TECHNICAL NOTE

# Liquid Crystals and Light Polarization for Beam Steering and Their Role in Developing ADAS and Autonomous Driving Solutions

## An Overview

This Technical Note aims to explain how liquid crystals and light polarization are used in autonomous driving and its applications. The document starts with an overview of terminologies and proceeds to explain the workings of liquid crystals and light polarization and how these two technologies combine to change the direction of light. Finally, the document details the usage of liquid crystals and light polarization within autonomous driving through beam steering and the advantages the system offers.

## Basics of Liquid Crystals and Light Polarization

To understand liquid crystals and light polarization, a refresher on terminology is provided below:

- **Phase transitions:** When an object changes its state, such as an ice cube turning into water, this is called phase transition. Phase transition is not limited to an object changing state from solid to liquid; other examples include liquid to gas, gas to a liquid, liquid to a solid, etc. The key challenge in using liquid crystals for autonomous driving technologies is maintaining the liquid crystal temperature so that it doesn't undergo a phase transition.

- **Isotropic and anisotropic liquids:** The molecules within solids, liquids and gases have different behaviors and characteristics. Molecules in isotropic liquids are close to one another, arranged randomly, possess random orientation and move around at low speeds. On the other hand, molecules in a solid object are compactly packed and exhibit little movement. Anisotropic liquids are liquids whose molecules orient in a particular direction. Liquid crystals are anisotropic liquids and critical to enable solid-state beam steering.

- **Birefringence:** Also known as double refraction, birefringence refers to the phenomenon where incident light beam on an anisotropic liquid is split into two beams. This happens because the anisotropic liquid has two refractive indices within its structure, which causes a phase shift in the incident light wave, thus leading to two different output directions (and path lengths).

- **Polarizer & analyzer:** The distinction between a polarizer and an analyzer is due to the purpose they serve. A polarizer and an analyzer act as filters, i.e., they allow only certain electromagnetic waves to pass through. While a polarizer is used to polarize light, an analyzer is used to determine if the light is polarized.

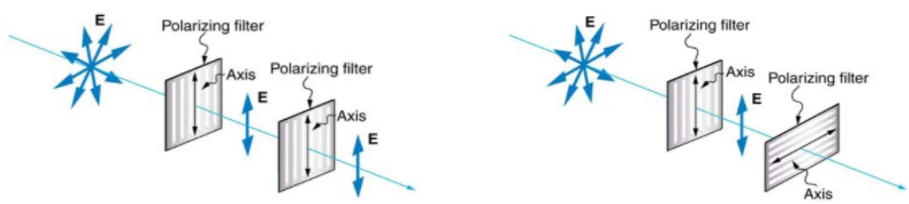


**Figure 1 – Unpolarized light passing through filters set up in parallel and in perpendicular, respectively. Source: Lumenlearning.com**

## How Do Liquid Crystals and Light Polarization Change Light Direction?

Most matter exists in a solid, liquid or gas state. However, another state known as liquid crystal exists between the solid and liquid states. Certain materials become a liquid crystal under the right conditions (such as temperature and pressure). Materials made of molecules that are long and possess a solid central region and slightly flexible ends tend to be better candidates to enter the liquid crystal phase. Liquid crystals are anisotropic liquids.

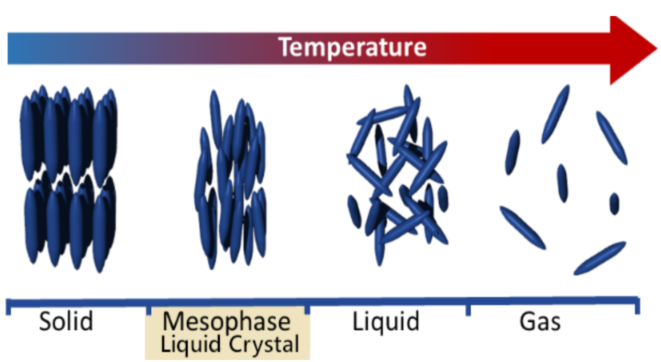


**Figure 2 – Molecule orientation in various states**

Most light that humans experience is unpolarized light. The electromagnetic waves that constitute light vibrate in all planes. However, polarized electromagnetic waves vibrate in two planes perpendicular to the propagation direction or a combination of two of those planes (circular polarization). A polarizing film is used to polarize light, i.e., filter the electromagnetic waves that vibrate in directions not parallel to the polarizing film.

Liquid crystals have the capability to change the direction of polarized light. While there are multiple ways of achieving a change in the direction of the light, such as through twisted nematic crystals, LeddarTech achieves this by using two liquid crystal-based components to accomplish two different tasks. The first is a layer of dynamically controllable liquid crystal cells that control the direction of circular polarization. The second component is a layer of passive liquid crystals, where the orientation of the liquid crystal molecules is fixed in a pattern. This is exemplified in Figure 3.

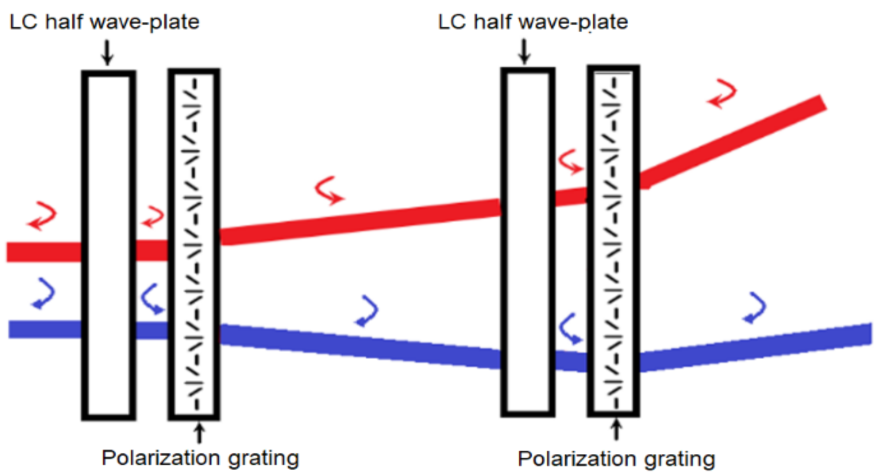


**Figure 3 – Two layers of liquid crystals used for beam steering**

Passing through the first layer, light is circularly polarized and is deflected to one angle or its opposite angle, depending on that direction of polarization. The second liquid crystal component, also referred to as a polarization grating, does this deflection. To change the direction of circular polarization, liquid crystal molecules are oriented according to the desired direction at any given moment by applying an electric voltage across the cell.

## Liquid Crystallization and Polarization in ADAS and Autonomous Driving

Liquid crystals and light polarization are used for beam steering in LiDAR sensors. Beam steering refers to changing the direction of laser pulses in a LiDAR and it enhances LiDAR performance by sub-segmenting (dividing) the field of view into smaller sections and redirecting the emitter LiDAR and/or receiver detector towards that segment.

Importantly, since liquid crystals and light polarization are solid-state technology, it enables the development of beam steering without any moving parts and enables development of solid-state LiDARs critical to on-road automotive OEMs, off-road OEMs and various other applications. LeddarSteer actively manages the temperature in the beam steering unit through a heat control loop. Additional benefits of digital beam steering are:

- Enhanced signal-to-noise ratio and LiDAR range
- Reduced size, cost and complexity of the LiDAR components
- Smaller optical system required in the LiDAR
- Solid-state technology with no moving parts, for higher MTBF (mean time between failures)
- Extended FoV elevation and azimuth; up to 120° per axis

Videos, pictures and Spec Sheet on digital beam steering and more insights on its role in developing autonomous solutions are available at leddartech.com/solutions/leddarsteer-digital-beam-steering/.

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