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Liquid Crystals in Photonics and Optics

Harsh Verma
Jss Academy of Technical Education,
Noida.

***Abstract*:- Everyday incidents have led to the universal familiarity with substances that undergo a single transition from the solid to the isotropic liquid phase. The melting of ice at 0o C to form liquid water is perhaps the most common such phase transition. A large range of organic materials exhibits more than a single transition in passing from solid to liquid, thereby necessitating the existence of one or more intermediate phases.**

Liquid crystals are organic materials, that are complex liquids but combines the properties of both the crystalline (optical and electrical anisotropy) and the liquid (molecular mobility & fluidity) states.

Liquid crystals exquisite the control of light propagation, due to their optical anisotropy & orientational order. Inspired by recent advances, in applications of liquid crystals in optics & photonics, we propose a soft matter for the advancement in optics & photonics, due to liquid crystals.

The crystals that are used in photonics applications are "THERMOTROPIC TYPE". The term "THERMOTROPIC" arises because transitions involved in these mesophases are mainly affected by changing temperature. Distinct thermotropic liquid crystals exist & many different mesophases have been discovered in the last few decades: Nematic, Smectic A, Smectic C, Columnar, Blue phases. The organic molecules typically consist of a long chain structure, containing a side chain (4-Cyano-4'-pentylbiphenyl is a commonly used nematic liquid crystal and frequently goes by the common name 5CB).

A. DISPLAY APPLICATIONS

In-display applications, the liquid crystal is used to modulate the light transmission through the different pixels. In VA (vertically aligned) or IPS (In-Plane Switching) displays, a bright pixel is obtained by rotating the incoming polarization over 90o.In-Plane Switching involves the liquid crystals being arranged horizontally, i.e., parallel to the glass plates, and switching the orientation of the molecules of the liquid crystal between the glass substrates.

B. WAVEGUIDES

To make an optical filter or an optical switch, the liquid crystal plays a vital role. There are many applications in which the propagation of light in free space is not essential such as optical communication & optical sensing. For these optical applications, it can be useful to lock up the light in waveguides. Because the liquid crystals are easily influenced by electric field or temperature change their presence in the cross-section of the waveguide can be used to modify the Refractive Index of the light in the waveguide. A slab waveguide may be a one-dimensional stack of homogeneous layers, where the light is confined in one (or more) layers of the stack, most probably to the middle layer. In the simplest form of isotropic materials, a central layer with the very best index of refraction is sandwiched between two other materials with lower refractive indices. Depending on the thickness of the central layer (and on the index of refraction contrast) one or more modes (TM or TE) can propagate through this one-dimensional structure.

C. LASING

The role of liquid crystal for lasing applications is bifold:

1. Liquid crystal can be used for to tune the cavity length of an existing laser.

2. Liquid crystal can act as a gain medium & cavity at the same time.

I. TUNING LASER WITH LIQUID CRYSTAL

By changing the orientation of liquid crystal, the effective cavity length gets changed.

In this way, the emission wavelength can be used, as long as the gain medium has a gain spectrum that extends over desired wavelength. Another way of tuning laser is by using liquid crystal tunable mirror,

as a Filter or Switching element.

II. LIQUID CRYSTAL LASER

Circularly polarized light with either right or left handedness and with a wavelength that is situated in the stop band is reflected, the other handedness is not reflected, which gives rise to the transmission spectrum. This spectrum is recorded for a mixture of 54% chloestrylpelargonate and 46% E7 nematic liquid crystal (Fig. 1a & b). When light is generated inside the liquid crystal with a wavelength within the stop band, it is difficult for the light to exit the cell along the pitch, and this gives rise to resonance for the light.

Fig.1(a) Perfect Cholesteric Phase

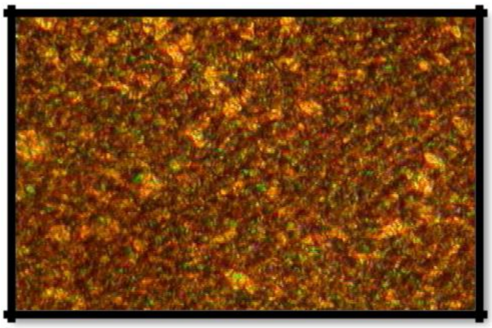

Fig.1(b) Perfect Nematic Phase

D. SPATIAL LIGHT

MODULATORS

Spatial light modulators are versatile optical components that are used to manipulate the amplitude or phase pattern of light. A matrix of electrically addressable pixels in which the orientation of the liquid crystal is administered by applying potential differences. As a result, the intensity outline of the light beam propagating through the SLM is modulated in space by the image imposed on the micro display. The liquid crystal induces a variable phase delay per pixel to modulate the wavefront.

I. HOLOGRAPHIC APPLICATIONS

Holographic systems are grounded on the inherent Fourier transform in the far-field of a hologram illuminated by coherent light. The resulting phase image can be generated by an SLM in which the liquid crystal induces per pixel the desired phase. Hence, SLMs can be used as reconfigurable diffractive optical elements (DOEs) for dynamic beam shaping, correction, and sampling. This allows giving rise to complex intensity profiles suited for laser material.

II. LASER BEAM STEERING

Shaping the phase delay across the SLM allows nonmechanical beam steering correspondingly as in a prism or blazed grating: linear phase retardation induces an optical path difference due to the difference in effective refractive index. As a consequence, the wavefront is tilted by this optical phased array Continuous tuning of the beam deflection within a limited range can be realized by either changing the period or the blaze of the phase profile. In application, mainly two factors limit the steering efficiency of liquid crystal phased arrays. The first constraint is associated with a non-ideal 2π phase transition because the liquid crystal deforms continuously. In addition, the voltage applied over the liquid crystal changes abruptly between two neighboring pixels at the 2π phase transitions. Nevertheless, the liquid crystal orientation will be guided by fringing electric fields between the pixels since the cell thickness is typically comparable to the pixel dimensions in search of high resolution. As a consequence, the 2π phase transition is not only continuous because of the finite extent of the elastic deformation but the flyback region is also elongated due to fringing fields.

CONCLUSION

In this work we have shown the advancements in optics and photonics with liquid crystals. As an example, we have shown how the In-plane Switching was designed to solve the main limitations of the twisted nematic (TN) matrix LCDs which were prevalent in the late 1980s.

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