

## Multilayer Liquid Crystal Devices: Toward Ultra-compact and Versatile Photonic Fabrication

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Flat optical components based on liquid crystals (LCs) have emerged as powerful tools for compact, lightweight, and highly efficient photonic systems. These devices offer several advantages, including high efficiency, polarization selectivity, and ultrathin form factors, making them particularly attractive for applications in augmented reality (AR) and virtual reality (VR). In particular, LC-based diffractive optical elements can achieve near-unity diffraction efficiency by exploiting geometric phase control. A key challenge, however, has been the fabrication of multilayer LC devices that integrate multiple optical functions within a single thin-film stack. Conventional photoalignment materials often require aggressive solvents (such as DMF), which are incompatible with previously deposited LC layers. This adds complexity to the process, necessitating vacuum-deposited protective interlayers.

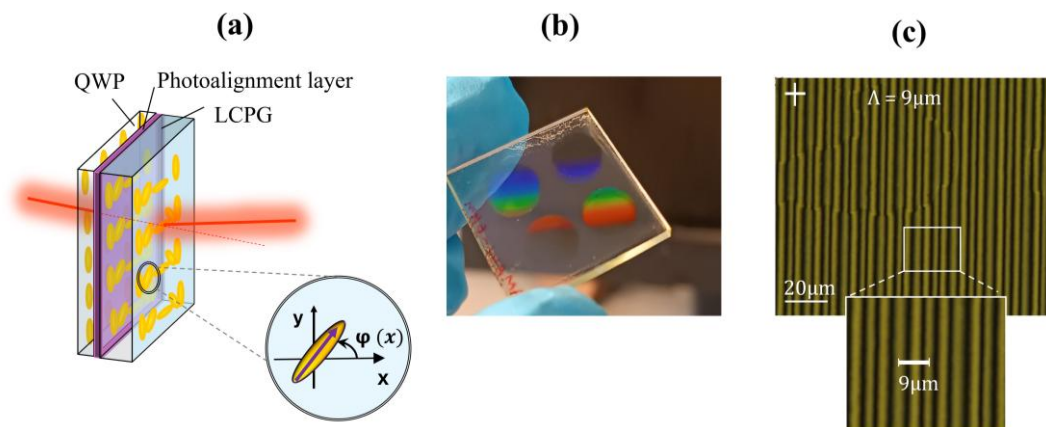


Figure 1. Multi-layer geometric phase grating (a) schematic configuration (b) device photograph (c) Polarizing optical microscope image.

In this study, we demonstrate a novel approach to fabricate high resolution photopatterned LC polarization gratings using water-soluble photoalignment material AbA-2522 that eliminates these barriers while maintaining alignment quality equivalent to conventional alignment materials [1]. This eco-friendly solution, making use of water as a solvent, enables direct multilayer processing without layer damage, dramatically simplifying device fabrication. We successfully fabricated compact transmissive devices integrating LC polarization gratings with and underlying quarter-wave plate (QWP), achieving a first-order diffraction efficiency of 65.4% for 9  $\mu\text{m}$  period gratings with linearly polarized incident light at  $\lambda = 457 \text{ nm}$  (Figure 1). Polarized optical microscopy confirms excellent alignment uniformity across various grating periods (3–9  $\mu\text{m}$ ), with the water-soluble approach showing no damage to underlying polymerized LC layers. This is in contrast to the results obtained with conventional alignment materials that produced significant defects and layer degradation.

This water-soluble photoalignment method establishes a practical pathway for advanced multilayer photonic devices, addressing fundamental fabrication challenges that have limited multilayer LC device development for next-generation AR systems and integrated photonic applications.

### References

[1] F. Abbasi, K. Neyts, I. Nys, and J. Beckman, *Crystals* **16**, 62 (2026).