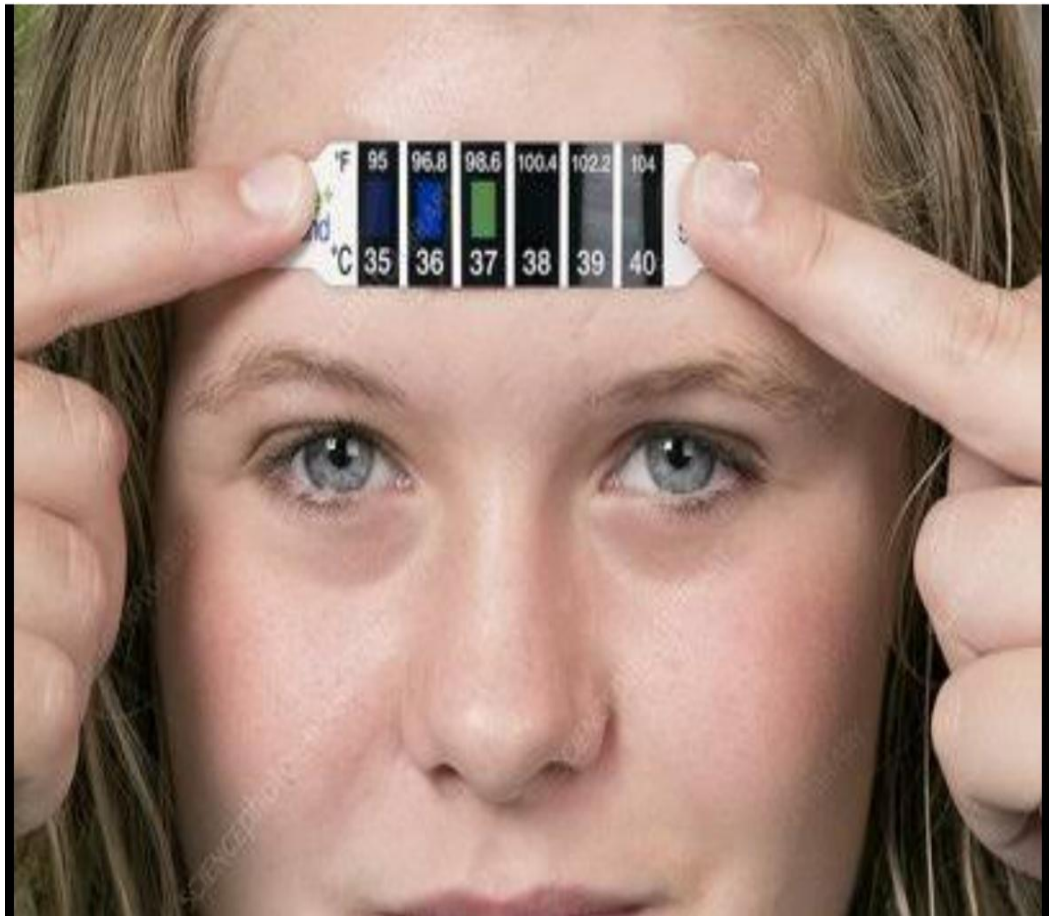




ADVANTAGES OF LCD

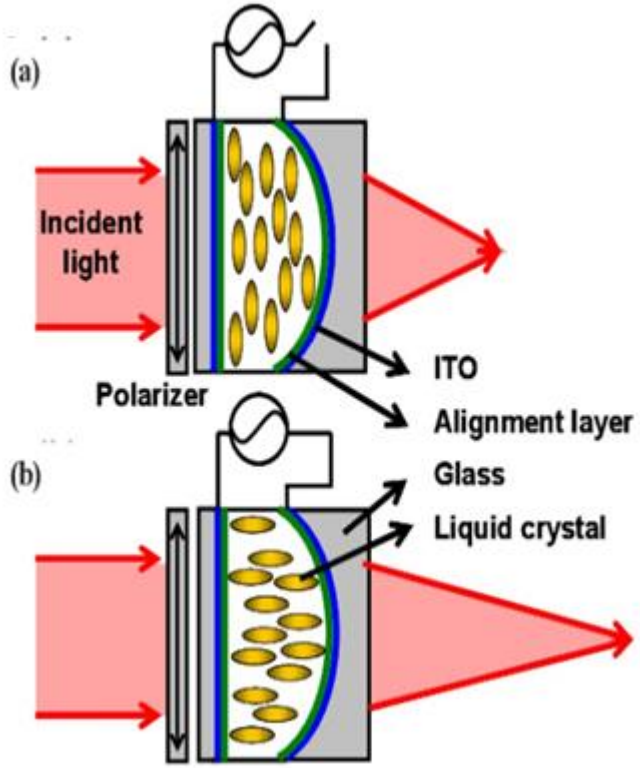
Brightness	Produces very bright images due to high peak intensity. Very suitable for environments that are brightly lit .
Emissions	Produce considerably lower electric, magnetic and electromagnetic fields than CRTs.
Geometric Distortion	No geometric distortion at the native resolution. Minor distortion can occur for other resolutions.
Power Consumption	Energy efficient. Consume less than 1/3 the power of a comparable CRT. Consume less electricity than a CRT and produce little heat.
Physical Aspects	Take up about 40% less desk space. LCDs are thin and compact.
Screen Shape	Completely flat screen.
Sharpness	At the native resolution, the image is perfectly sharp. Adjustments are required at all other resolutions which can result in measurable degradation to the image.

Liquid crystal thermometer

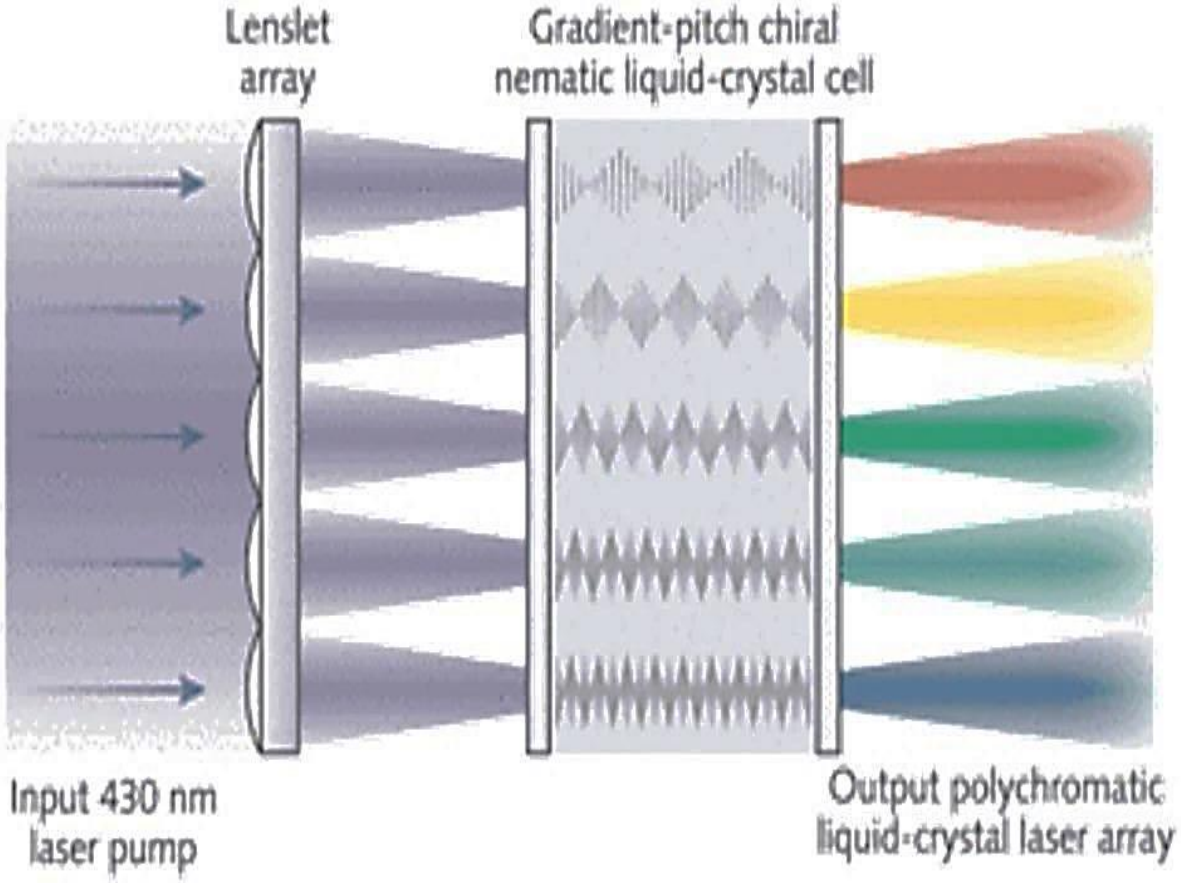


Liquid crystal Lenses

Focus can be tuned by applying electric field.

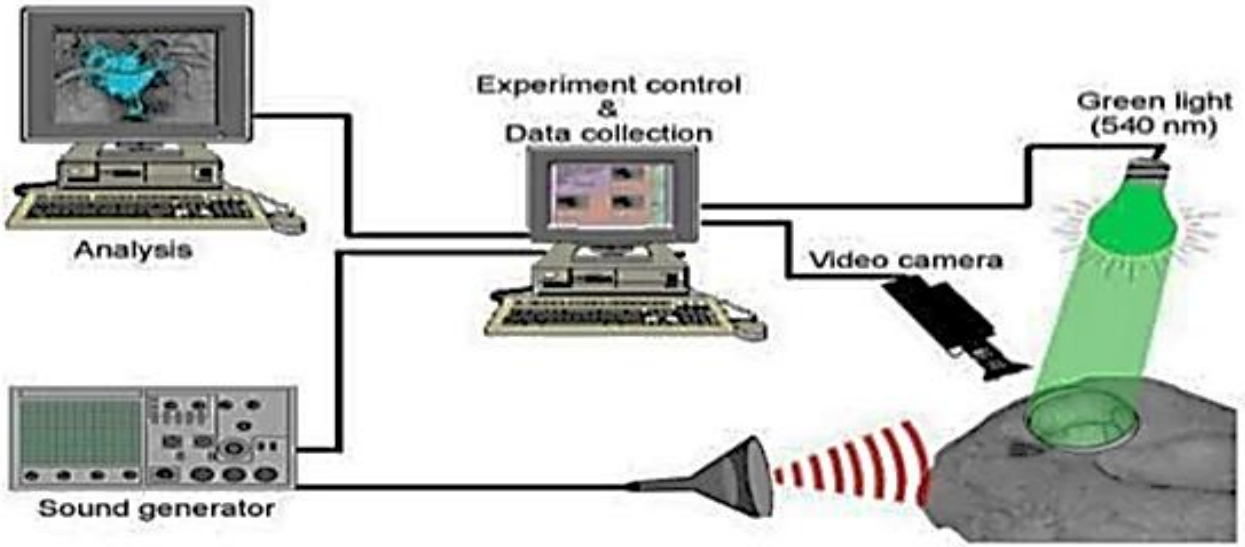


Liquid crystal laser



Optical Imaging

- Optical Imaging is an emerging technology with great potential for improving disease prevention, diagnosis, and treatment in the medical office, at the bedside, or in the operating room



Helmets and bullets proof Jacket