

Tunable focal length of microlens array coupled with smectic liquid crystal designed for fast switching

Jae-Hoon Kim¹, Jin Seog Gwag², and Min Young Jin²

¹Department of Electronics and Computer Engineering, Hanyang University, Seoul, 133-791, South Korea, jhoon@hanyang.ac.kr

²Research Institute of Information Display, Hanyang University, Seoul 133-791, Korea

Keywords: smectic liquid crystals, microlens array, tunable focal length

Abstract

Various types of dynamic optical devices have been presented to march in step with the rapid progress in information technology needing very fast response time which can show real-time reconfiguration. For instance, optical switches such as image integration components in 3-D displays, beam-steering, and optical interconnects should be electrically reconfigurable to tune optical properties during very short time and then, dynamic lens in them is needed unavoidably as a optical modulator which can control continuously light intensity through tuning of focal length. To perform the function as optical modulator, microlens array has been combined with liquid crystal (LC) materials which can be controlled electrically by large electro-optical anisotropy [1]. However, those approaches have a high operating voltage and relatively a long focal length due to the limited moving range of LC under electric field. So we have proposed a new type dynamic lens array technology, which composed a polymer lens and two serial LC layers of a static solid-liquid crystalline phase (for focusing) and a dynamic liquid crystal phase (for modulation of polarization) as shown in Fig. 1 [2]. It has many merits such as low driving voltage and relatively a short focal length. The switching time of it, however, may be not sufficient to be applicable optical systems with real-time reconfiguration due to the intrinsic speed of nematic LC.

In this paper, we present the electro-optical characteristics at dynamic lens array system with smectic LC designed for a fast switching time. The lens array system is composed of a dynamic LC layer [DLCL] and a static liquid crystalline polymer layer [SLCPL] with large optical anisotropy on the concave microlens structure made of the UV curable polymer. The incident light is focused or defocused depending on the polarization state at SLCPL. As an optical description, incident light becomes a linear polarized light by polarizer and DLCL (smectic liquid crystal) set at half-wave retardation rotates the polarization direction of the light. Under electric field with plus polarity, the optic axis of DLCL is rotated by 45° and then, the incident linear polarization is rotated by 90°. Consequently the linear polarization is parallel to the direction of extraordinary refractive index of SLCPL and then, the light converges due to the larger refractive index of SLCPL than that of the lens. On the other hand, under electric field with minus polarity, the optic axis of DLCL is coincident with the incident linear polarization direction, and then, the incident linear polarization is not rotated to any direction. Consequently the linear polarization is parallel to the direction of ordinary

refractive index of SLCPL and then, the light diverges due to the smaller refractive index of SLCPL than that of the lens.

To obtain the fast switching time and continuous rotation of polarization, we used a commercial FLC Felix 016-100 (Clariant) that exhibits a smectic *C* phase and FLC Felix-020 (Clariant) with electroclinic effect as the optical LC modulator. Experimental manner for fabrication follows the previous paper [3].

As a result of experiment, Fig. 2 shows indirectly a tunable focal intensity controlled electrically, as illustrated by image of focused spot at fabricated dynamic lens array system with the smectic LCs. Their switching times were measured under 100 μ s sufficient to real-time reconfigurable optical system. More detailed description will be done at the scene of the presentation by author of this paper.

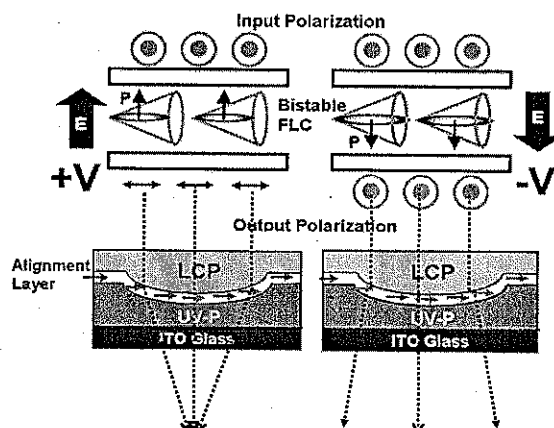


Fig. 1. Schematic diagram of the proposed dynamic lens array system

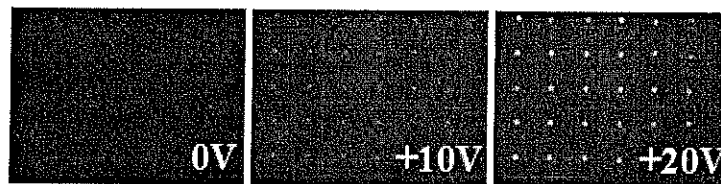


Fig. 2. Images of focusing pattern depending on voltage

References

- [1] B. Lee, S. Jung, and J-H. Park, "Viewing-angle-enhanced integral imaging by lens switching," *Opt. Lett.* **27** 818 (2002).
- [2] Choi, Y. S., Kim, H. R., Lee, K. H., Lee, Y. M. & Kim, J. H. A liquid crystalline polymer microlens array with tunable focal intensity by the polarization control of a liquid crystal layer. *Appl. Phys. Lett.* **91**, 221113 (2007).
- [3] Y. Choi, C.-J. Yu, J.-H. Kim, and S.-D. Lee, "Fast switching characteristics of surface-relief microlens array based on a ferroelectric liquid crystal," *Ferroelectrics*. **312**, 25 (2004).

Acknowledgments: This work was supported by Samsung Electronics Co. Ltd. and the Korea Research Foundation Grant Funded by the Korean Government (MOEHRD, Basic Research Promotion Fund).

PA20	Nematic liquid crystal alignment in planar cells with periodically modulated electric field K.R. Daly, G. D'Alessandro, M.Kaczmarek	115
PA21	Tuning SOI filters with Liquid Crystals W. De Cort, J. Beeckman, K. Neyts, R. Baets, R. James, F.A. Fernández	117
PA22	Photorefractive effect enhancement in Polymer-Liquid Crystal Composite materials A.I. Denisov, J.-L. de Bougrenet de la Tocnaye, C. Carré	119
PA23	Tunable broadband in-fiber polarizer based on Photonic Liquid Crystal Fiber Slawomir Ertman, Tomasz R. Woliński, Dariusz Pysz, Ryszard Buczynski, Edward Nowinowski-Kruszelnicki, Roman Dabrowski	120
PA24	Electrically Tunable Microring Resonator-Based Filters with Hybrid Aligned Nematic Liquid Crystal Cladding Fei Fan, Alexander Muravsky, Vladimir Chigrinov, Xianshu Luo, Linjie Zhou, Andrew W. Poon	122
PA25	Image analysis for polarization difference imaging system Piotr Garbat, Marek Sutkowski, A. Walczak	124
PA26	Bistable photonic devices using Organosiloxane Smectic A liquid crystals Damian Gardiner, Harry Coles	126
PA27	Kerr effect studies on mixtures of the two isothiocyanato tolane base liquid crystals A. Ghanadzadeh, H. Tajalli, E. Vahedi	128
PA28	Electrospun cellulose nanofiber membranes for liquid crystal optical devices M.H. Godinho, P.L. Almeida, S. Kundu, J.P. Borges, J.L. Figueirinhas	130
PA29	Relaxation behaviour of a monomer/LC blend after exposure to ultraviolet light Z. Hadjou Belaid, L. Méchernne, U. Maschke	131
PA30	Guest-Host Effects in Liquid Crystals with Disc-Shaped Azo Dyes: Application in Optical Storage Devices Gurumurthy Hegde, M.R.Lutfor, V.G.Chigrinov, H.S.Kwok	133
PA31	Polarization Selective Wavelength Tunable Filter T. Hui, J. Beeckman, R. Zmijan, K. Neyts	135
PA32	Dispersions of pentadentate Schiff bases and their transition metal complexes in nematic liquid crystals Z. Khouba, T. Benabdallah, U. Maschke	137
PA33	Tunable focal length of microlens array coupled with smectic liquid crystal designed for fast switching Jae-Hoon Kim, Jin Seog Gwag, Min Young Jin	139
PA34	FDTD simulation of energy exchange in liquid crystals V.O. Kubytskyi, V.Y. Reshetnyak, T.J. Sluckin, S.J. Cox	141
PA35	Multiplexer and Variable Optical Attenuator based on PDLc for Polymer Optical Fiber networks P. C. Lallana, C. Vázquez, B. Vinouze, K. Heggarty, D. Sánchez	143
PA36	Photoinduced anisotropy and volume holographic recording in liquid crystalline diblock copolymers with azobenzene units Patricia Forcén, Luis Oriol, Carlos Sánchez, Rafael Alcalá, Soeren Hvilsted, Katja Jankova	145
Poster Session B		147
PB1	Characterization of LCoS displays based on Mueller matrix analysis: depolarization and phase shift effects A. Lizana, I. Moreno, C. Iemmi, A. Márquez, J. Campos, M. J. Yzuel	147
PB2	Behavior of Response time in an Electroclinic Liquid Crystal with Large induced Tilt and Polarization U. Manna, J. K. Song, J. K. Vij, J. Naciri	149
PB3	Wide band gap cholesterics as advanced structures for laser tuning M. A. Matranga, G. Petriashvili, M. P. De Santo, R. Barberi	151

LCP-2008 Workshop Programme

Monday 21 July 2008

08:00	Registration		
09:00	Welcome message		F.A. Fernandez - W.A. Crossland
Session 1 chair: N. Collings Nonlinear optical effects and devices			
09:10	Plenary	I.C. Khoo	Liquid crystalline nonlinear optical meta-materials
09:50	Invited	T. Sluckin	Surface-mediated non-linear optical effects in liquid crystals
10:20	Oral	L. Natarajan	Improvement of electro-optical performance of polymer stabilized cholesteric liquid crystals by holographic patterning
10:40 Coffee break			
Session 2 chair: S.E. Day Devices and applications 1			
11:10	Invited	E. Yao	Applications of spatial light modulators
11:40	Oral	T.D. Wilkinson	Patterned multiwall carbon nanotube electrode arrays for liquid crystal photonic devices
12:00	Oral	T. Wolinski	Multi-parameter sensing based on photonic liquid crystal fibers
12:20	Oral	T. Scharf	Passive birefringent micro-optics devices
12:40	Oral	V. Chigrinov	Liquid crystal devices for photonics applications
13:00 Lunch break			
Session 3 chair: T.D. Wilkinson Waveguides			
14:00	Invited	A. D'Alessandro	Liquid crystals in waveguides and switches
14:30	Oral	G. D'Alessandro	Liquid crystal configuration effects on the band-gap frequency of a tunable waveguide
14:50	Oral	J. Beeckman	Design of a liquid crystal tunable directional coupler
15:10	Oral	A. Walczak	Reconfigurable waveguide couplers in layered organic and hybrid structures
15:30	Poster session A		coffee
18:00	Reception at CAPE		(Transport provided): bus leaves at 17:30
Dinner - Not Provided			

Tuesday 22 July 2008

Session 4 chair: H. Coles Lasing			
09:00	Invited	P. Palffy-Muhoray	The effects of nanoparticles on lasing in cholesteric liquid crystals
09:30	Oral	P. Hands	Liquid crystal laser arrays
09:50	Oral	F. Serra	Overlapped band-gaps of cholesteric liquid crystal elastomers for tunable lasers
10:10	Oral	A. Ghanadzadeh Gilani	The photophysical properties of three Coumarin laser dyes in anisotropic media
10:30 Coffee break			
Session 5 chair: J.R. Sambles Alignment of liquid crystals			
11:00	Invited	S. Faetti	Measurements of azimuthal anchoring energies
11:30	Oral	V. Chigrinov	Photo aligning of liquid crystals utilizing new azo dyes: Characteristic properties and physics of applications
11:50	Oral	P. Camorani	Azo-containing polymer brushes: photoalignment and application as command surfaces
12:10	Oral	D. Reznikov	Monodomain alignment of the smectic A liquid crystalline phase from the isotropic phase
12:30 Lunch break			

Session 6	chair: K. Neyts	Devices and applications 2
13:30	Invited J.R. Sambles	Microwave applications of liquid crystals
14:00	Oral A. Uddin	Liquid crystal based planar waveguide devices
14:20	Oral J. Stumpe	Polymer- LC based electrically switchable diffractive device
14:40	Oral Y. Panarin	Liquid crystals in optical switching: Problems and solutions
15:00	Coffee break	
Session 7	chair: I.-C. Khoo	NLO and solitons
15:30	Invited K. Neyts	Non-linear optical effects and solitons in liquid crystals
16:00	Oral M. Warengem	Linear optics ray tracing and non linear soliton trajectory in nematic liquid crystals
16:20	Oral A. Miroshnichenko	Light-induced Freedericksz transition in periodic structures with a nematic liquid crystal defect
16:40	Invited C. Lee	AFOSR programmes
17:10	Poster session B	coffee
19:15	Workshop dinner	
Wednesday 23 July 2008		
Session 8	chair: N. Mottram	Modelling of liquid crystals
09:00	Invited S. Elston	Modelling of liquid crystals for photonics
09:30	Oral R. James	Twist walls, disclinations and the In-Plane Switching structure
09:50	Oral M. Yakutovich	Mesh free simulation of liquid crystals using modified smoothed particle hydrodynamics
10:10	Oral D. deBoer	Linear and circular polarisation gratings in and beyond the paraxial approximation
10:30	Oral V. Reshetnyak	Modelling of hybrid liquid crystal - inorganic photorefractives
10:50	Coffee break	
Session 9	chair: O. Trushkevych	Nanoparticles in liquid crystals
11:10	Invited Y. Reznikov	Diluted LC nanocolloids - Problems and perspectives
11:40	Oral O. Buchnev	Enhancement of photorefractive response in liquid crystals with ferroelectric nanoparticles
12:00	Oral P. Arora	Dielectric and electro-optic properties of new ferroelectric liquid crystalline mixture doped with carbon nanotubes
12:20	Invited G. Love	Particle Interactions in liquid crystals induced by the flexoelectric effect
12:50	Closing remarks: N. Collings	
13:00	Lunch	
Afternoon:	Chauffered Punting - Tour of the Colleges (£6)	

2nd International Workshop on Liquid Crystals for Photonics
LCP2008
21-23 July, Cambridge, UK

