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GUEST EDITORIAL

Special Section Guest Editorial: Micro-optical Systems Based on Liquid Crystals

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Liquid crystal (LC) is a superior material for light modulations, amplitude, and phase modulations. With the many versatile applications of LCs that have been developed, the manufacturing of liquid crystal displays (LCD) has matured. In this special section, we have eight articles covering amplitude modulators (LCDs for virtual reality (VR) and microdisplays for augmented reality (AR)) and phase modulators (LC lenses, LC antennas, LC geometric phase element for vertical cavity surface emitting laser (VCSEL) projector, and material study).

In LC amplitude modulators, the pixel sizes of TFT-LCDs are limited by glass-based manufacturing technology. Wu and Tsai et al. break the limits of LCDs to achieve the pixel size ∼12 microns and demonstrated the highest resolution of LCD (2.56 in. and 2117-pixels per inch 4K liquid crystal display) for virtual reality. With different pixel design and adding on light field technology, Wu and Chang et al. demonstrated high-resolution light field liquid crystal display technology (3.1 in., 1411-pixels per inch, pixel size: 18 microns) for virtual reality. For virtual reality application, the requirement of immersive experience, wider field-of-view, the images with high resolutions and a compact optical system leads to the need for large enough display sizes (>2 in.). The display size larger than 1 in. as well as cost are very challenging for OLED so far.

As for augmented reality, liquid-crystal-on silicon (LCOS) micro-displays with pixel size less than 0.5 in., wafer-level manufacturing technology, are more suitable. Typically, LCOS microdisplays suffer from problems such as bulkiness, low brightness, low reliability, and high power consumption, and they all limit application in uses related to augmented reality. However, Li et al. proposed a new design, named front-lit for LCOS, to solve all the problems.

For the LC phase modulators, three articles presented in this section proposed three LC optical elements based on the same fundamentals of LC: phase modulations. Lin et al. studied orientation fluctuations of gradient refractive-index (GRIN) LC lenses and found the root cause of unavoidable haze which leads to a challenge in image quality of GRIN LC lenses. The study indicates LC with larger elastic constant reduces the perturbation of the LC molecules and then it could reduce haze induced by orientation fluctuations. This research can provide a better understanding for engineers and researchers to develop better GRIN LC lenses. The applications of GRIN LC lenses are eyeglasses, AR/VR, portable imaging systems, and machine vision.

Another interesting application of LC phase modulators is LC antennas. Yagi-Uda shaped metamaterial absorber (YUMA) could be operated in X- and Ku-bands of the microwave spectrum. YUMA exhibits three distinct absorption peaks and has polarization controllability as well as wide incidence angle stability. Yakovkin and Reshetnyak demonstrated the potential of LC in fine-tuning the resonance properties of Yagi-Uda antenna arrays. The reorientation of the LC allows for control over the frequency of absorbance and reflectance peaks. This approach provides the potential for dynamic manipulation of antenna properties, enabling real-time adaptability. The impacts of LC antennas are satellite and terrestrial communication, radar applications, air traffic control, and defense tracking systems.

As to the sensing application using LC phase modulators, Chen et al. proposed a reflowable LC geometric phase element for VCSEL projector. The authors integrated a VCSEL projector and LC geometric phase elements to demonstrate a switchable pattern projector. Many different geometric phase patterns are fabricated, such as MLA and gratings, to realize an LC diffuser, beam multiplier, and angular extender for different applications. The switchable pattern projector could realize two projected patterns by only one VCSEL projector with fast-switching time (<5 ms) and high optical efficiency (>95%). The impact of this study is the face recognition and three-dimensional sensing in mobile application.

In this section, we have two more articles: one reports the effect of the photovoltaic field on small sessile nematic LC droplets, and the other is related to blue phase liquid crystals (BPLC). Karapinar et al. studied the optical illumination-induced rearrangement and merging/splitting of microsized droplets of some well-investigated commercial nematic LC compounds on the surface of LN:Fe substrates. As to BPLC, BPLC displays a highly twisted nematic LC on cooling down from the isotropic phase. The temperature range is quite limited. In order to widen the temperature range, nanoparticles could help to stabilize BPLC. Gudimalla et al. studied how magnetic nanoparticles stabilize lattices of topological lines in blue phase. The impacts of this study are three-dimensional lasers, tunable photonic crystals, microlens arrays, and LCDs with fast response time.

We thank the authors for contributing to this special section which provides insightful updates about LC-related photonic devices beyond displays and how LCDs go to the manufacturing limits and then open the possibility in AR and VR. We hope this special section inspires readers to investigate and invent more micro-optical systems based on liquid crystals.