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6. AUTHOR(S) Prof. Shin-Tson Wu				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) College of Optics and Photonics: CREOL & FPCE University of Central Florida Telephone: (407) 823-4763 Email: swu@mail.ucf.edu			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U. S. Army Research Office P.O. Box 12211 Research Triangle Park, NC 27709-2211			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.				
12 a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12 b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) For adaptive foveated imaging using a high resolution spatial light modulator (SLM), high birefringence and low viscosity LC mixtures are highly desirable. A higher birefringence enables a thinner liquid crystal layer to be used which results in a faster response time. Low viscosity is always favorable as it helps to reduce the SLM response time. For the thin-film-transistor (TFT)-addressed SLM, high resistivity is an extra requirement. In this report we review our development on the single compounds syntheses and mixtures with required high birefringence and relatively low viscosity within the time of the project.				
14. SUBJECT TERMS Foveated imaging, Spatial light modulator, liquid crystal materials			15. NUMBER OF PAGES 10	
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1. List of papers submitted or published under ARO sponsorship during reporting period.

(a) Manuscripts submitted, but not published

1. S. Gauza, A. Parish, S. T. Wu, A. Ziolk, and R. Dabrowski, "Physical properties of laterally fluorinated isothiocyanato phenyl-tolane liquid crystals", *Liq. Cryst.* (2007).
2. S. Gauza, Y. Zhao, T. LeCor, S.T. Wu, A. Ziółek, R. Dąbrowski, O. Catanescu, and L.C. Chien, "High Figure-of-Merit Laterally Fluorinated Biphenyltolane-isothiocyanates" *Mol. Cryst. Liq. Cryst.* (2007)

(b) Papers published in peer-reviewed journals

1. H. Ren, Y. H. Fan, S. Gauza and S. T. Wu, "Tunable microlens arrays using polymer network liquid crystal" *Optics Comm.* 230, 267-271 (Feb. 1, 2004)
2. H. Ren, Y. H. Fan, and S. T. Wu, "Polymer network liquid crystals for tunable microlens arrays" *J. Phys. D: Appl. Phys.* 37, 400-3 (Feb. 7, 2004)
3. H. Ren, Y. H. Fan, S. Gauza and S. T. Wu, "Tunable-focus cylindrical liquid crystal lens" *Jpn. J. Appl. Phys.* 43, 652-3 (Feb. 2004)
4. Y. Huang, S. T. Wu and Y. Zhao, "All-optical switching characteristics in bacteriorhodopsin and its applications in integrated optics" *Optics Express* 12, 895-906 (March 8, 2004)
5. Y. Huang, S. T. Wu, and Y. Zhao, "Photonic switching based on the photo-induced birefringence in bacteriorhodopsin film" *Appl. Phys. Lett.* 84, 2028-30 (March 22, 2004)
6. C. O. Catanescu, S. T. Wu and L. C. Chien, "Tailoring the physical properties of some high birefringence isothiocyanato-based liquid crystals" *Liq. Cryst.* 31, 541-555 (April 2004)
7. Y. H. Lin, H. Ren and S. T. Wu, "High contrast polymer-dispersed liquid crystal in a 90° twisted cell" *Appl. Phys. Lett.* 84, 4083-5 (May 17, 2004)
8. C. O. Catanescu, L. C. Chien and S. T. Wu, "High birefringence nematic liquid crystals for display and telecom applications" *Mol. Cryst. Liq. Cryst.* 411, 93-102 (May, 2004)
9. H. Ren, Y. H. Fan, S. Gauza, and S. T. Wu, "Tunable-focus flat liquid crystal spherical lens" *Appl. Phys. Lett.* 84, 4789-91 (June 7, 2004)
10. H. Ren, Y. H. Fan, and S. T. Wu, "Liquid crystal microlens arrays using patterned polymer networks" *Opt. Lett.* 29, 1608-1610 (July 15, 2004)
11. Y. Huang, G. Siganakis, M. G. Moharam, and S. T. Wu, "All-optical display using photo-induced anisotropy in a bacterio-rhodopsin film" *Opt. Lett.* 29, 1933-1935 (August 15, 2004)
12. S. Gauza, J. Li, S. T. Wu, A. Spaldo, R. Dabrowski, Y. N. Tzeng, and K. L. Cheng, "High birefringence and high resistivity isothiocyanate-based nematic liquid crystal mixtures", *Liq. Cryst.* 32, 1077-1085 (August, 2005).
13. Y. H. Lin, H. Ren, Y. H. Fan, Y. H. Wu, and S. T. Wu, "Polarization-independent and fast-response phase modulation using a normal-mode polymer-stabilized cholesteric texture", *J. Appl. Phys.* 98, 043112 (August 15, 2005)
14. Y. Huang, J. Fu, D. Hagan, S. T. Wu, X. Huang, and M. A. El-Sayed, "Ultraviolet protection using intensity-dependent spectral shift in bacteriorhodopsin", *IEEE J. Special Topics in Quantum Electronics* 11, 902-905 (July/August 2005)
15. Y. H. Fan, H. Ren, X. Liang, H. Wang, and S. T. Wu, "Liquid crystal microlens arrays with switchable positive and negative focal lengths", *J. Display Technology* 1, 151-156 (September 2005)
16. A. Spaldo, R. Dabrowski, J. Dziaduszek, E. Scibior, S. Urban, S. Gauza, and S. T. Wu, "Liquid crystalline materials with high birefringence", *J. Optical Technology* 72, 659-661 (Sept. 2005)
17. H. Ren and S. T. Wu, "Polymer-based flexible microlens arrays with hermaphroditic focusing properties", *Appl. Opt.* 44, 7730-7734 (Dec. 2005)
18. S. Gauza, C. H. Wen, B. Wu, and S. T. Wu, "Fast-response nematic liquid crystal mixtures" *J. SID* 14, 241-246 (March 2006)
19. S. Gauza, C. H. Wen, B. Wu, and S. T. Wu, "High figure-of-merit nematic mixtures based on totally unsaturated isothiocyanate liquid crystals", *Liq. Cryst.* 33, 705-710 (June 2006)
20. S. Gauza, C. H. Wen, Y. Zhao, S. T. Wu, A. Ziolk, and R. Dabrowski, "Isothiocyanato-tolanes based high birefringence and fast response time mixtures for photonic applications", *Mol. Cryst. Liq. Cryst.* 453, 215-226 (2006)

21. S. Gauza, S. T. Wu, A. Spaldo, and R. Dabrowski, "High performance room temperature nematic liquid crystals based on laterally fluorinated isothiocyanato-tolanes," *J. Display Technology* **2**, 247-253 (Sept. 2006)
22. S. Gauza, Y. Zhao, T. Le Cor, S. T. Wu, A. Ziolk, R. Dabrowski, C. O. Catanescu, and L. C. Chien "Enhancing birefringence by doping fluorinated biphenyl-tolanes", *J. Display Technology* **2**, 327-332 (Dec. 2006)
23. R. Dabrowski, J. Dziaduszek, A. Ziolk, L. Szczucinski, Z. Stolarz, G. Sasnouski, V. Bezborodov, W. Lapanik, S. Gauza, and S. T. Wu, "Low viscosity, high birefringence liquid crystalline compounds and mixtures", *Opto-Electronics Review* **15**, 47-51 (Jan. 2007)
24. S. Gauza, X. Zhu, S. T. Wu, W. Piecek, and R. Dabrowski, "Fast switching liquid crystals for color-sequential LCDs", *J. Display Technology* **3**, 250-252 (Sept. 2007)
25. A. Parish, S. Gauza, S. T. Wu, Jerzy Dziaduszek, and R. Dabrowski, "New fluorinated terphenyl isothiocyanate liquid crystals", *Liq. Cryst.* (Jan. 9, 2008).

(c) Papers published in non-peer-reviewed journals or in conference proceedings

1. Y. H. Lin, H. Ren and S. T. Wu, "Twisted PDLC for high contrast reflective displays" *SID Tech. Digest* **35**, 614-7 (2004)
2. Y. B. Huang, X. Y. Zhu, H. Ren, Q. Hong, T. X. Wu, S. T. Wu, S. H. Lin, and H. P. Shieh, "Full-color transreflective Ch-LCD with image-enhanced reflector" *SID Tech. Digest* **35**, 882-5 (2004). (*SID Distinguished Student Paper Award*)
3. S. Gauza, C. H. Wen, B. Tan, Y. H. Wu, Y. H. Lin and S. T. Wu, "High-birefringence and low-viscosity isothiocyanate LCs and applications to 50- μ s response switching device" *SID Tech. Digest* **35**, 1304-7 (2004).
4. Y. H. Fan, Y. H. Lin, H. Ren, S. Gauza and S. T. Wu, "Fast-response polymer network liquid crystals for optical communications" *SID Tech. Digest* **35**, 1526-9 (2004).
5. Y. H. Fan, H. Ren, and S. T. Wu, "Electrically controlled lens and prism using nanoscale polymer-dispersed and polymer-networked liquid crystals" (Invited paper) *Proc. SPIE* **5289**, 63-73 (2004).
6. H. Ren, Y. H. Fan, Y. H. Lin, and S. T. Wu, "Tunable-focus liquid crystal lens" (Feature article) *OE Magazine* pp. 21-23 (September, 2004).
7. S. Gauza, C.H. Wen, S. T. Wu, R. Dabrowski, C. S. Hsu, C. O. Catanescu, and L. C. Chien "High birefringence liquid crystals for photonic applications", *Proc. SPIE "Optics and Optoelectronics"*, 5947-6 (Poland, August 28 - September 2, 2005).
8. S. Gauza, C.H. Wen and S.T. Wu, "Isothiocyanato-tolanes based high birefringence and fast response time mixtures for photonic applications" 11th International Topical Meeting On Optics of Liquid Crystals, OLC 2006, Clearwater, Florida, USA (October 2005)
9. J. Harriman, S. Gauza, S.T. Wu, D. Wick, B. Bagwell, T. Martinez, D. Payne and S. Serati, "Transmissive spatial light modulators with high figure-of-merit liquid crystals for foveated imaging applications", (Invited paper) *Proc. SPIE* **6135**, 61350C (Jan. 2006).
10. S. Gauza, Y. Zhao, T. LeCor, S.T. Wu, A. Ziółek, R. Dąbrowski, O. Catanescu, and L.C. Chien, "High Figure-of-Merit Laterally Fluorinated Biphenyltolane-isothiocyanates" 21st International Liquid Crystal Conference, Keystone, Colorado, USA (July 2006)
11. S. Gauza, X. Zhu, S. T. Wu, W. Piecek, and R. Dabrowski, "High birefringence liquid crystals for color-sequential LCDs" *SID Symposium Digest* **46**, 142-145 (2007) (May 21-25, Long Beach, CA).
12. S. Gauza, A. Parish, S.T. Wu, A. Spadło, and R. Dabrowski, "Physical properties of laterally fluorinated isothiocyanato phenyl-tolane single liquid crystals components and mixtures" 12th International Topical Meeting On Optics of Liquid Crystals, OLC 2007, Puebla, Mexico (October 2007)
13. A. Parish, S. Gauza, S.T. Wu, J. Dziaduszek, and R. Dabrowski, "New fluorinated terphenyl isothiocyanate liquid crystals" 12th International Topical Meeting On Optics of Liquid Crystals, OLC 2007, Puebla, Mexico (October 2007)

(d) Papers presented at the meetings, but not published in conference proceedings

1. S. Gauza, C. H. Wen, S. T. Wu, N. Janarthanan and C. S. Hsu, "Super high birefringence isothiocyanato biphenyl-bistolane liquid crystals" *MRS Fall Meeting* (Nov 29, 2004)
2. S. Gauza, M. Jiao, H. Xianyu, Q. Song, S.T. Wu, and R. Dabrowski, "High birefringence liquid crystals for photonic and display applications" 17th Conference on Liquid Crystals, Augustow, Poland (September 2007)

2. Demographic Data for this Reporting Period:

(a) Number of Manuscripts submitted during this reporting period:	40
(b) Number of Peer Reviewed Papers submitted during this reporting period:	25
(c) Number of Non-Peer Reviewed Papers submitted during this reporting period	13
(d) Number of Presented but not Published Papers submitted during this reporting period	2

3 Demographic Data for the life of this agreement:

(a) Number of Scientists Supported by this agreement (decimals are allowed)	0
(b) Number of Inventions resulting from this agreement	0
(c) Number of PhD(s) awarded as a result of this agreement	3
(d) Number of Bachelor Degrees awarded as a result of this agreement	0
(e) Number of Patents Submitted as a result of this agreement	0
(f) Number of Patents Awarded as a result of this agreement	5
(g) Number of Grad Students supported by this agreement	5
(h) Number of FTE Grad Students supported by this agreement	0
(i) Number of Post Doctorates supported by this agreement	3
(j) Number of FTE Post Doctorates supported by this agreement	0
(k) Number of Faculty supported by this agreement	2
(l) Number of Other Staff supported by this agreement	0
(m) Number of Undergrads supported by this agreement	1
(n) Number of Master Degrees awarded as a result of this agreement	0

4 "Report of inventions" (by title only)

1. Adaptive liquid crystal lens
US patent 6,859,333 (Feb. 22, 2005).
2. Tunable electronic lens and prisms using inhomogeneous nano scale liquid crystal droplets
US patent 6,864,951 (March 8, 2005).
3. Tunable electronic lens and prisms using inhomogeneous nano scale liquid crystal droplets
US patent 7,042,549 (May 9, 2006).
4. Electrically tunable polarization-independent micro lens using polymer network twisted nematic liquid crystal,
US patent 7,079,203 (July 18, 2006).
5. Variable focus liquid lens
US patent 7,142,369 (Nov. 28, 2006).

5. "Scientific progress and accomplishments" (Description should include significant theoretical or experimental advances)

1. Developed novel fluorinated isothiocyanato tolane and terphenyl single compounds and mixtures with high birefringence and low viscosity.
2. Developed novel fluorinated isothiocyanato phenyl-tolane single compounds and mixtures with high birefringence and relatively low viscosity.
3. Formulated high birefringence, wide nematic range, and high figure-of-merit mixtures BOSS-1, 2, 3, 4, and 5.
4. Invented novel tunable-focus liquid lenses.

6 "Technology transfer" (any specific interactions or developments which would constitute technology transfer of the research results). Examples include patents, initiation of a start-up company based on research results, interactions with industry/Army R&D Laboratories or transfer of information which might impact the development of products.

1. We shipped a high birefringence liquid crystal mixture to Dr. Le Li of Kent Optronics (a start-up company in New York) for testing his switchable cholesteric filter. Telephone number: 845-897-0138.
2. We shipped a high birefringence liquid crystal mixture to Ms. Jamie Harriman of Boulder Nonlinear Systems for testing their spatial light modulator. Telephone number: 303-604-0077.
3. We licensed our patents of tunable-focus liquid lens to Dr. Robert Batchko of Holochip; a start-up company located in Albuquerque, New Mexico. Telephone number: 650-906-1064.

c. "Copies of technical reports," which have not been previously submitted to the ARO, must be forwarded with the Interim Progress Report. (See page 5 "Technical Reports" section for instructions)

Foveated wide field-of-view imaging for missile warning/tracking using adaptive optics

1. Objectives:

The main objective of this program is to develop high birefringence, low viscosity, and high resistivity liquid crystal (LC) mixtures for foveated imaging using a high resolution transmissive spatial light modulator.

2. Status of Effort:

We have synthesized five different classes of isothiocyanates liquid crystals and evaluated their mesomorphic properties and electro-optical performance. These new LC single components show a high birefringence and relatively low viscosity. However, their melting temperatures are relatively high because of their long molecular conjugation. To lower the melting points, we have formulated eutectic mixtures.

3. Accomplishments

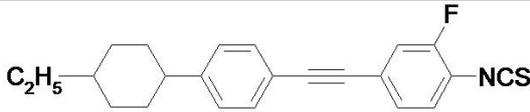
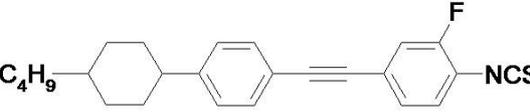
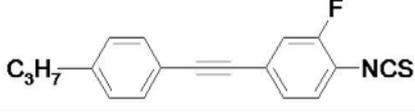
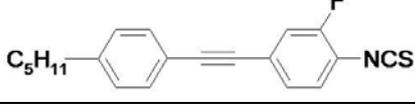
3.1 Motivation

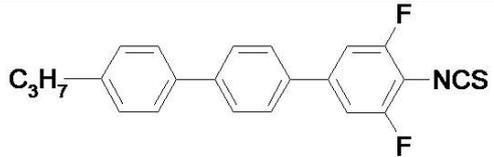
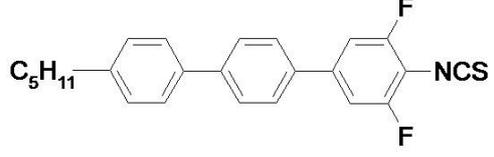
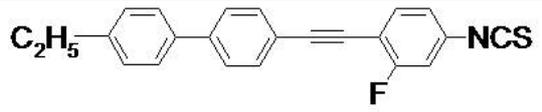
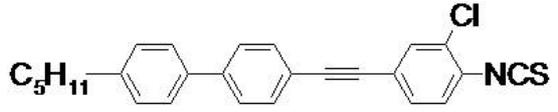
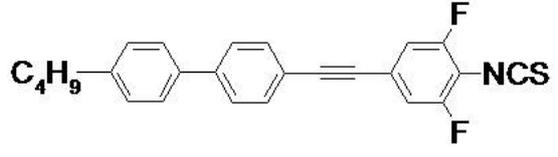
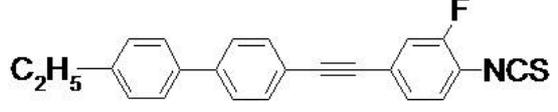
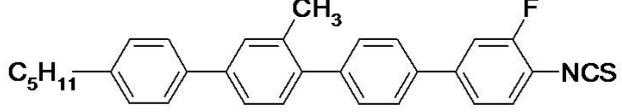
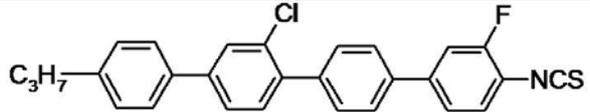
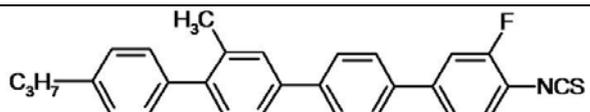
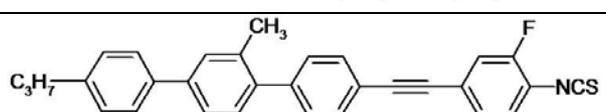
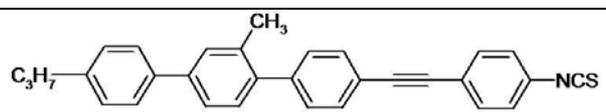
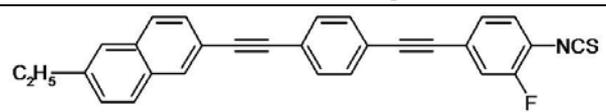
For adaptive foveated imaging using a high resolution spatial light modulator (SLM), high birefringence and low viscosity LC mixtures are highly desirable. A higher birefringence enables a thinner LC layer to be used which results in a faster response time. Low viscosity is always favorable as it helps to reduce the SLM response time. For the thin-film-transistor (TFT)-addressed SLM, high resistivity is an additional requirement. Sample of such high birefringence mixtures were delivered to BNS for SLM integration, according to roadmap of the project. High performance SLM were further delivered to Sandia National Lab for foveated imaging system demonstration.

3.2 High birefringence and fast-response time liquid crystals

We developed several different classes of liquid crystal single components based on isothiocyanate (NCS) terminal group. The NCS compounds are less viscous than the CN ones; but on the other hand, they tend to exhibit smectic phases. The CN group has a larger dipole moment ($\mu=3.9D$) than NCS ($\mu=3.7D$) because of its linear structure. However, due to the very strong polarization of the carbon-nitrogen triple bond, the Huckel charges of carbon and nitrogen are high and well localized. Accordingly, dimmers are formed by strong intermolecular interactions between the nitrile groups. This is the main reason responsible for the observed relatively high viscosity of the cyano-based LC mixtures. In contrast, the dipole moment of the NCS group is ~30% lower than that of a CN. The NCS compounds do not form dimmers so that their viscosity is lower than the corresponding CN compounds. The LC single compounds we developed contains a highly polar isothiocyanato (-NCS) terminal group. To provide extended p-electron conjugation, the rigid cores of the components were designed to be either aromatic multiple rings structure (terphenyl, quaterphenyl), tolane or blend of both types (phenyl-tolane). Table 1 shows some exclusive examples of high birefringence structures according to the level of birefringence exhibited by the compounds synthesized for the project.

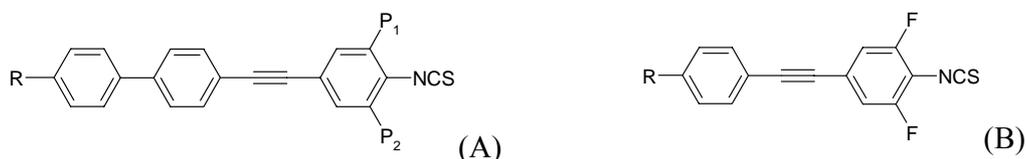
Table 1. Examples of the structures developed within the timeline of BOSS project.

No	Structure	Phase Transition Temperatures [°C]
LC compounds with $\Delta n \sim 0.35-0.40$		
		Cr 109 N 240 Iso
		Cr 78 N 239 Iso
		Cr 76 Iso
		Cr 49 Iso

		Cr 107 N 212 Iso
		Cr 100 S 156 N 187 Iso
LC compounds with $\Delta n \sim 0.40-0.55$		
		Cr 147 N 245 Iso
		Cr 104 N 207 Iso
		Cr 65 (SmB 50) N 212 Iso
		Cr 146 N 255 Iso
		SmB 114 N 280 Iso
		Cr 155 N 300 Iso
		Cr 109 N 306 Iso
		Cr 156 N 300 Iso
		Cr 166 N 317 Iso
LC compounds with $\Delta n \sim 0.60-0.70$		
		Cr 217 N 322 Iso

	Cr 128 N 242 I
	Cr 142 Sm-X 184 N 252 Iso
LC compounds with $\Delta n \sim 0.70-0.75$	
	Cr 178 SmA 250 N 342 Iso
	Cr 128 SmA 160 N 256 Iso
	Cr 106 N 244 Iso

In general, with increasing π -electron conjugation, significant increase of melting point temperature is observed. It is balanced at some level by mono or multiple lateral substitutions. As for the BOSS mixtures formulation the structures (A) and (B) are most attractive among presented in Table 1. The detailed analysis of the electro-optical performance of the tolane and phenyl-tolane compounds family was described in the 2006 and 2007 reports. Those compounds typically show $\Delta n \sim 0.35-0.50$ at $\lambda = 633$ nm wavelength and room temperature. The lateral fluoro substitution near the NCS group serves for three purposes: 1) it lowers the melting temperature of the single compound, 2) it increases the resistivity of the compounds, and 3) it increases the dielectric anisotropy which is helpful for reducing the operating voltage. A tradeoff is that it also reduces the birefringence and increases the viscosity.



Structure A could be a single or double fluorinated phenyl-tolane and B is a (3,5) difluorinated tolane. We confirmed that from optical response time judged by Figure-of-Merit (eq.1), this kind of molecular structure exhibits the most attractive balance between high birefringence (Δn) due to the elongated π -electron conjugation length and rotational viscosity.

We developed and delivered five different mixtures within the timeline of the project. Table 2 shows the electro-optical properties of the delivered mixtures in comparison to popular, commercially available, high birefringence E44 mixture from Merck.

Table 2. Electro-optical and physical properties for Merck's E44 and BOSS mixtures.

	E-44 (Merck)	BOSS-1	BOSS-2	BOSS-3	BOSS-4	BOSS-5
Physical Properties	@ 25C, 1kHz					
V_{th} [Vrms]	1.8	1.6	--	--	1.4	1.3
$\epsilon_{ }$	17.8	19.8	--	--	21.1	27.0

ϵ_{\perp}	4.1	4.2	--	--	3.9	4.2
$\Delta\epsilon$	13.7	15.6	--	--	17.2	22.8
Electro-optical Properties						@ 25C, 1kHz
Δn (633/530nm)	0.25/0.27	0.38/0.42	0.49/0.53	0.52/0.56	0.44/0.49	0.45/0.49
γ_1/K_{11} [ms/mm ²]	22.8	10.5	25.0	40+	11.3	12.6
FoM [mm ² /s]	2.7	13.8	9.6	<5.0	17.1	16.2
Mesomorphic Properties [Phase Transition Temperature]						@ 5deg/min
T_M^*/T_C [°C]	-6/100	-10/110	12/168	16/210	18/110	4/126
*Cr(S)->N						

All developed mixtures show a birefringence $\Delta n \sim 0.4-0.5$ at room temperature condition and visible wavelength. As already mentioned above, increasing conjugation length through the molecule also results in an increased rotational viscosity. Moreover, melting point temperature becomes unfavorably high, see Table 1. If only birefringence is considered, the best performing mixture among presented in Table 2 is BOSS-3 with $\Delta n \sim 0.52/0.56$ measured at $\lambda = 633\text{nm}$ and 530nm wavelength. At the same time mixture BOSS-3 exhibits the highest visco-elastic coefficient (γ_1/K_{11}) due to increased rotational viscosity. All together, despite its highest birefringence, its Figure-of-Merit is the smallest. This makes BOSS-3 less attractive for practical applications. When mixture BOSS-1, BOSS-4 and BOSS-5 are compared, beside of birefringence and visco-elastic coefficient, the mesomorphic properties come to play an important role. In this category BOSS-1 mixture is the most favorable as its melting temperature is the lowest among the developed mixtures. The FoM of BOSS-1 averages at $\sim 14 \mu\text{m}^2/\text{s}$, which assures a fast response time with the visco-elastic coefficient of $10.5 \text{ ms}/\text{mm}^2$, which is the lowest for the mixtures presented in Table 2. Tests performed at BNS facility have proven that BOSS-1 is the most promising one from the application standpoint. Therefore BOSS-1 mixture was further modified and synthesized in large quantity for ionic purification. LC mixture resistivity is an important parameter especially for active matrix-based spatial light modulator. A low resistivity LC mixture could not hold the displayed image steadily leading to image flickering. The LC resistivity could be affected by impurities. A certain amount of impurities always exists in organic compounds and mixtures. They can be of different kinds:

1. Non-polar, non-dissociation like neighbored homologues of a given compound. Such impurities can be determined by calorimetric (DSC) or chromatographic (GC or GC/MS) methods. They only have a minor influence on the resistivity of the LCs.
2. Polar, completely dissociated like inorganic salts, acids or bases as residuals after syntheses. Even a small amount of such impurities have a major influence on the LC resistivity. This type of impurities can be easily determined by resistivity measurements. Typically they are relatively easy to be removed from the single compounds during recrystallization processes.
3. Polar, partially dissociated like organic acids, phenols or bases. Their dissociation level depends on the dielectric constant of the whole LC mixture system. They change the electrical resistivity drastically and can be reduced by repeating the purification processes.

In order to obtain high chemical stability, all the BOSS-1 mixture compounds were synthesized with special attentions paid to the chemical purity. The chemical purity of the single compounds and also all the intermediate products was measured by GC/MS (gas chromatography/mass spectroscopy) method and an average value of 99.99 % was obtained for the final structures by using FID (Flame Ionization Detector) detector at the GC part of the setup. The ion purification process requires large quantity samples in order to obtain a high value of resistivity. BOSS-1 mixture was purified in multistep ion exchange procedures. The resistivity of BOSS-1 was measured to be $\sim 10^{+13}$ Ohm, see Table 3.

Table 3. Resistivity measured before and after the ion purification process.

Sample	Resistivity [Ohm]	Recovery [gm]	Water content [ppm]
BOSS -1A (Before)	8.2*E+10	23.0	96
BOSS -1A (After)	1.1*E+13	15.0	85

Photochemical stability is also an important issue in case of the high birefringence LCs. We measured electro-optical performance and all of the parameters listed in Table 2 vs. exposure time. The wavelength range of the light going through the sample was adjusted to the range of 432-682nm. The power of the collimated beam was estimated to be $\sim 100-120 \text{ mW}/\text{cm}^2$. Very promising results were

obtained within 80 hours of continuous exposure. There was no noticeable change of the measured value of: threshold voltage, dielectric and elastic constants as well as birefringence and rotational viscosity within the time of exposure. The clearing point temperature (T_c) remains the same. In order to check the thermal stability of our high birefringence BOSS mixture we choose a temperature of 125°C which is 15 degrees above the clearing point. We measured total phase retardation (at 70°C) and calculate the birefringence and visco-elastic coefficient periodically during this test. The Figure-of-Merit value was also calculated. During the test period we did not observed any change of the optical threshold, birefringence or visco-elastic coefficient value.

4. Summary

All tests performed show that BOSS-1 type mixture overpasses commercially available high birefringence mixtures in terms of electro-optical performance while its photochemical and thermal stability allows the applications in the visible and infrared spectral regions. Therefore, BOSS-1 mixture has strongest application potential among mixtures developed within the project timeline. BOSS-1 enables switching speed 3X shorter than achieved with a commercial LC when used in a reflective 512x512 LCoS at $\lambda=633$ nm. When BOSS-1 was used in a transmissive 1280x1024 SLM, its switching speed was ~6X faster than that of a commercial LC mixture, according to BNS data. The difference is due to different cell gap employed. Our high birefringence and relatively low viscosity LC enables a thinner cell gap to be used, which leads to a faster response time.

Enclosure 2

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