

# Switchable Holographically Formed Polymer-dispersed Liquid Crystal Layers

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Holographically formed polymer-dispersed liquid-crystals (H-PDLCs) consist of nematic liquid crystals arranged with polymers in a composite by layers. The index differences between the LCs and polymer cause a Bragg mismatch that results in the diffracted reflection of light as a visibly encoded hologram. However, if the LCs are carefully selected so that their ordinary index closely correlates with the refractive index of the polymer, the application of an electric field will change the orientation of the LCs causing the two layers to become Bragg-matched. In this case, light will not be reflected and the H-PDLC will become transparent. Because of the importance and potential of H-PDLCs in advancing optical technology in applications such as reflective liquid crystal displays, switchable filters, and image capturing applications, H-PDLCs were investigated through the formation of diffraction gratings on a multi-layered switchable H-PDLC. The technology was demonstrated and related engineering problems were solved by constructing a multi-layered switchable H-PDLC holographic display that can be addressed by an electrical system.

## 1. INTRODUCTION

### A. Definition

A hologram is a medium that stores an interference wave pattern as a diffraction grating. A hologram stores complete information about a wave including not only its amplitude and frequency, but also the phase information of a wave. Reconstructed information from the hologram varies with respect to viewing angle. In this manner, a hologram stores a three dimensional record of the recorded object.

### B. Brief history

Holography was first developed by Hungarian physicist Dennis Gabor in the late 1940s<sup>1</sup>. In 1947, using a primitive source of semi-coherent light and a microscopic transparency that listed the names of important contributors to the field of optics, Gabor produced the world's first hologram. It was blurry and less than one centimeter wide. In 1948 and 1949, he published two important papers about holography for which he was awarded the Nobel Prize in Physics in 1971. The invention of the laser in 1960 provided the length of coherent monochromatic light needed to create finer, clearer, and more complex holograms. Since then, improvements have been made in holographic emulsions, optical components, and processing

methods. Methods of creative holography and mass production of holograms by embossing have made holograms more practical and more widely available. Today, scientists continue to improve and find practical applications for holography.

## 2. H-PDLCs

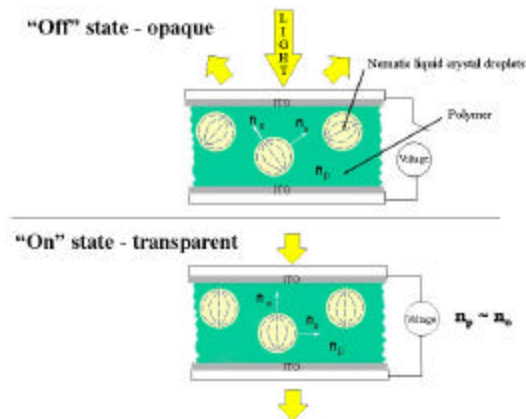


Figure 2.1: Top - H-PDLC reflects light from index-mismatch between LCs and polymer. Bottom - Electric field aligns LCs for index-match between LCs and polymer. Light is not reflected.

Holographically formed polymer-dispersed liquid crystals (H-PDLCs) are a type of polymer-dispersed liquid crystal (PDLC) formed by holographic photopolymerization-induced phase

separation<sup>2,3</sup>. They consist of nematic liquid crystal droplets, such as BL038, dispersed initially in a matrix of photoreactive mers, such as urethane oligomers<sup>2,3</sup>. When exposed by a laser, the mers chain into polymers that, organize into stratified planes consisting of distinct alternating planes of high and low liquid crystal droplet concentration. The liquid crystal droplets in the stratified planes assume random orientations and an index of refraction ( $n_o$ ) different from that of the polymer ( $n_p$ ), creating a mismatch in index of refraction between the polymer and liquid crystal planes and rendering the section of material opaque<sup>2,3</sup>. When voltage is applied across the HPDLCs using the opposing conductive layers of indium tin oxide (ITO), the liquid crystal droplets align and assume an index of refraction ( $n_e$ ) very close to that of the polymer, effectively eliminating the index of refraction mismatch and making the material transparent.

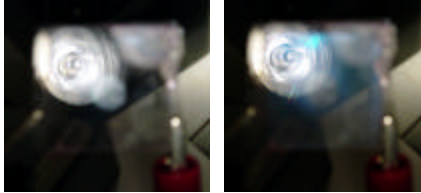


Figure 2.2: Left – A HPDLC with voltage applied is transparent. Right – Without voltage applied, the H-PDLC is reflective.

### 3. RECORDING PROCESS

The holographic recording process requires two coherent electromagnetic waves, usually produced by lasers, which intersect inside a photosensitive medium. One of the waves carries the information that will be recorded, and the other wave is just a plane wave with no information used as a reference. When these two beams intersect, an interference pattern is produced from the constructive and destructive interference caused by the superpositioning of the waves. The photosensitive material stores this interference pattern as a diffraction grating. To reconstruct the recorded information, or signal beam, the reference beam illuminates the recording material. The gratings stored inside the material diffract the reference beam and re-create the signal beam.

To record HPDLCs so that ambient white light would be reflected as the reconstruction of the hologram, a reflection geometry set-up was used (figure 3.1). The Coherent® laser produces a 1.5 watt green laser beam of 523nm. The beam travels through the spatial filter that reduces noise and expands the beam. The iris then adjusts the beam diameter, as the beam is split into two by the beam splitter. The mirrors adjust the path of the

laser as both beams intersect at the location of the H-PDLC where a mask overlay denotes the image recorded on to the H-PDLC.

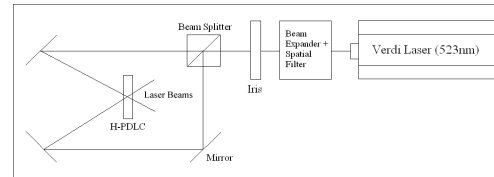


Figure 3.1: H-PDLC reflection recording

### 4. SWITCHING H-PDLCs

The BL038 nematic liquid crystals in the H-PDLCs with 10 $\mu$ m fiber glass spacers were ideally switched with an electric field of roughly 200 volts, 1 kilohertz frequency, and a square waveform. To generate this electric field, various square wave generator options were considered before settling on a modified Rtek circuit. Originally, a pre-built Rtek 2000 DC to AC inverter was provided to generate the electric field. However, the limits of the circuit set the maximum voltage of 80 volts. While 80 volts could faintly switch the hologram, it was not enough to orient the majority of liquid crystals in the HPDLCs. The Rtek circuit was reversed engineered, simulated in PSpice, and rebuilt on breadboards and PC boards.

The transformer in the Rtek circuit is the Mouser 42TL017 with a turn ratio of 1:8.75. This correlates with the output of roughly 80 volts for 9 volts input. In order to achieve an output of at least 200 volts, an input of at least 23 volts would be needed. By connecting three 9 volts batteries in series, 27 volts of input were achieved and output was calculated at 236 volts. Actual measurements with a multimeter indicated that the output voltage was roughly 261VAC. This increase in voltage is attributed to distortion of the square wave that causes spikes along the edges of the wave. Since a multimeter measures  $V_{rms}$ , the distortion causes a higher reading. The electric field of roughly 261 volts square wave was enough to switch 10 micron spaced H-PDLC almost completely.

### 5. CONCLUSION

Through this research, the various intricacies of H-PDLC technology were investigated and switching was successfully demonstrated by engineering a device that addressed H-PDLC layers.

### REFERENCES

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