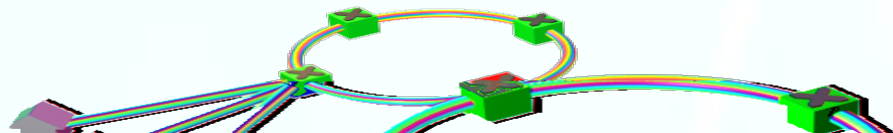


2014.5.8



非显示应用：液晶的下一个蓝海？





南京大学
NANJING UNIVERSITY

液晶与微纳光学研究组

Liquid Crystal and Nano-photonics Group

非线性与微纳光学 / 光纤传感与通讯 / 液晶材料与器件 / 其他

English

首页

简介

研究方向

研究团队

科研成果

招生招聘

常用链接

联系我们

公告

2013年4月9日

A313, 报告人: 陈烨、葛士军

2013年4月2日(周二)晚7:00唐仲英楼

A313, 报告人: 王磊、郑必才

2013年3月26日(周二)晚7:00唐仲英楼

A313, 报告人: 吴子建、陈锦辉

2013年4月22日(周二)晚7:00唐仲英楼

A213, 报告人: 国威、曲广媛

内部成员登录>>



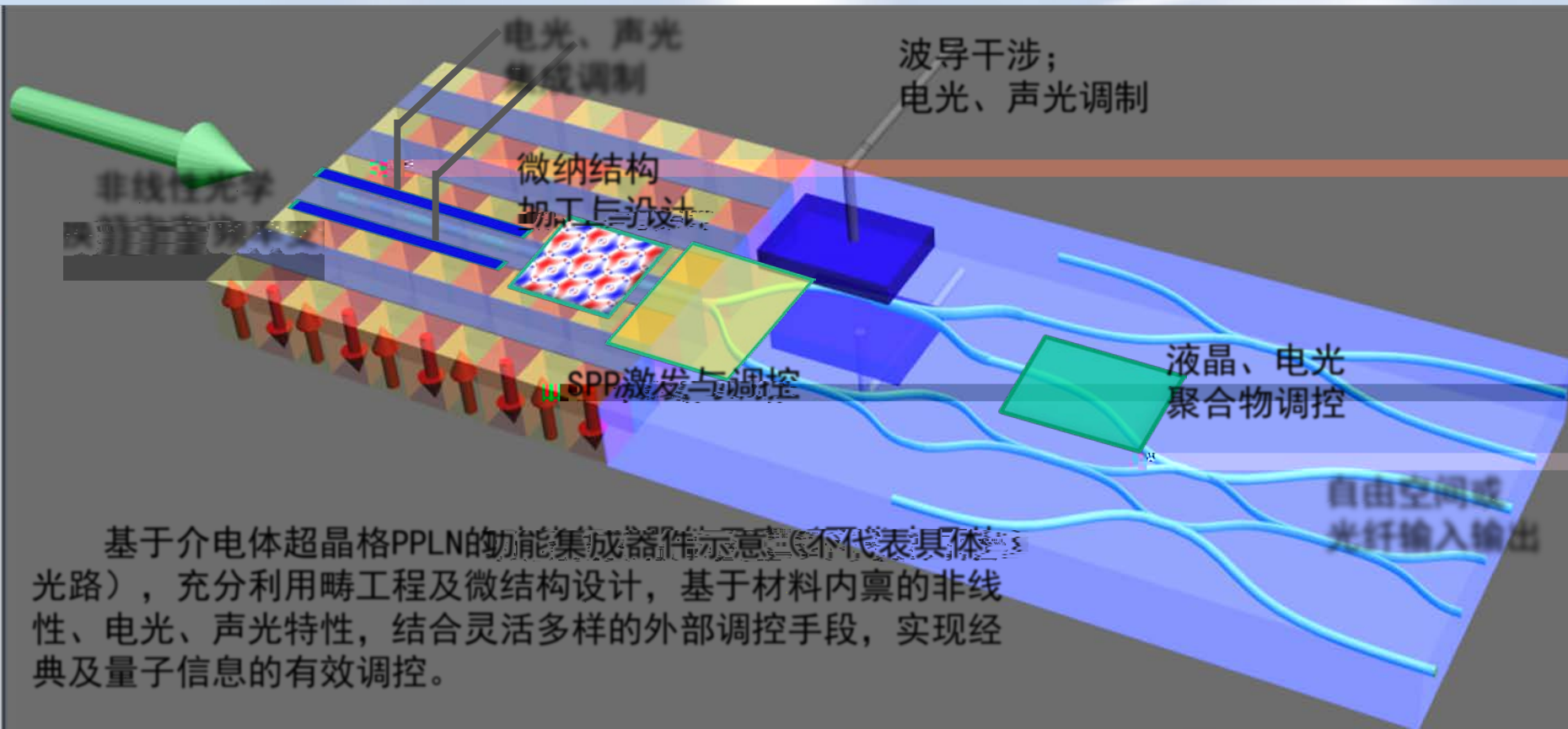
研究组2013年千岛湖春游

1 2 3 4 5

To make life a dream and to turn the dream into a reality

———— 我要把人生变成科学的梦，然后再把梦变成现实 ————

Maria



Science **276**, 2004; *Science* **284**, 1822; *PRL* **90**, 053903; *Sci. Rep* **4**, 4812
APL **77**, 3719; *APL* **78**, 1035; *APL* **85**, 3531; *APL* **101**, 151109 ; *APL* **104**, 171110
PRA **88**, 063827; *PRB* **82**, 155107; *OE* **17**, 11965; *OE* **18**, 7340; *OE* **19**, 380
OL **35**, 3327; *OL* **36**, 2533; *OL* **36**, 4434; ...



无处不在的液晶



1. Handheld



2. Notebook



3. Desktop



4. LCD-TV



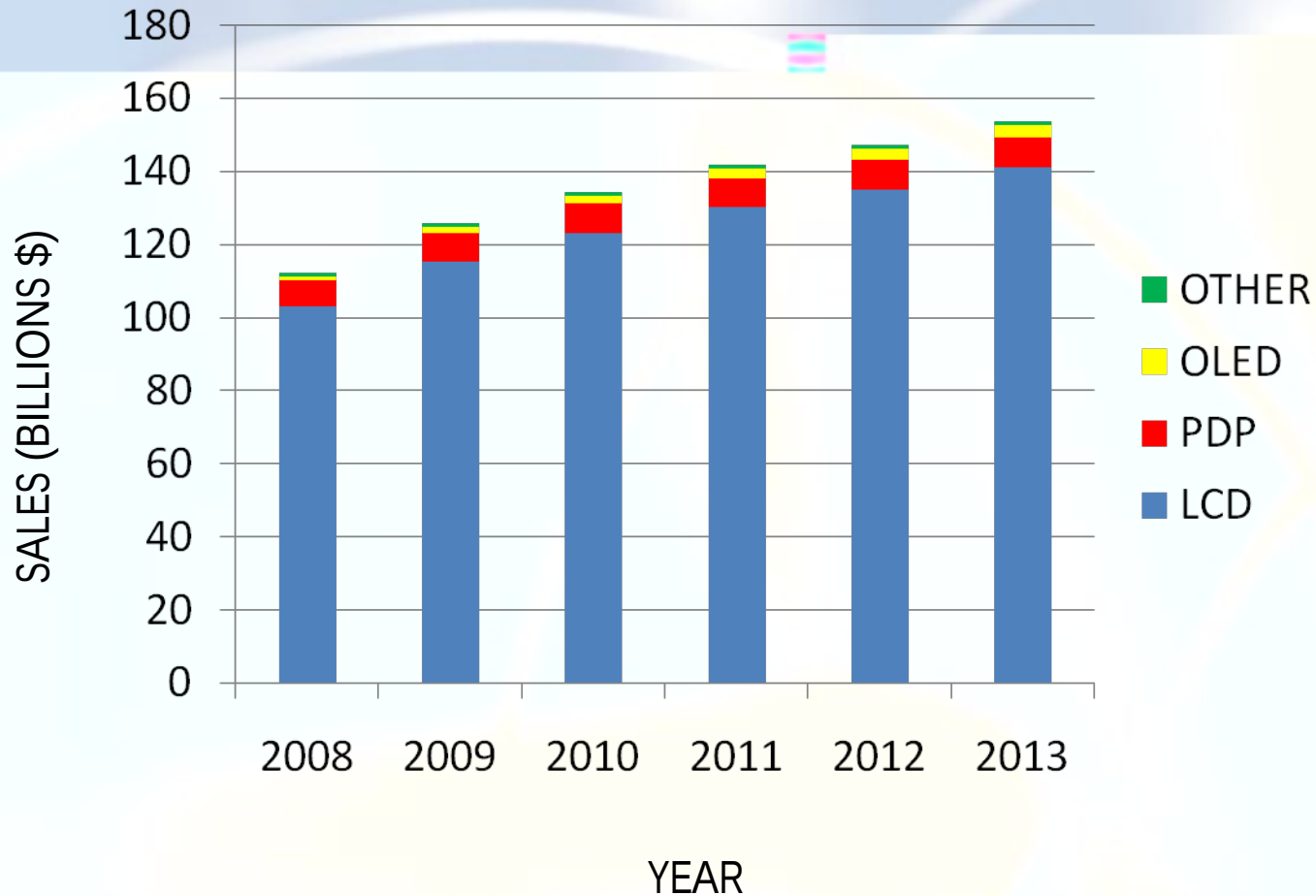
5. Rear-projection TV



6. Projector

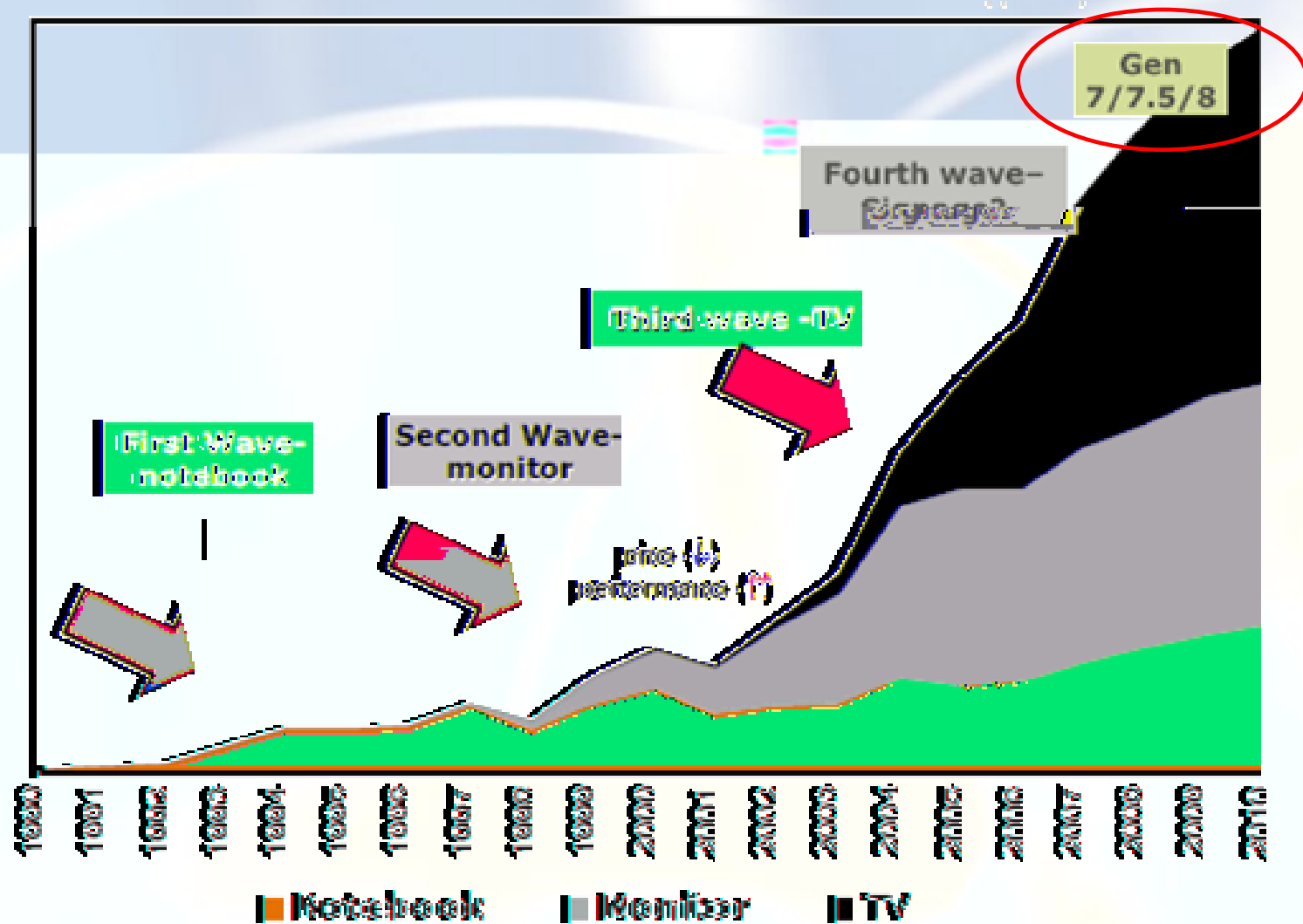


Market analysis: FPD Market

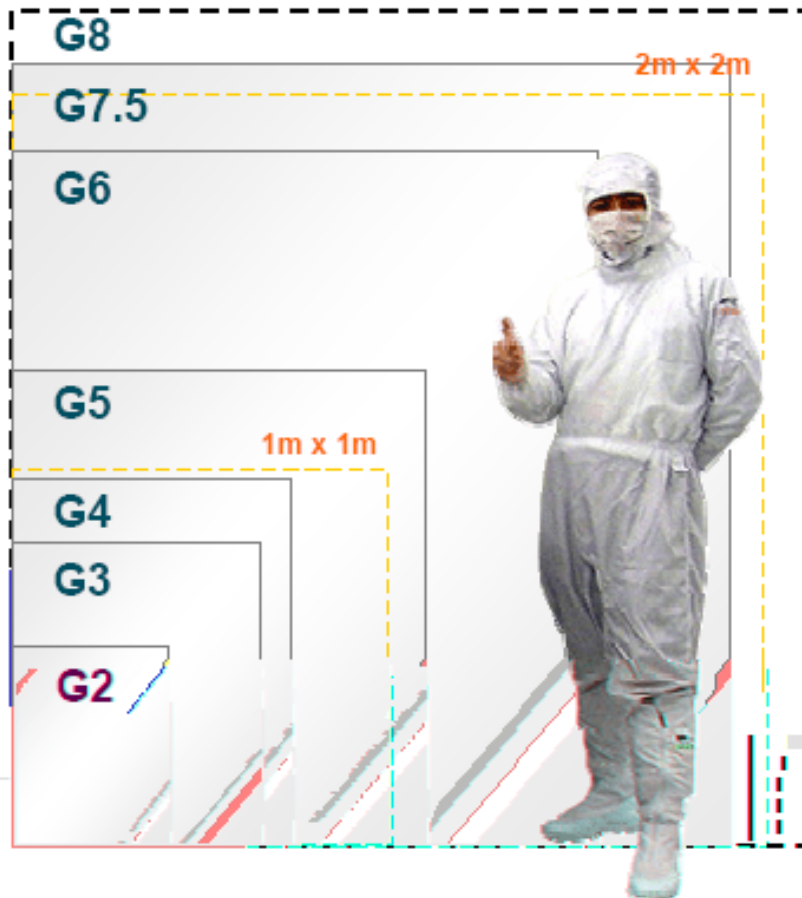




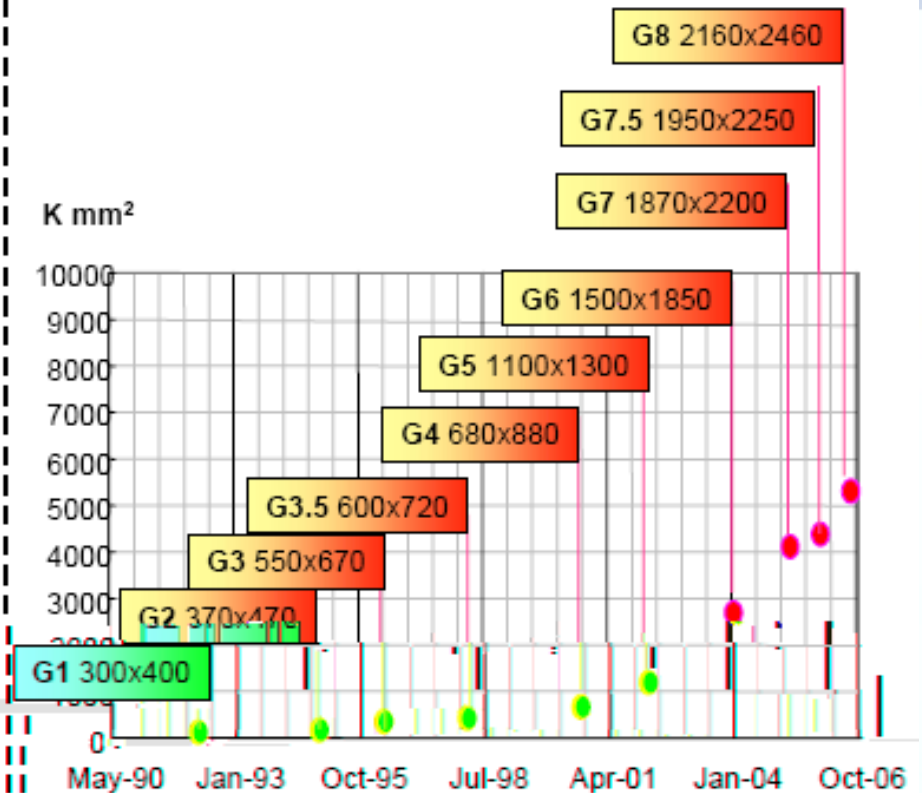
LCD win the market, history and trend



LaD Generation Migration



Relative Glass Size in Each Generation

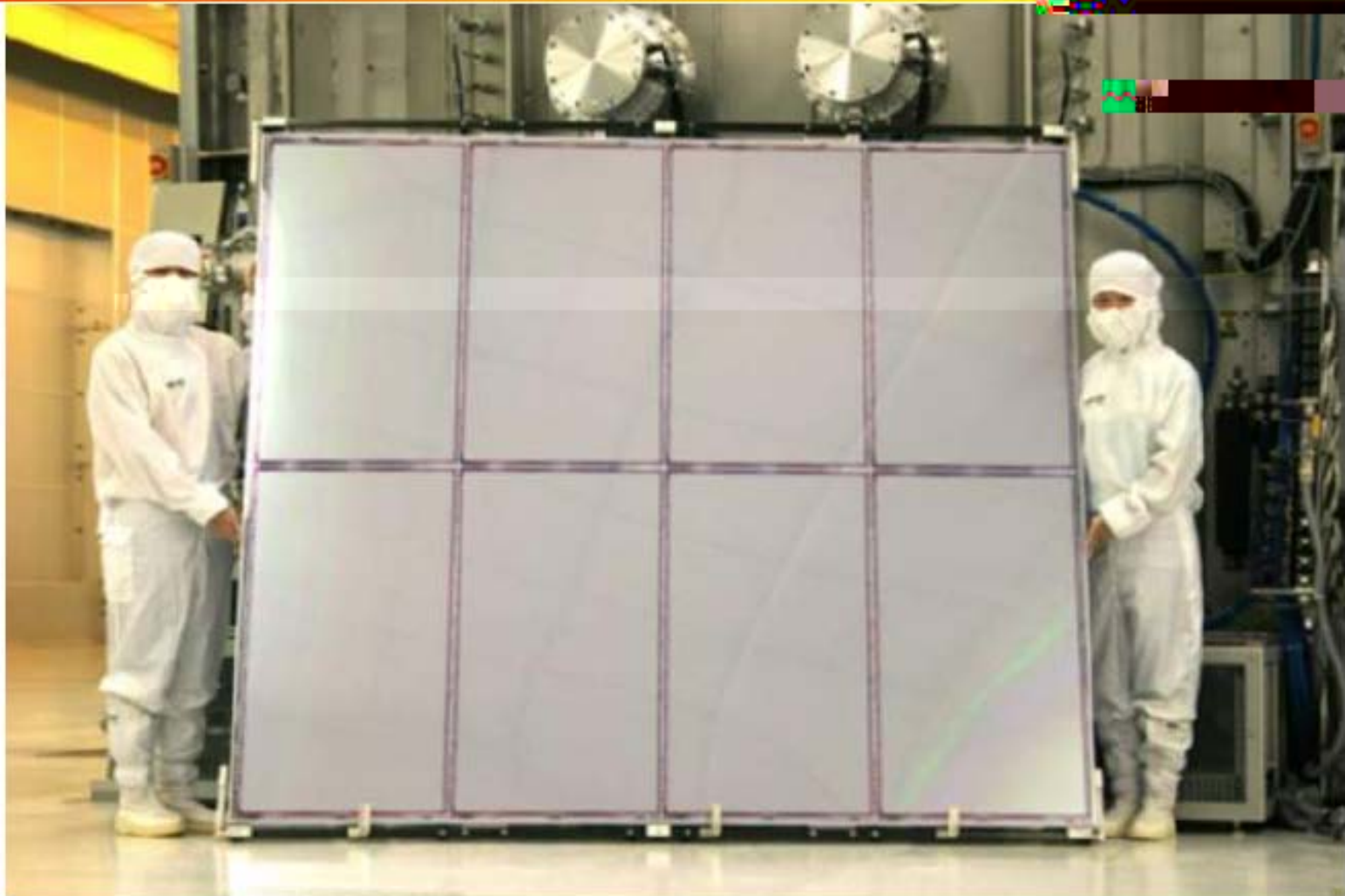


TFT LCD Generation Migration



LaD Generation Migration

2000/02 Taiwan 第 1035 号 出之 421





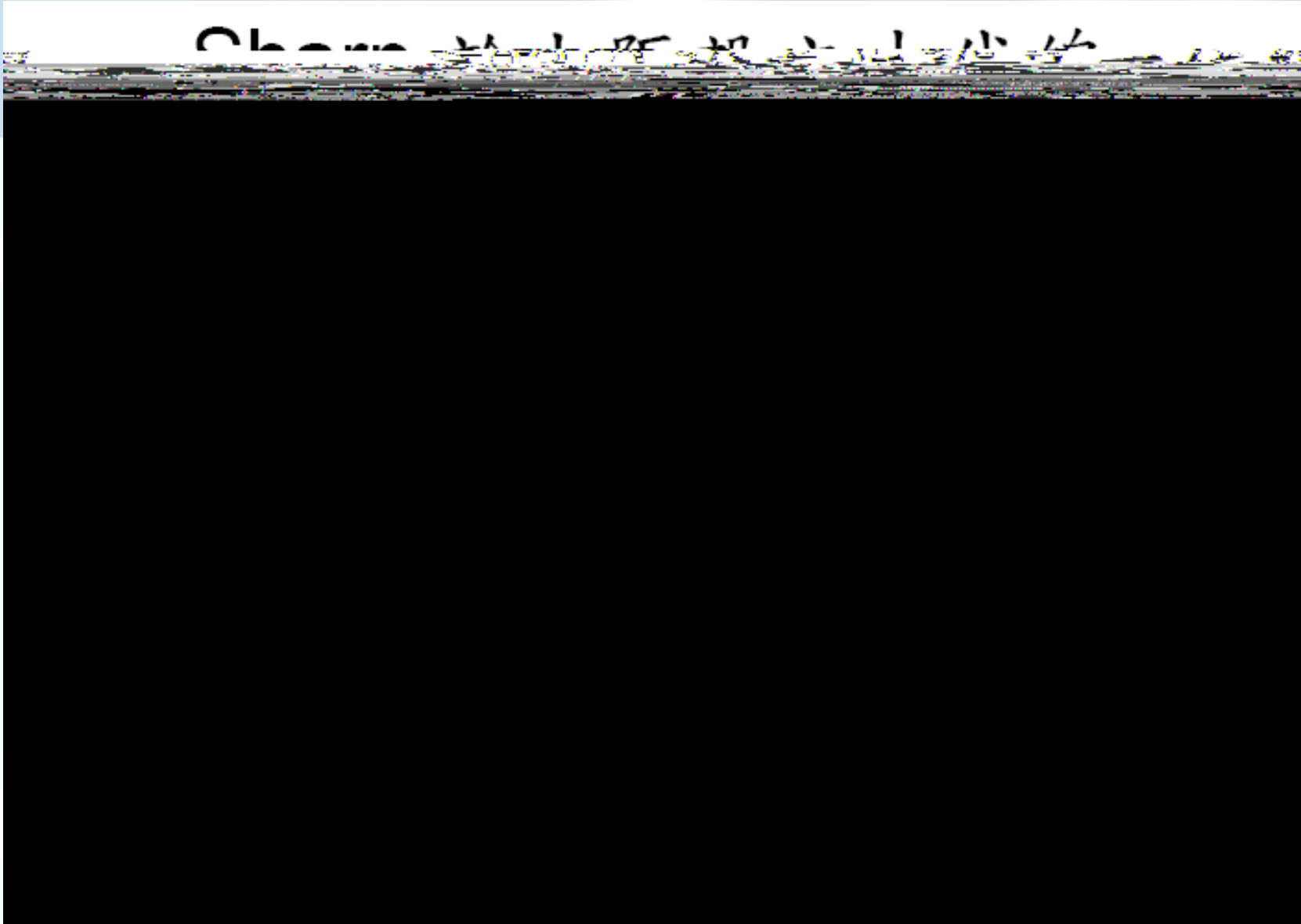
LCD Generation Migration

G7.5 巨大機台



Photo : 長達68公尺, 重量 242 噸

LCD Generation Migration



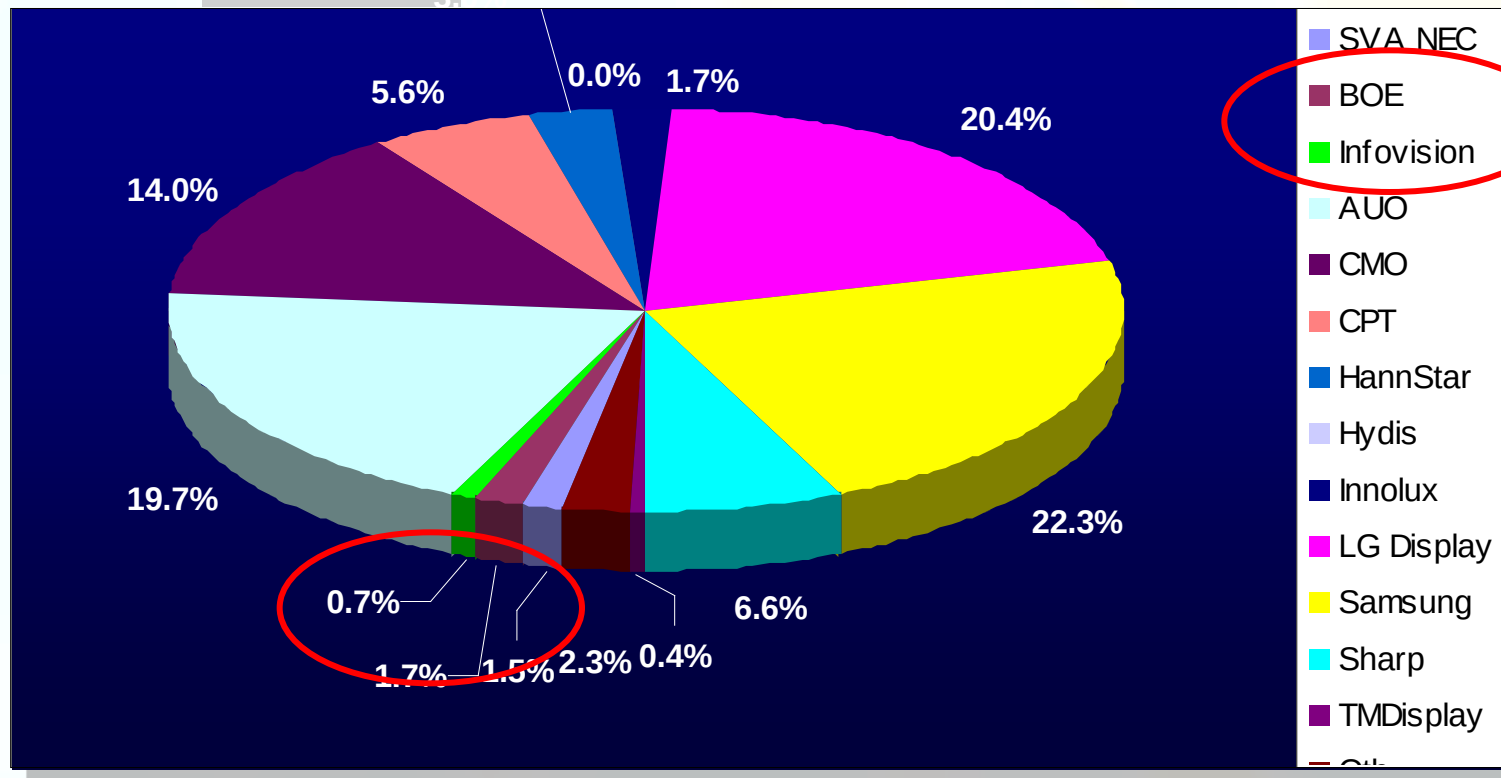
2008

TFT-LCD



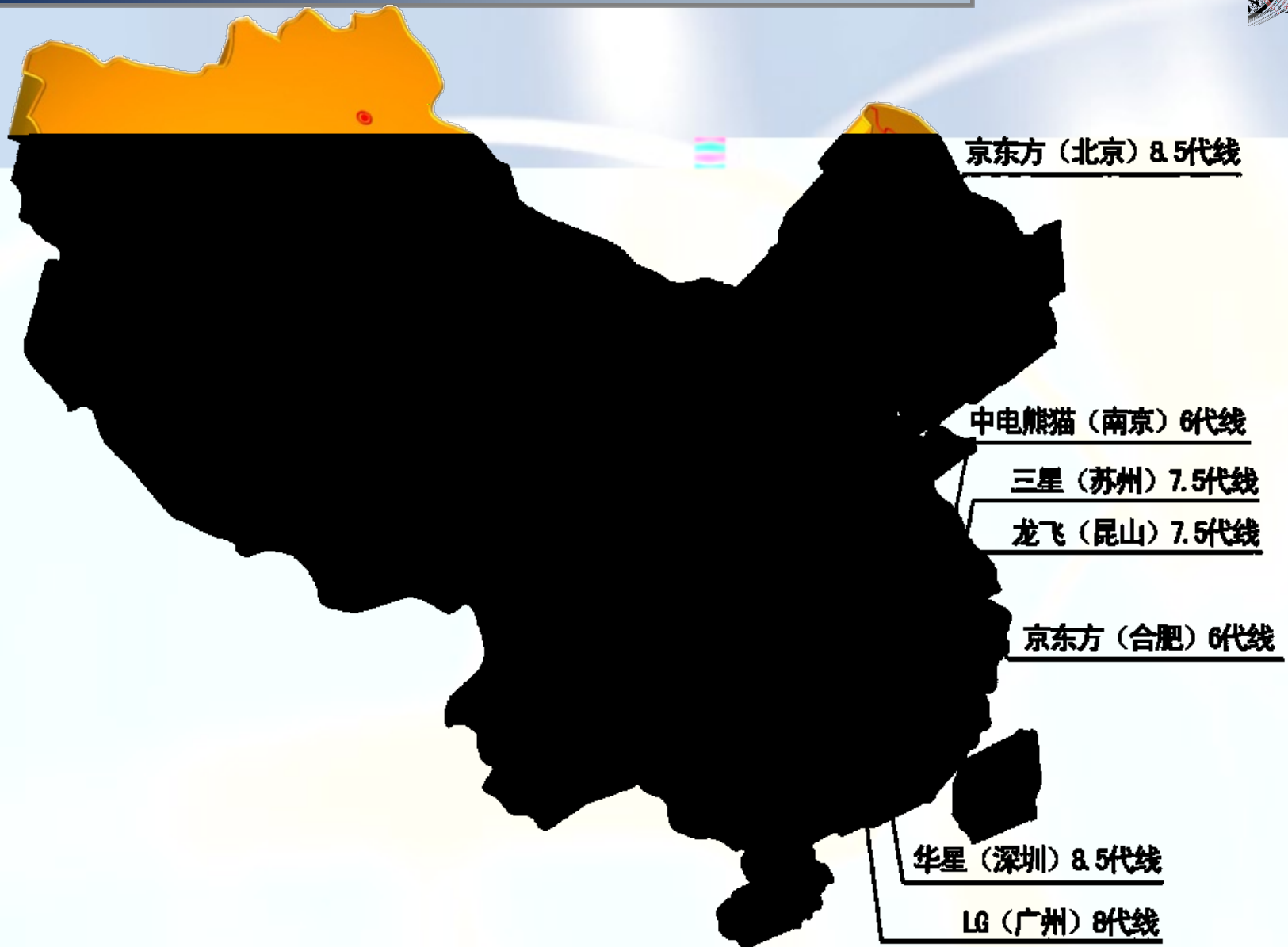
- TFT-LCD 5 3%

全球TFT-LCD制造商份额 (2007.5-2008.4, 按面积)





TFT-LCD



南京液晶谷



南京市人民政府
南京市人民政府

中国电子信息产业集团有限公司
中国電子情報産業グループ有限公司

日本国夏普株式会社
日本国シャープ株式会社

高世代液晶面板项目签字仪式

高世代液晶パネルプロジェクト調印式

2009年8月31日 北京 钓鱼台



✓ 1888

F.Reinitzer

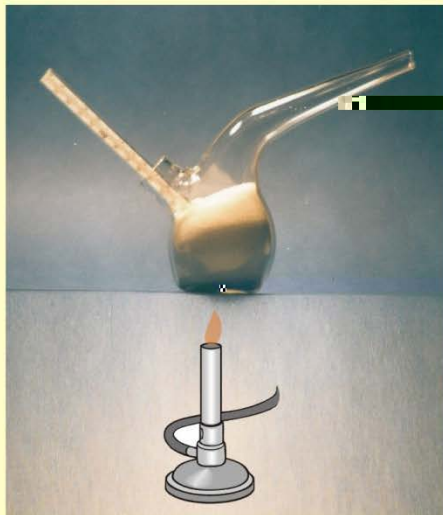
✓

✓

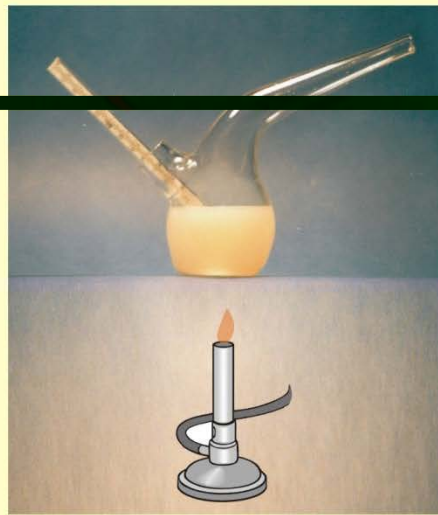
✓

✓

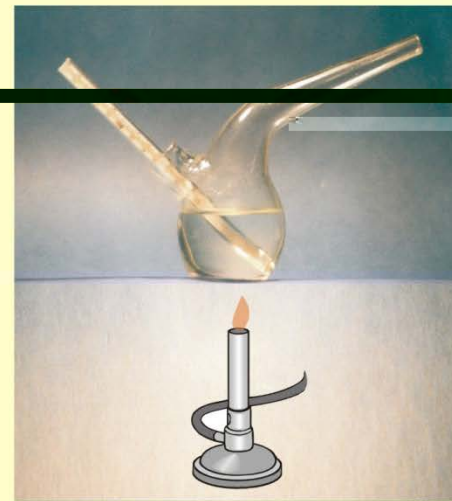
Liquid Crystal)

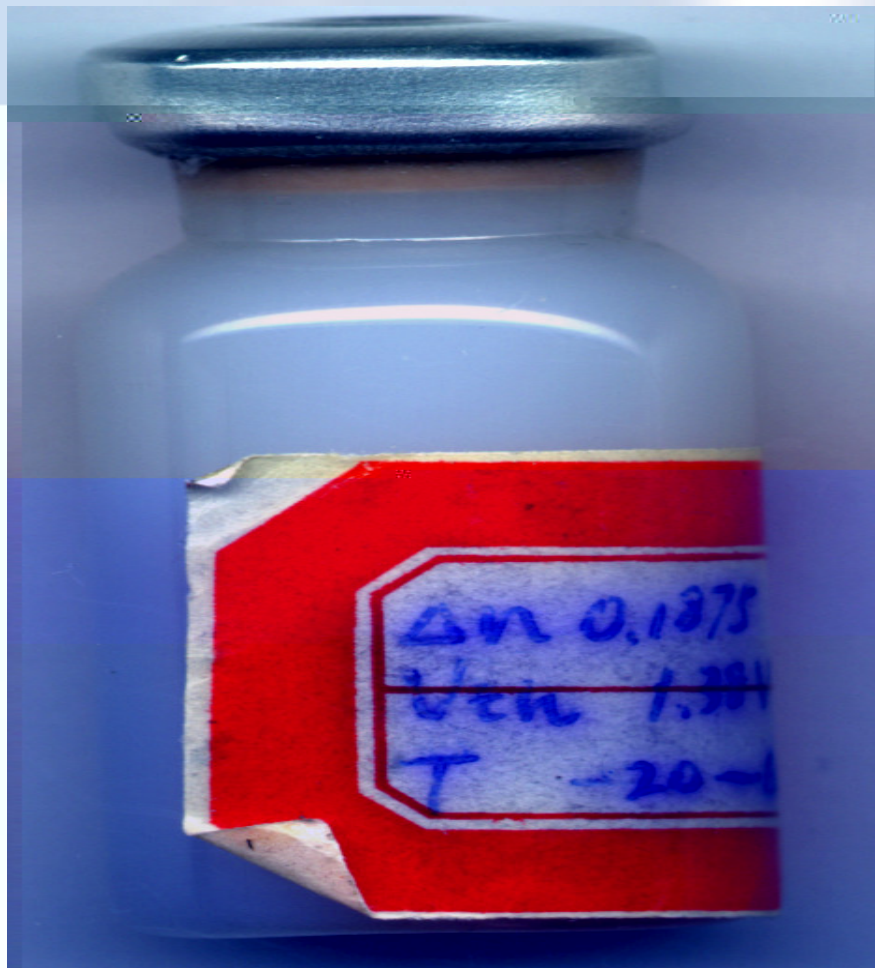


150 °C

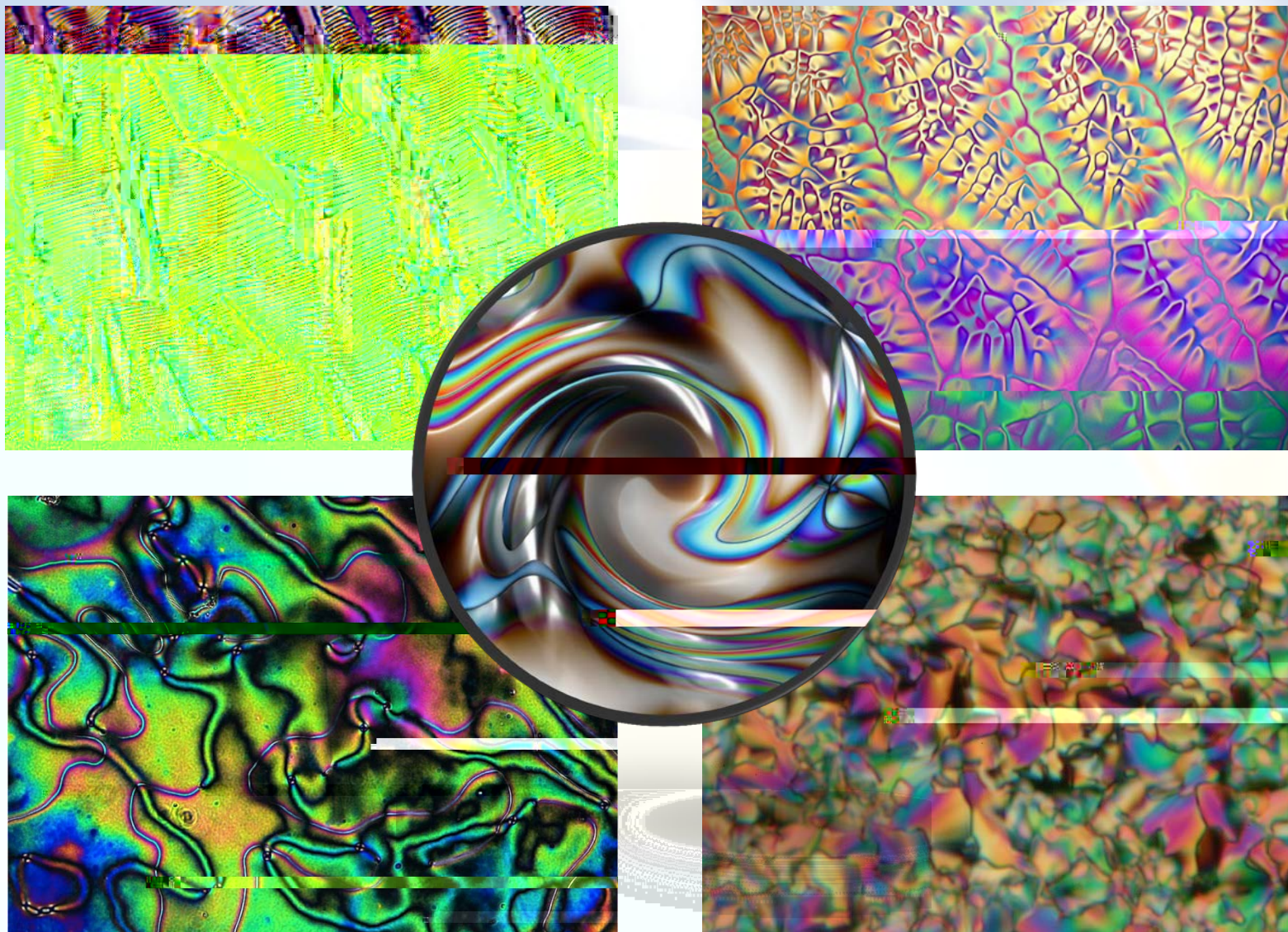


182 °C



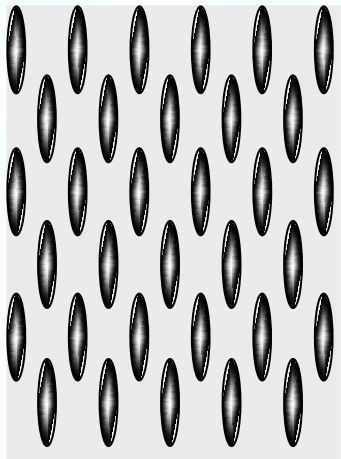


偏光显微镜下的液晶



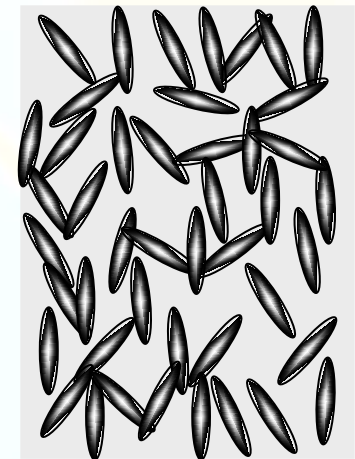
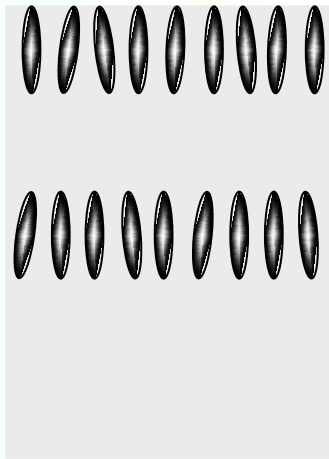


- Solid Anisotropic Liquid Isotropic
- As T increases, order parameter decreases.
Crystal: $S=1$; LC: $S\sim 0.6-0.8$, Isotropic: $S=0$.



Solid

Crystalline



Liquid

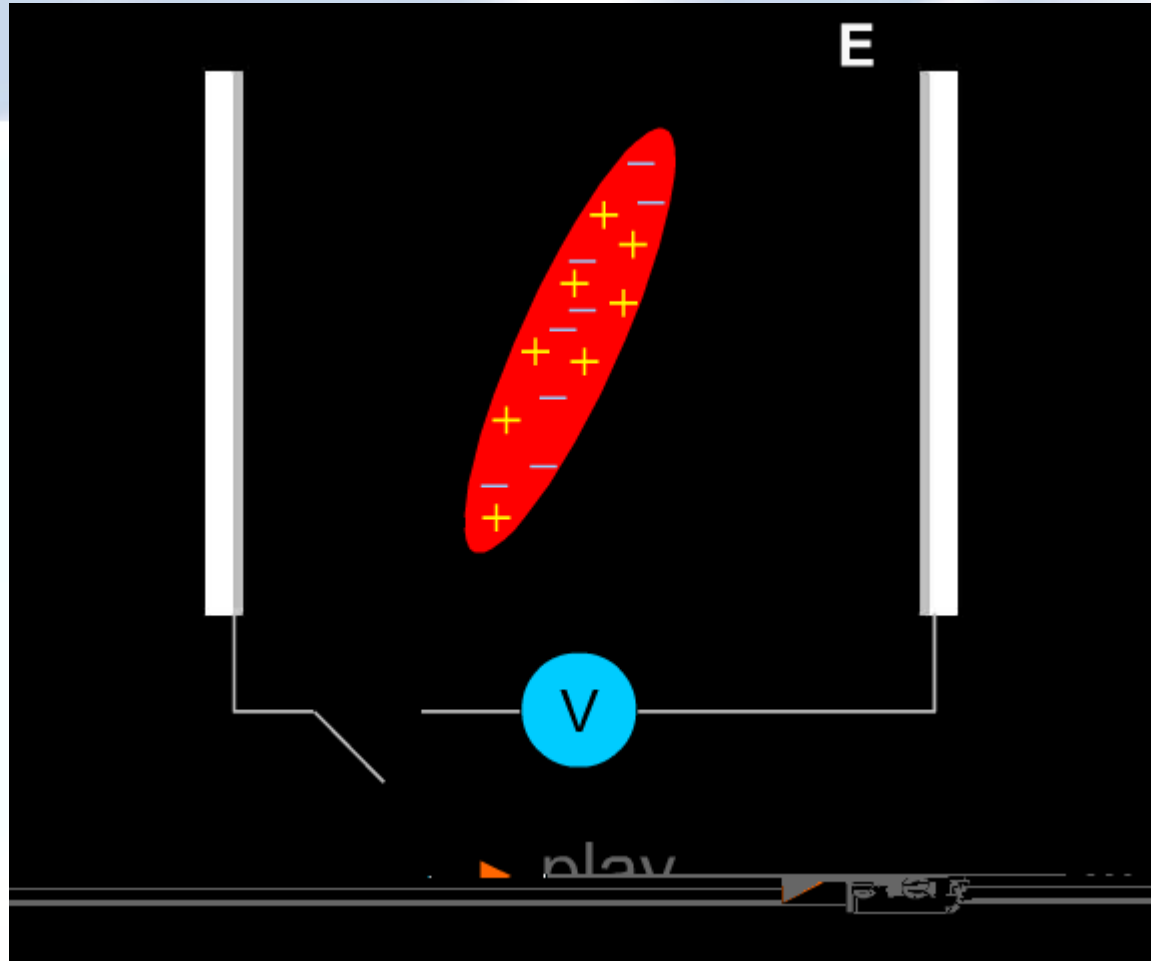
Isotropic

T_m

T_{NI}

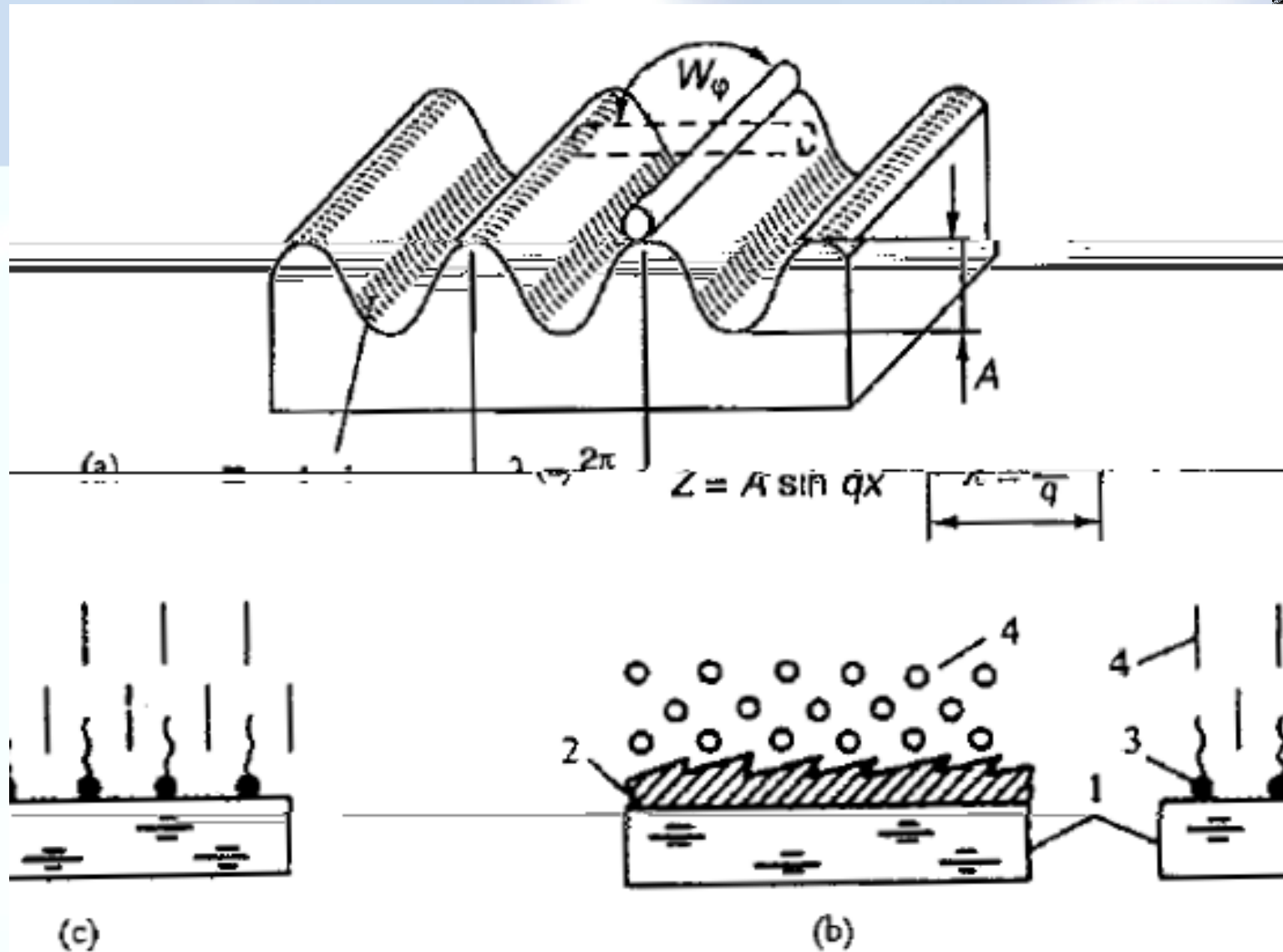
Temp.

电场下的液晶分子

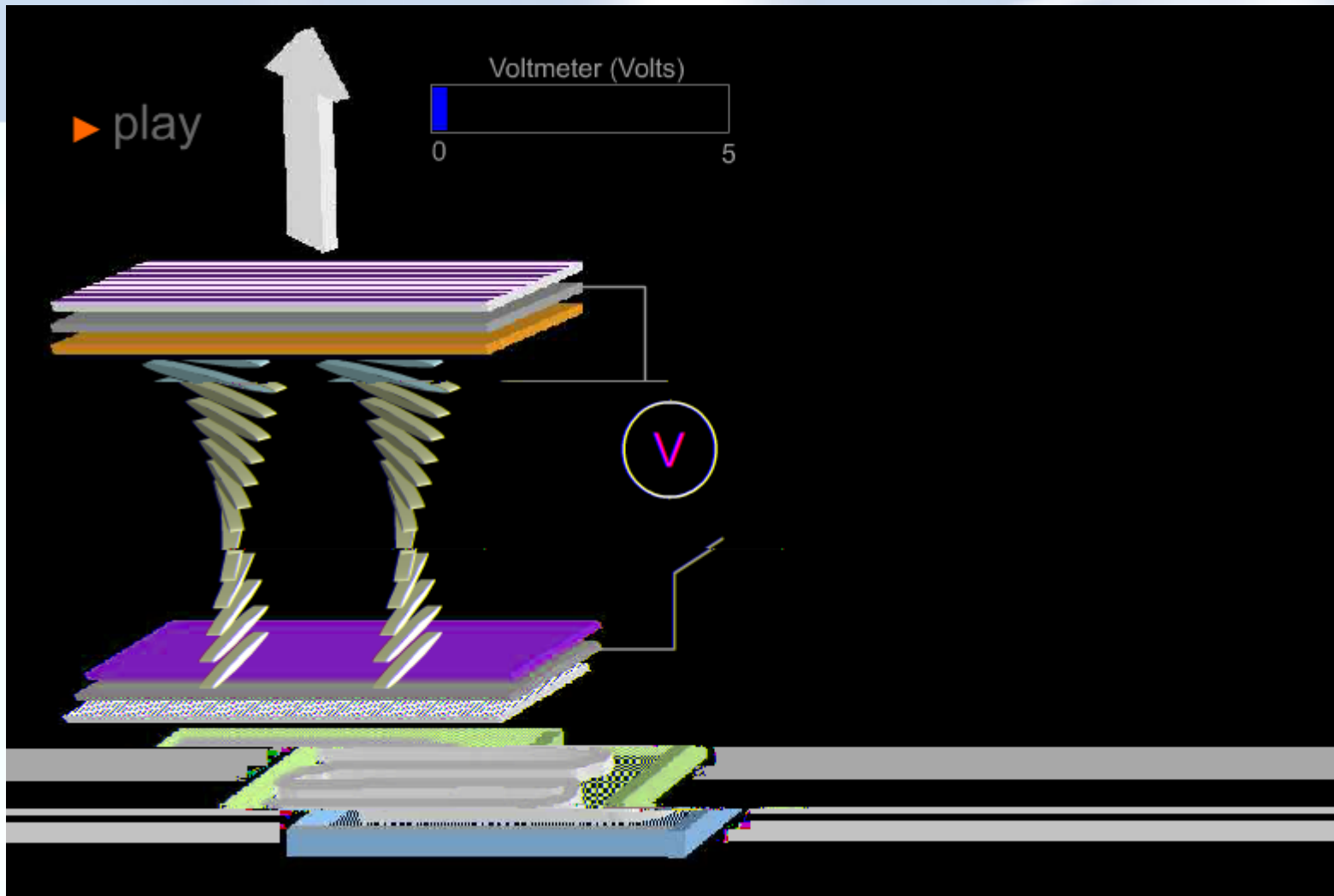




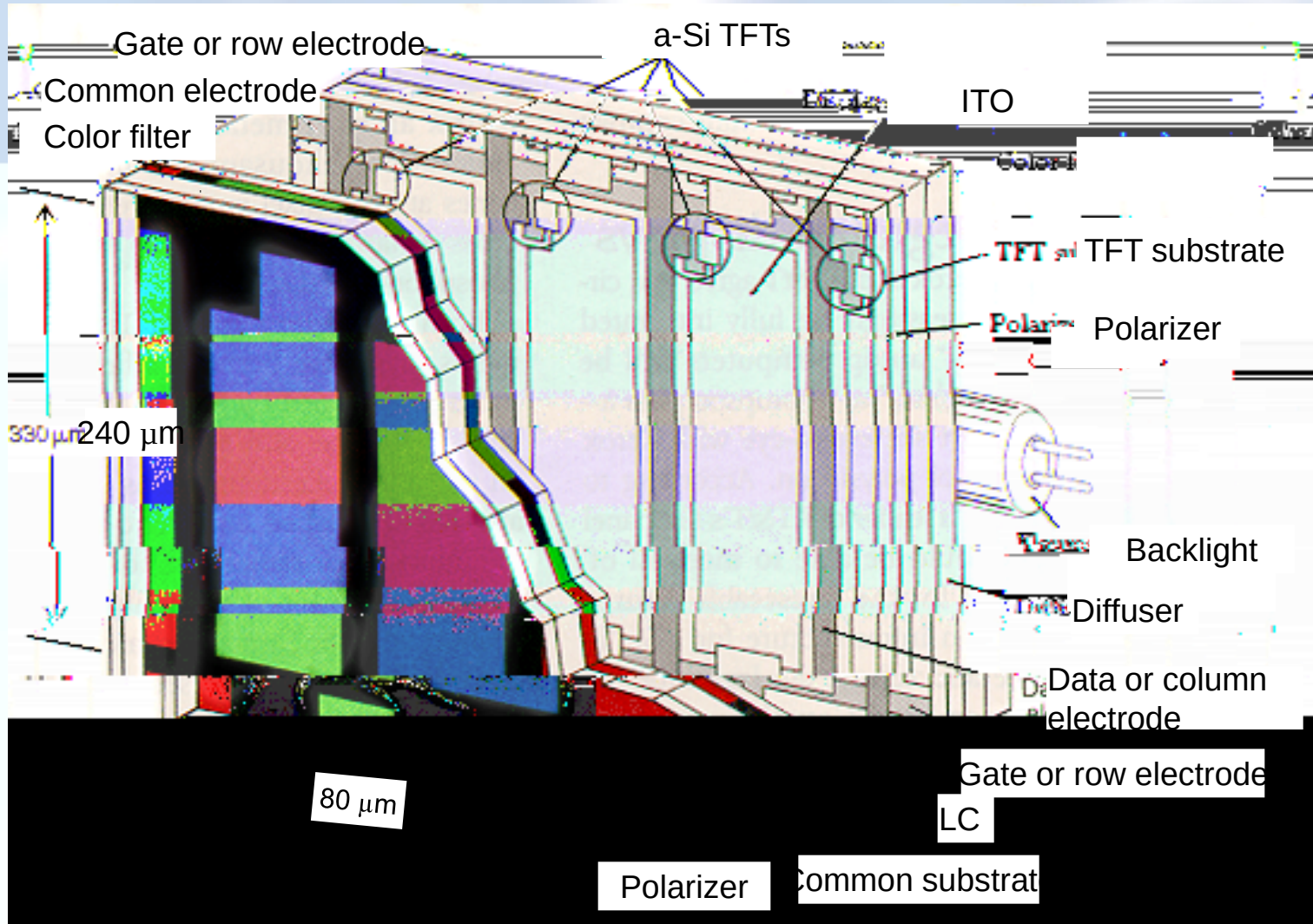
Methods of LC alignment



TN LCD Demo



Transmissive TFT-LCD



Each pixel is independently driven by a TFT



PANDA

熊猫

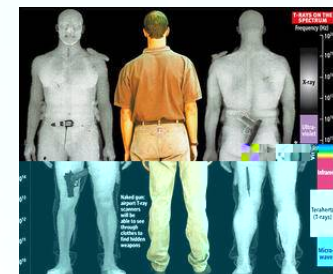
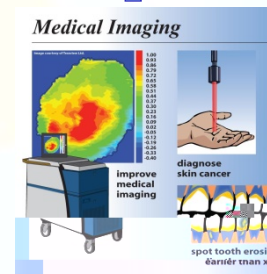
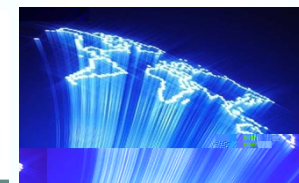
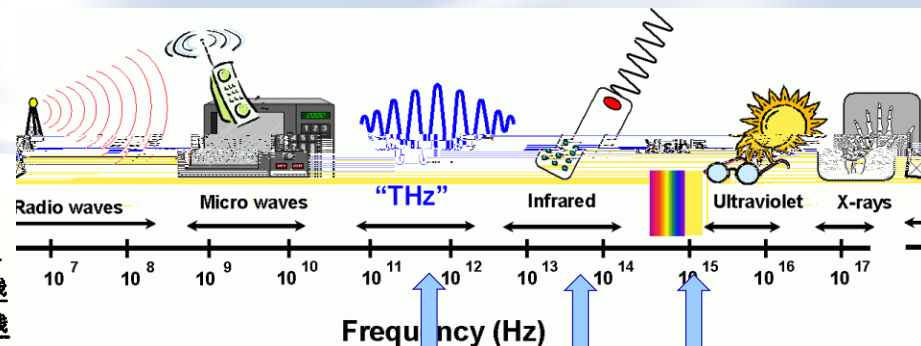
功夫™



熊 猫 液 晶 电 视

功夫还是熊猫好

非显示液晶材料及器件：光电产业的新蓝海？





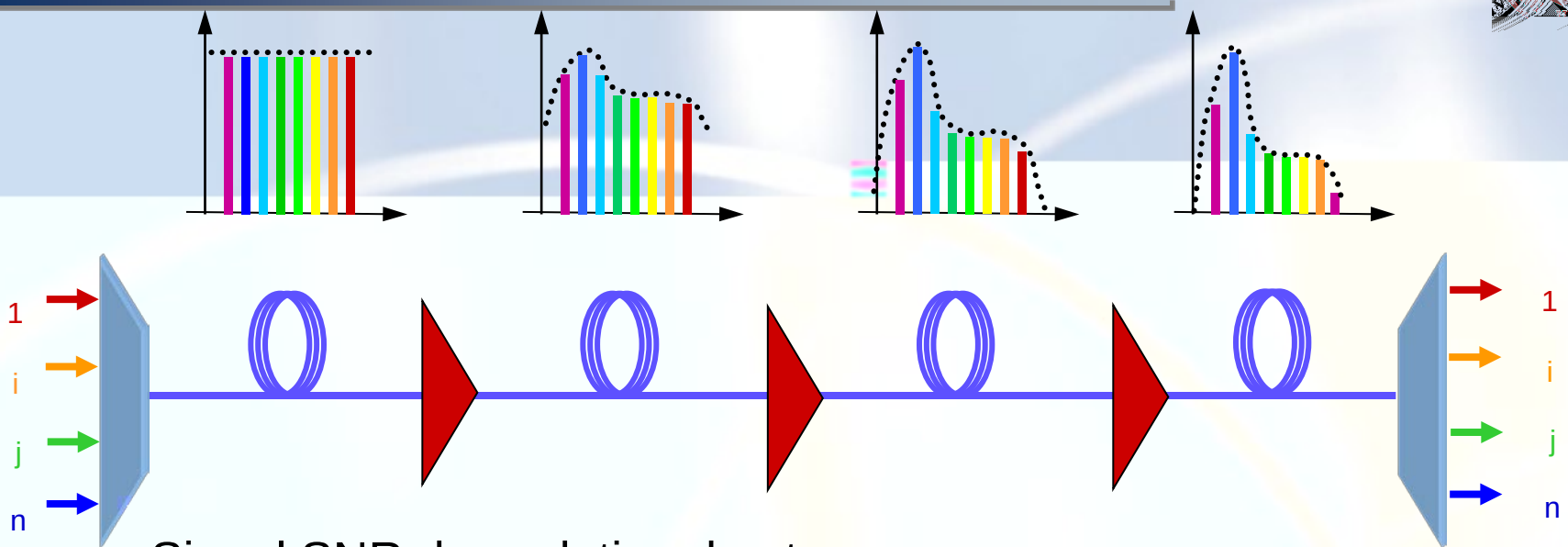


Outline

- ✓ Telecommunications and photonic applications
- ✓ LC based VOA (variable optical attenuator)
- ✓ LC based DWDM wavelength blocker
- ✓ LC based diffraction grating



DWDM Networks – an example of adaptation



Signal SNR degradation due to:

- ⇒ Non flat spectral response of the EDFA
- ⇒ Power dependancy of the response of the EDFA
- ⇒ **Wavelength Add & Drop**



DWDM networks – components requirements

Components inserted into a network have to be:

- ↪ Polarization Insensitive
- ↪ Weakly wavelength dependent
- ↪ Wide temperature range
 - ↪ Storage: -40°C to 85°C
 - ↪ Operating: -5°C to 70°C



LC, advantages

✓ Advantages:

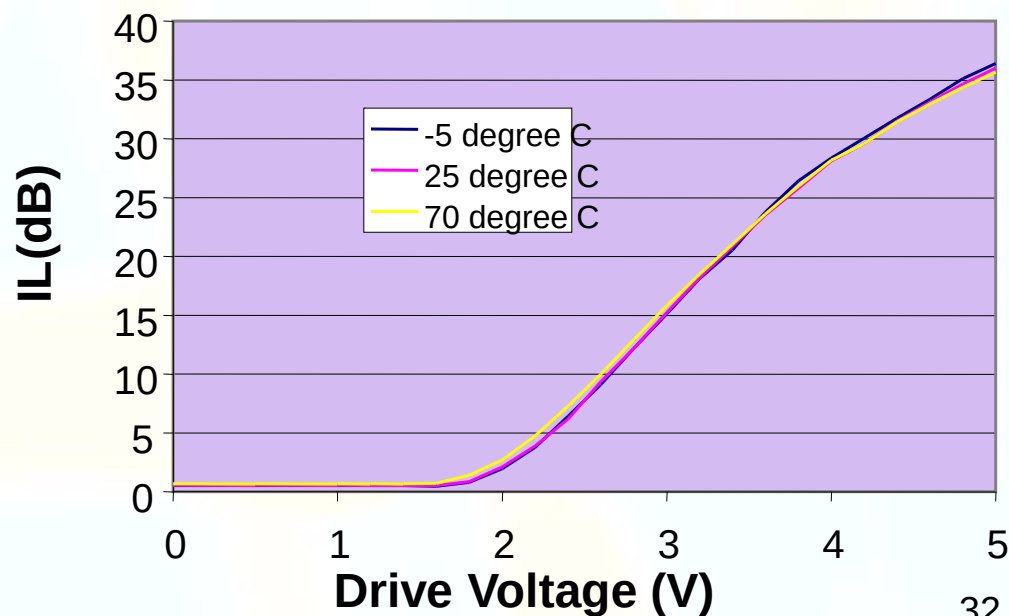
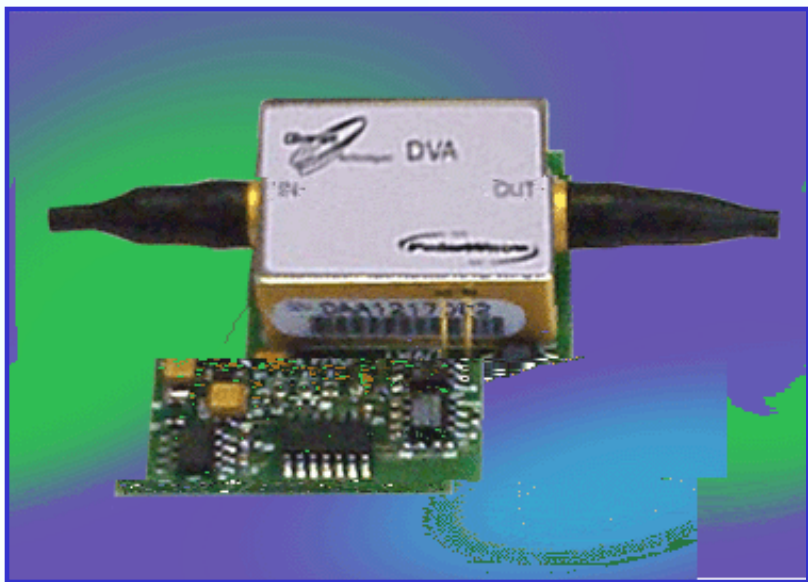
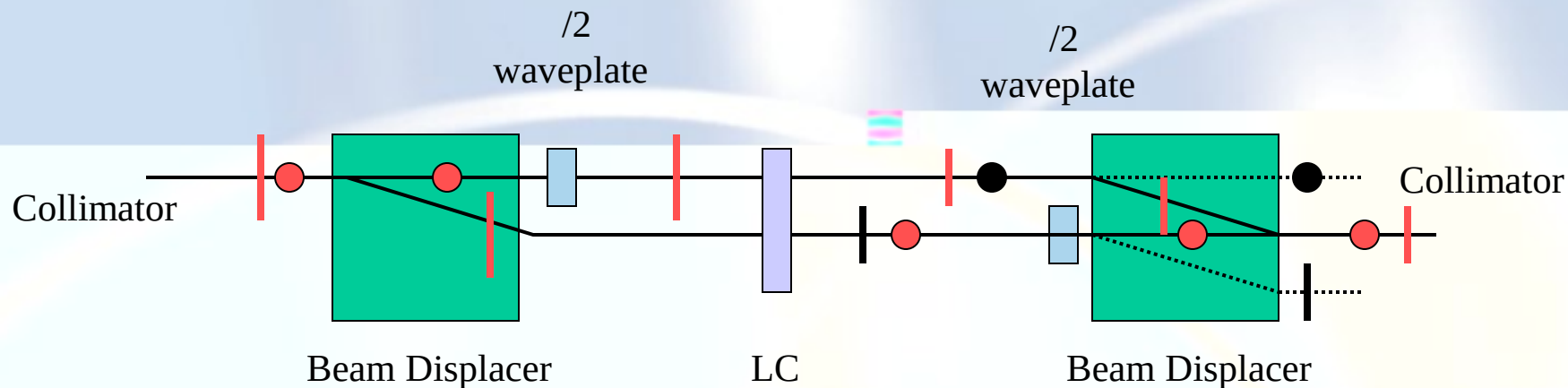
1. Switchable Large Optical Birefringence $n \sim 0.2 - 0.3$.
2. High Transmission at Near-IR Wavelengths, (<0.2 dB loss).
3. No Moving Parts - Long Lifetime.
4. Low Power Consumption.
5. Proven Technology - by Flat-Panel Display Industry.
6. Switching Times from milli- to micro- seconds.
7. Suitable for multi-channel DWDM operation



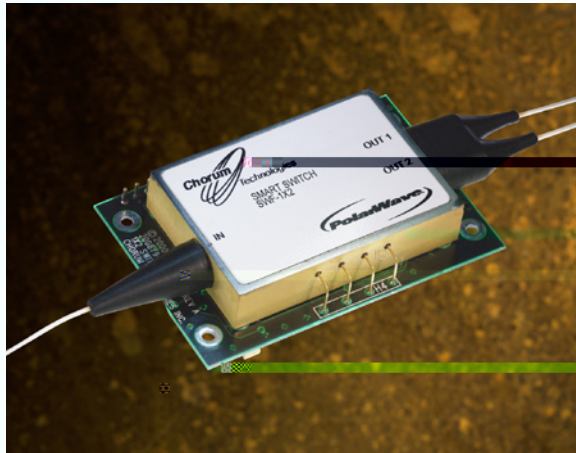
Outline

- ✓ Telecommunications and photonic applications
- ✓ LC based VOA (variable optical attenuator)
- ✓ LC based DWDM wavelength blocker
- ✓ LC based diffraction grating

TN LC based VOA (Chorum, EZconn)



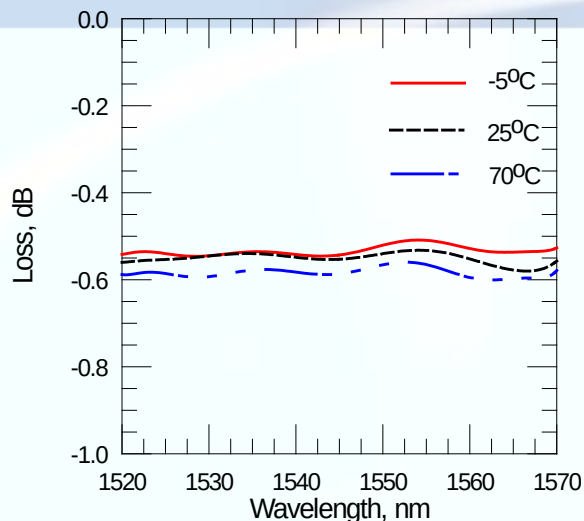
1x2 LC Switch



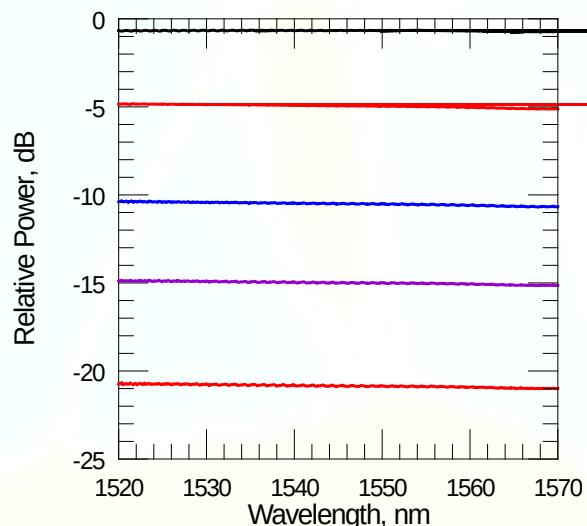
TN LC based VOA: Performances (Chorum, EZconn)



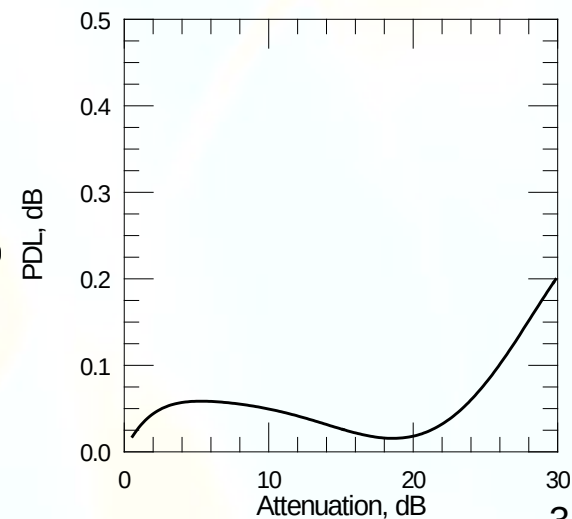
Low insertion loss,
highly athermal



Flat spectral response



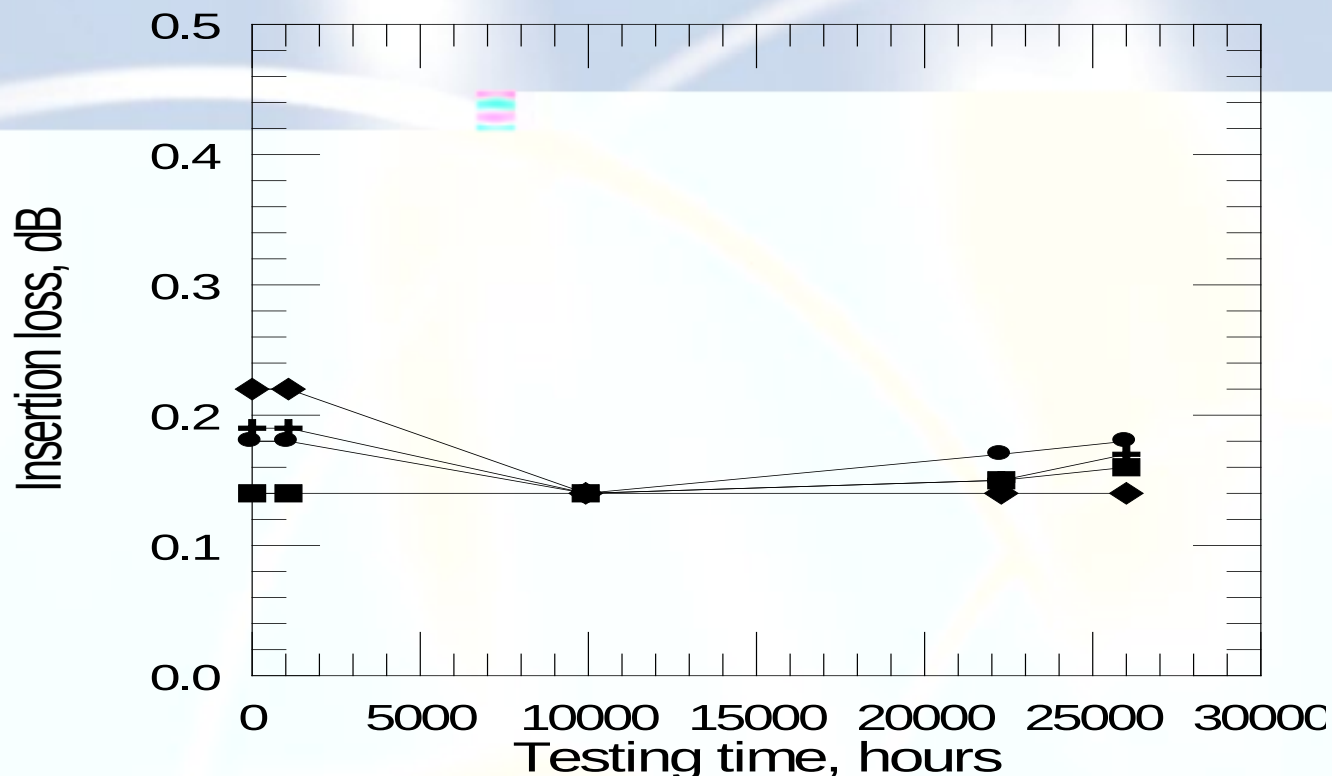
Small polarization
dependency



TN LC based VOA: Extensive Aging Test (Chorum)



> 50M cycles
(26000 hours)
@ 90C



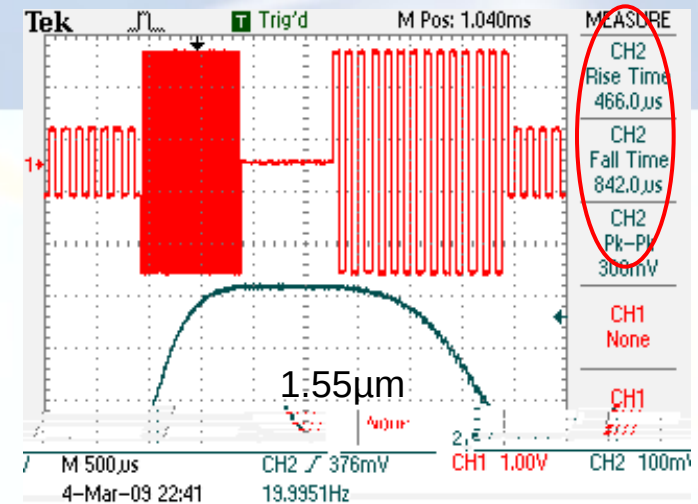
Merits: Reliable, low IL, low PDL, flat spectral response,

Drawback: slow response time.



Speed improvement

1. Thinner cell (Reflective type)
2. Overdrive and undershoot
3. Double-cell
4. Smart electrode design
5. Polymer network, stressed LC, etc.
6. Dual frequency addressing
7. Blue phase LC
8. ...



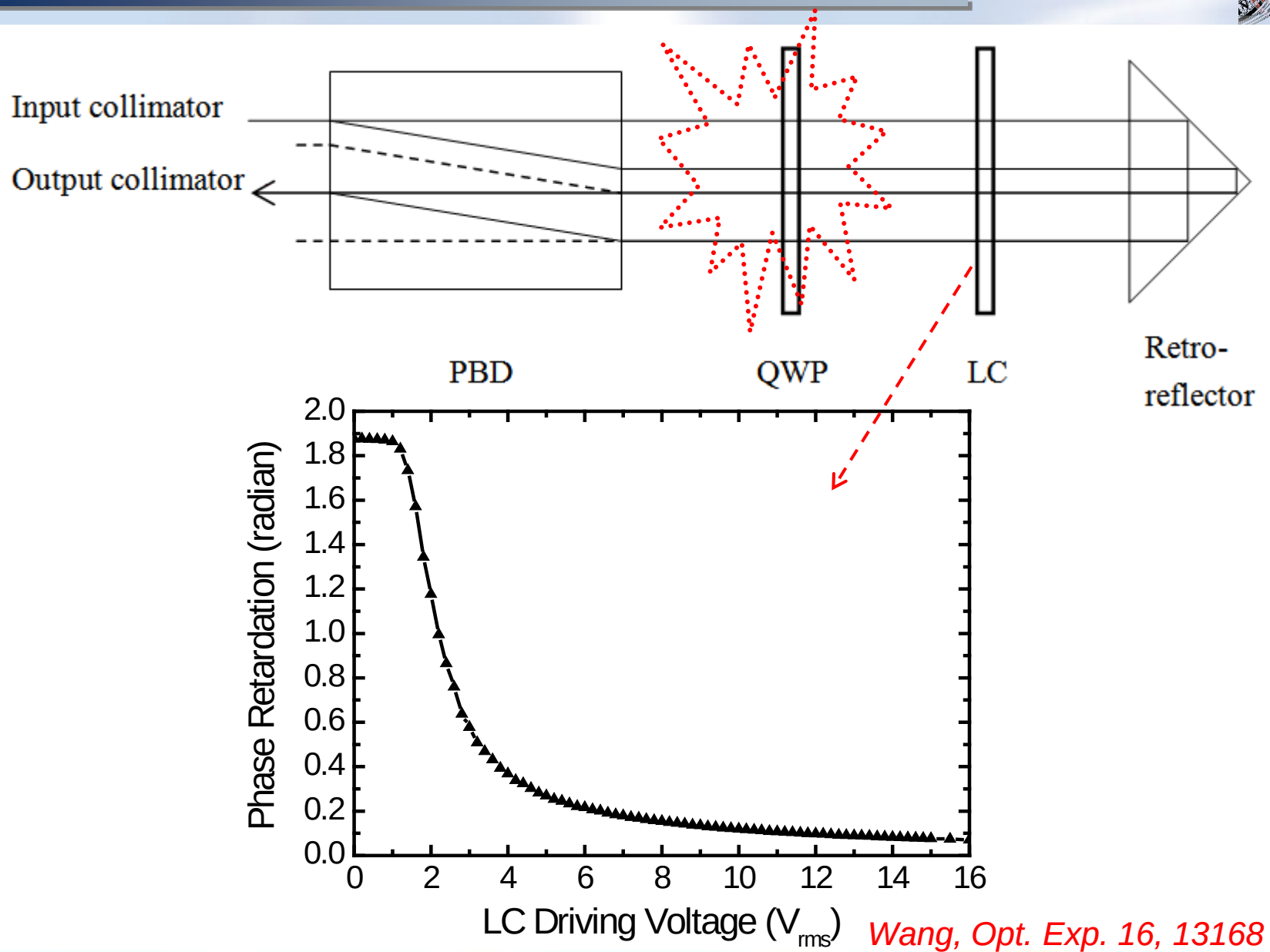
Liang, Jpn. J. Appl. Phys., **44**, 1292-1295 (2005)
Wu, Applied Optics **44**, 4394-4397 (2005)
Lu, Appl. Phys. Lett., **85**, 3354-3356 (2004)
Du, Appl. Phys. Lett., **85**, 2181-2183 (2004)
Lu, Opt. Express, **12**, 1221-1227 (2004)
Wu, Opt. Express, **12**, 6377-6384 (2004)

Further improvement:

Better performance, low cost, arrayed or multi-channel operation.

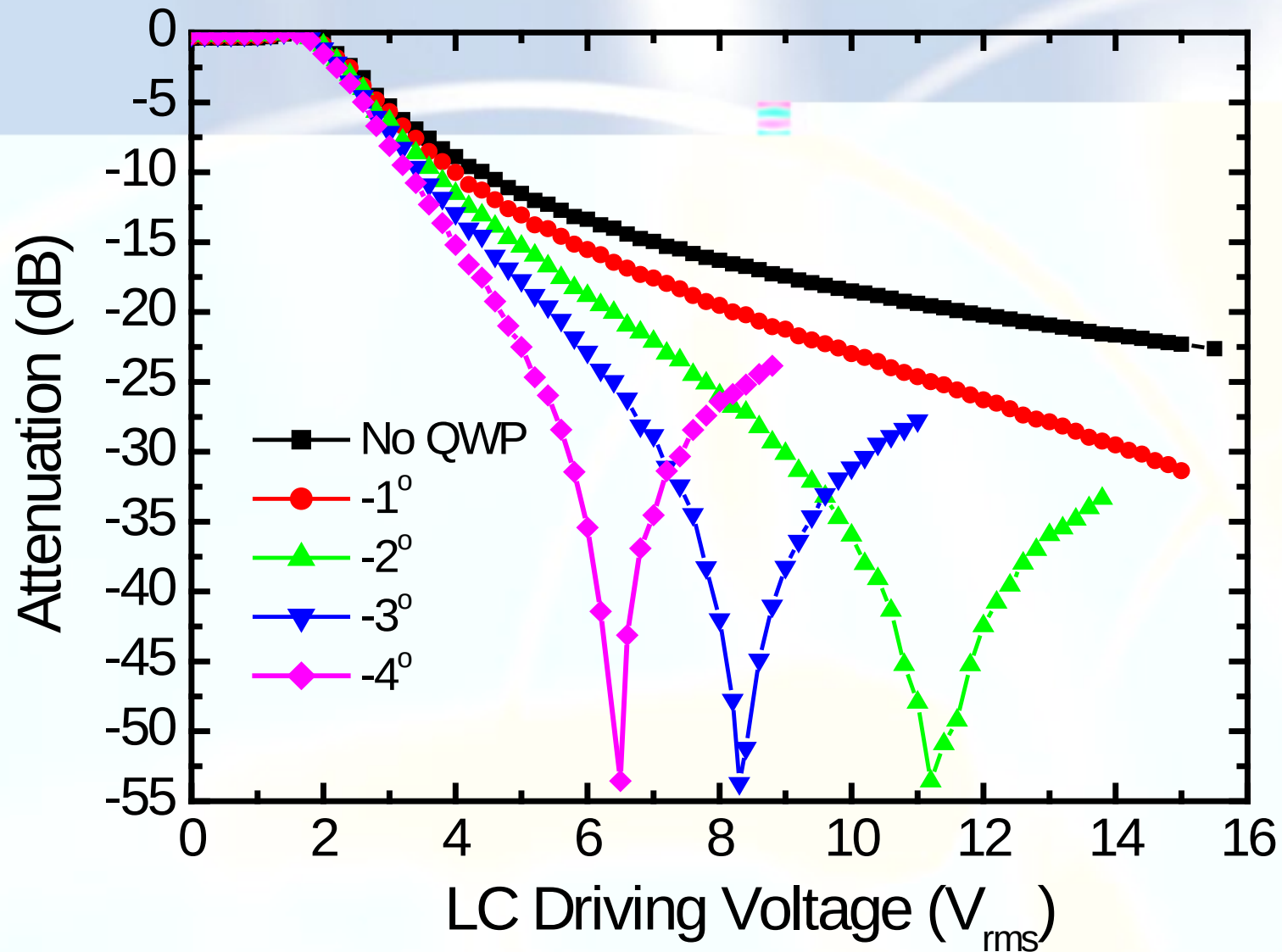


A compact ECB LC based VOA with low PDL (NJU)





Voltage-dependent transmittance



Outline

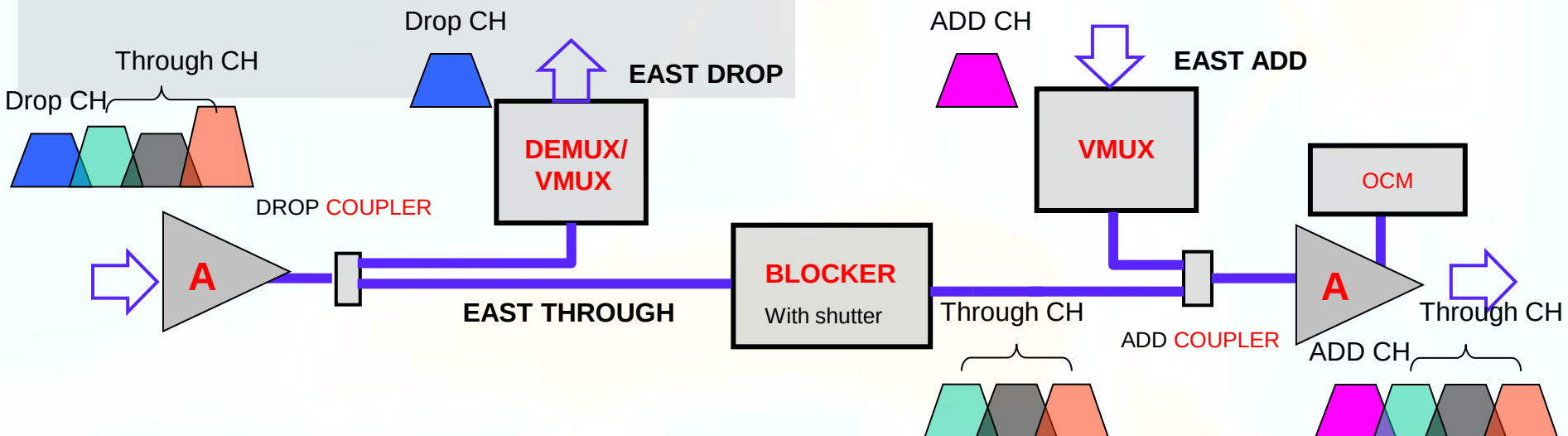
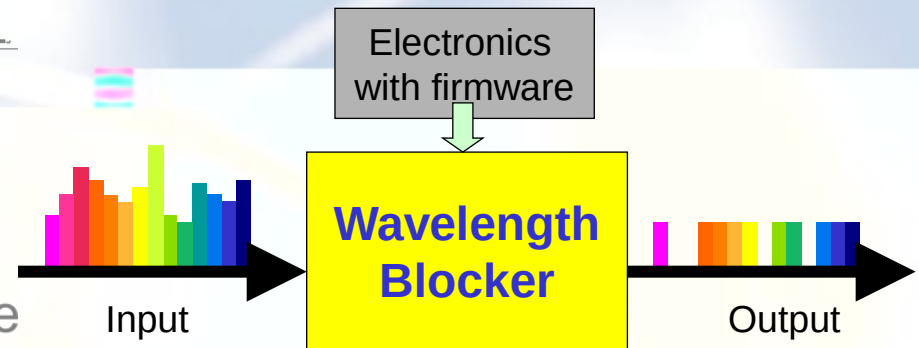


- ✓ Telecomm as an example for photonic applications
- ✓ LC based VOA (variable optical attenuator)
- ✓ LC based DWDM wavelength blocker
- ✓ LC based diffraction gratings
- ✓ LC based in-line polarizer and fiber-optic sensor
- ✓ LC for tunable THz applications
- ✓ LC for tunable optical vortex generation
- ✓ Other LC's photonic applications



Wavelength blocker and RODAM (NJU)

- ✓ λ -blocker is an enabling network element for dynamic optical networks
- ✓ Due to the analog nature of liquid crystals, the same device can be used as channel based DGBFF

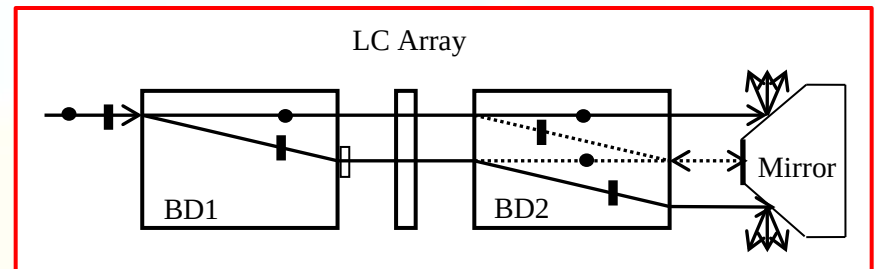
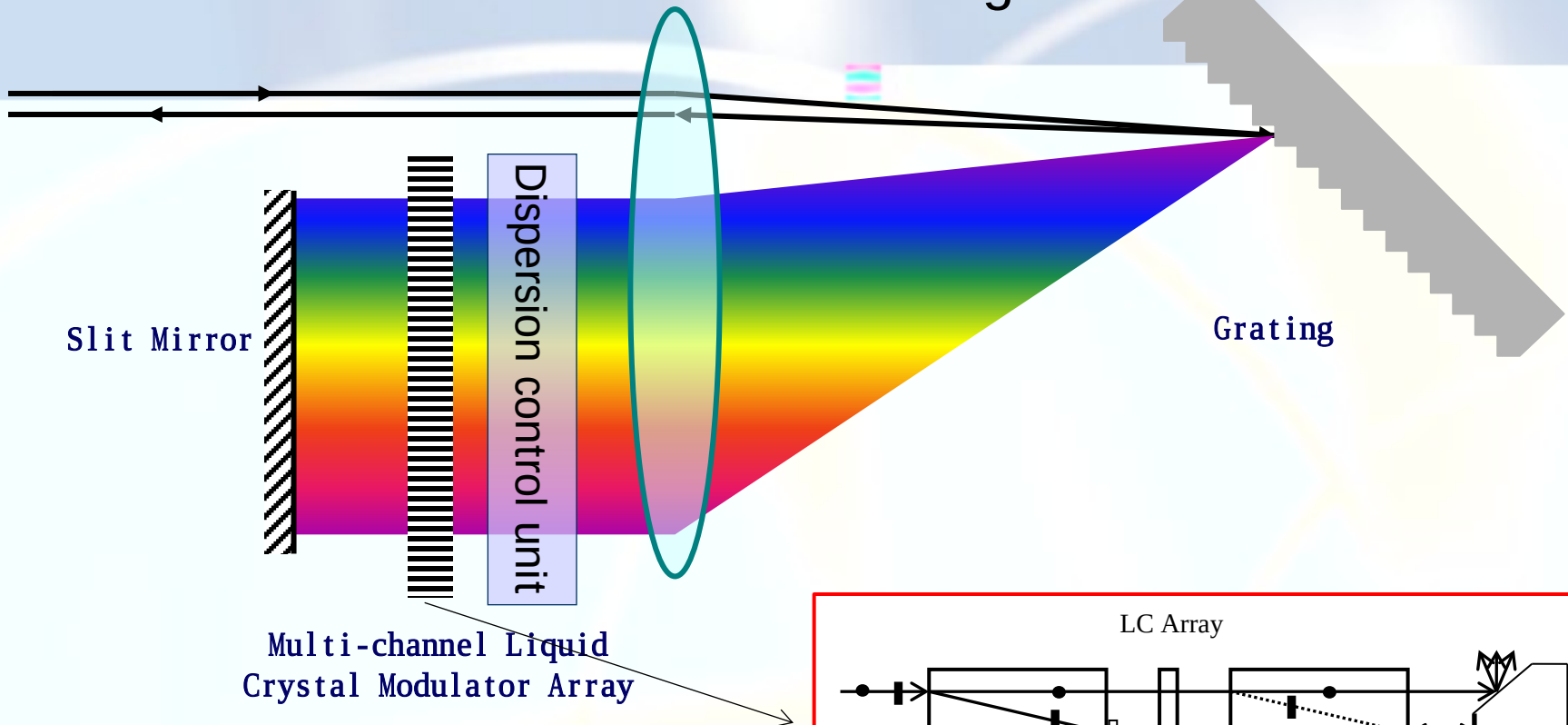


A Blocker based RODAM architecture

Design Proposal



A Wavelength Blocker

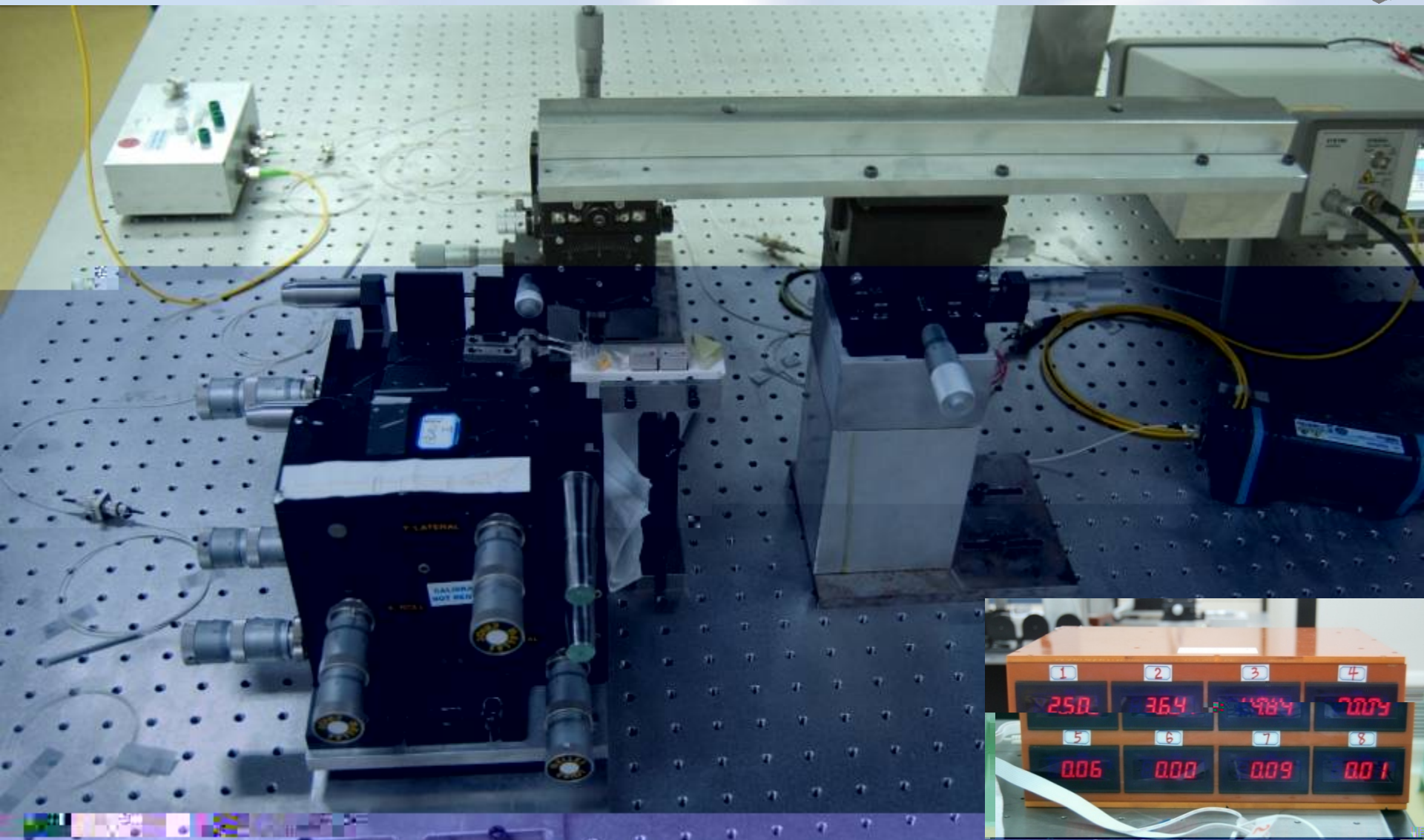


Huang, J. of Lightwave Tech. **28**, 822 (2010)

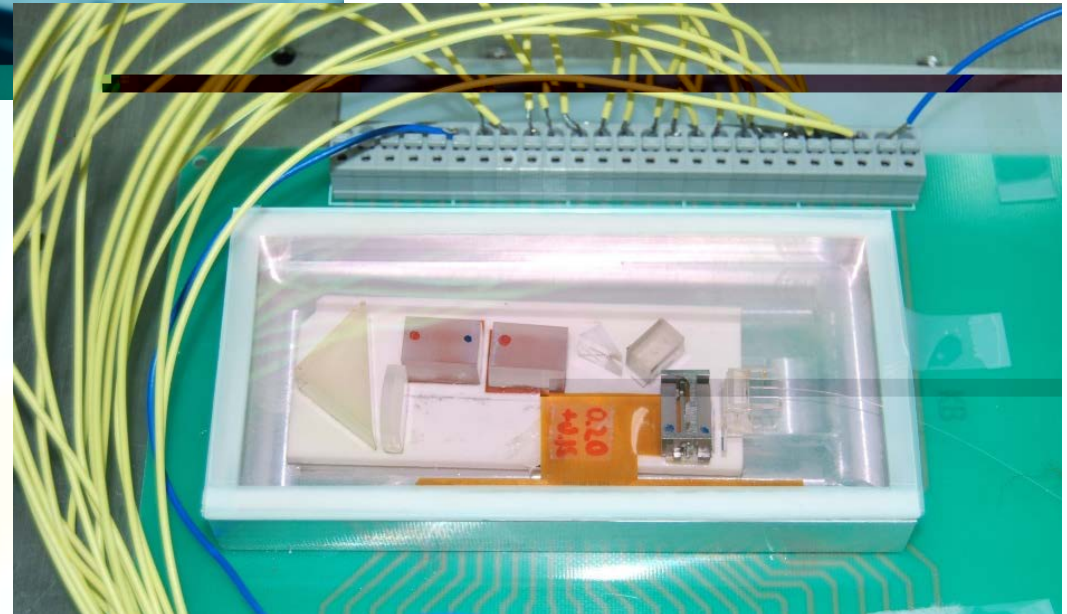
Optical Design of a 40CH/100G Blocker



Experimental setup of a 40CH λ -Blocker (NJU)

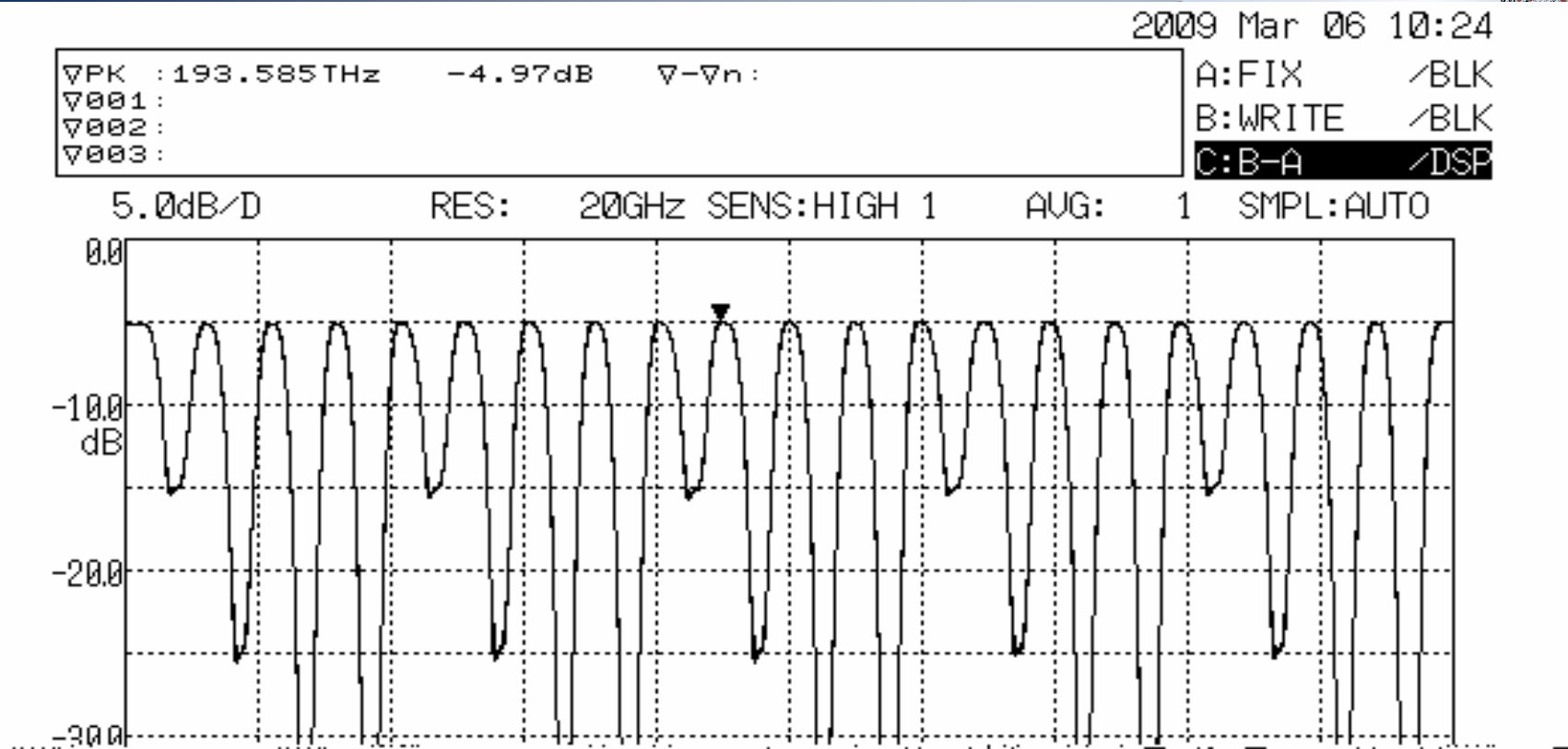


Blocker: Prototype





Spectral response



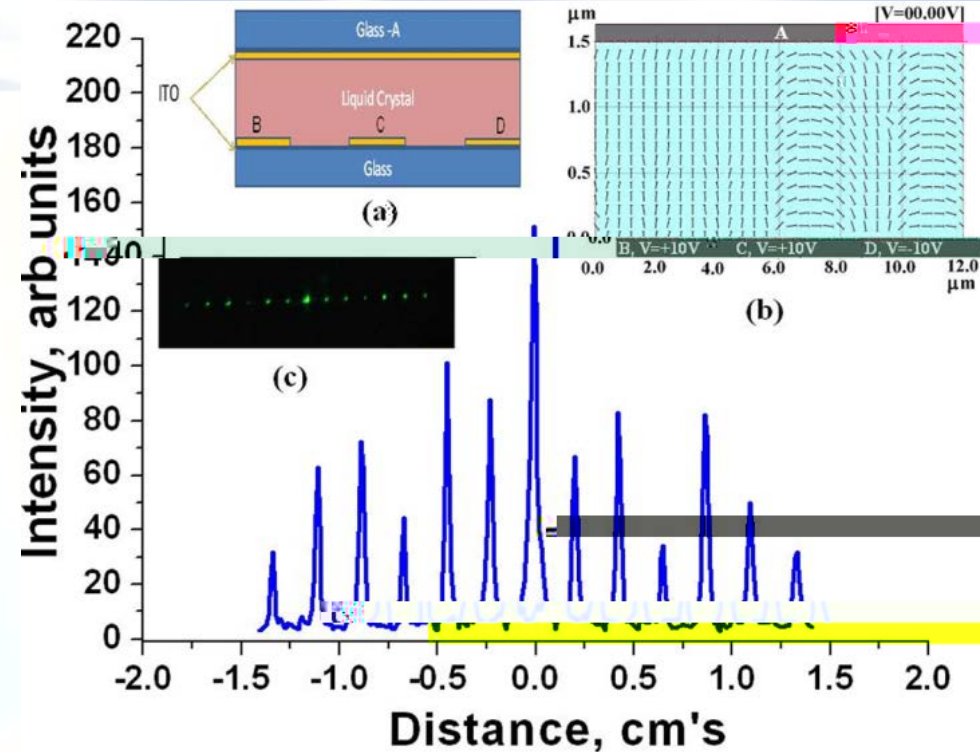
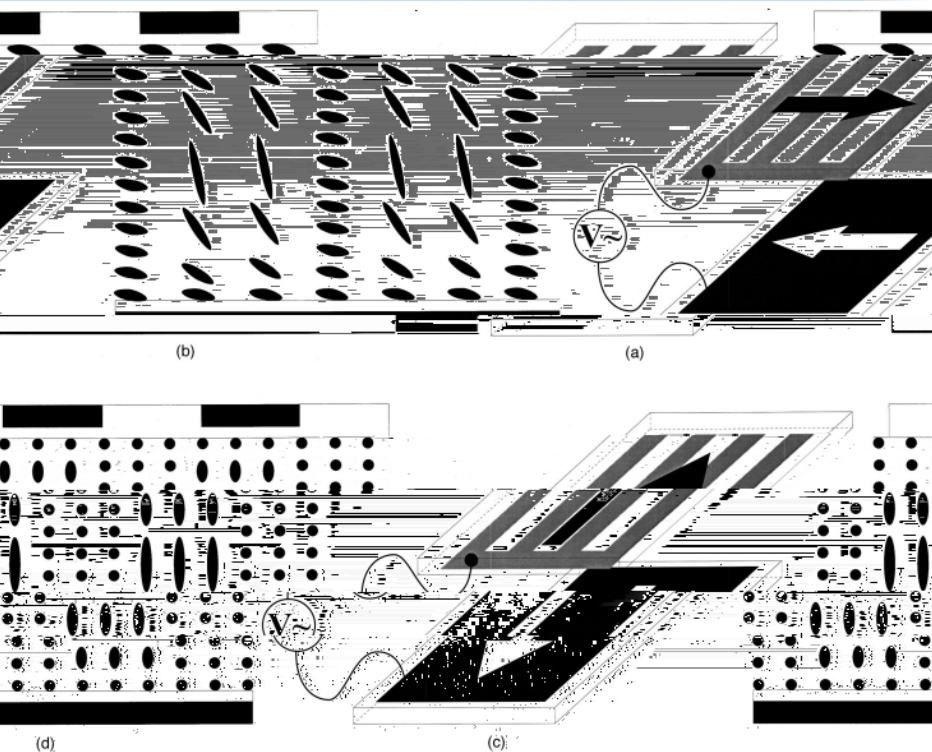
40 CH, 100GHz, IL<5.5dB, BW> $\pm$ 20GHz, Att_max>40dB, PDL<0.5dB, RL<-45 dB

Outline



- ✓ Telecomm as an example for photonic applications
- ✓ LC based VOA (variable optical attenuator)
- ✓ LC based DWDM wavelength blocker
- ✓ LC based diffraction gratings

Fabrication strategies- Patterned electrodes



M. Bouvier and T. Scharf.
Opt. Eng. 39, 2129 (2000)
(Switzerland)

Fan *et al.* Appl. Phys. Lett. 100, 111105 (2012)
(Prof. Chigrinov's group)

Rubbing vs. Photoalignment for LC devices



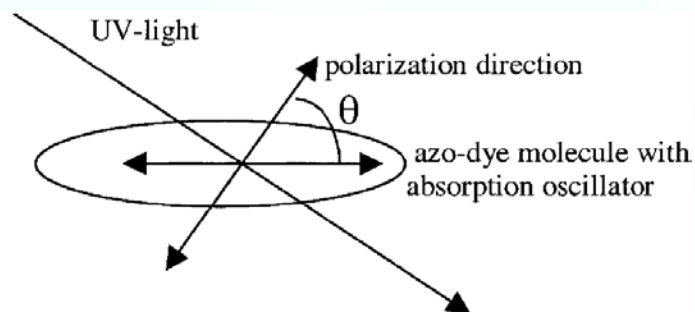
Rubbing

- Particles

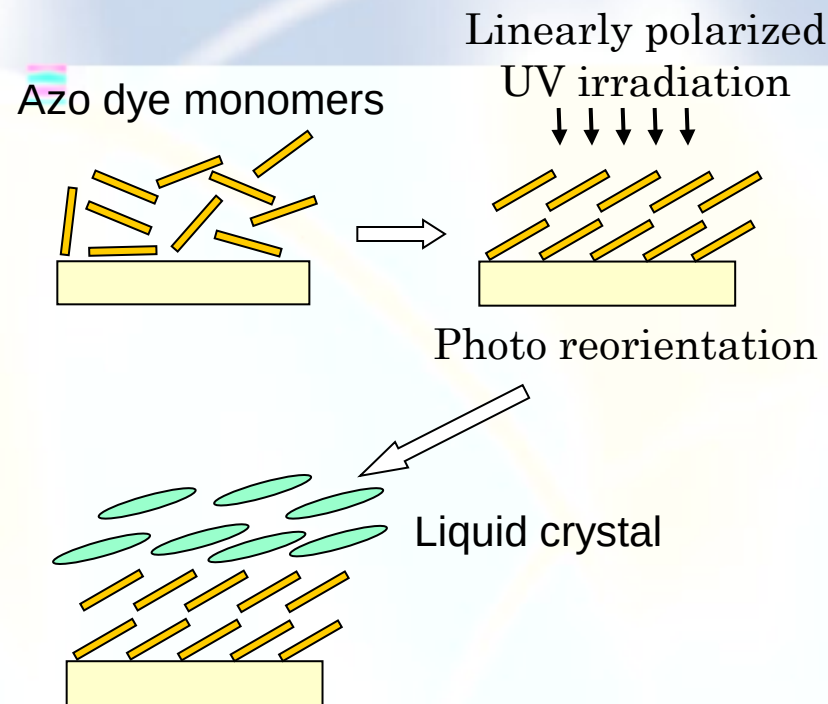
SD1 for Photo-alignment



Sulphonic acid azo dye (SD1) ()

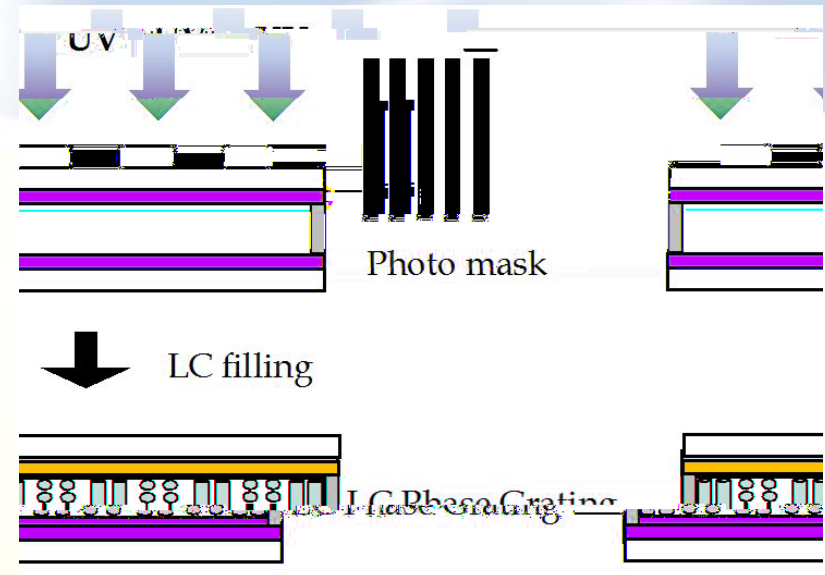
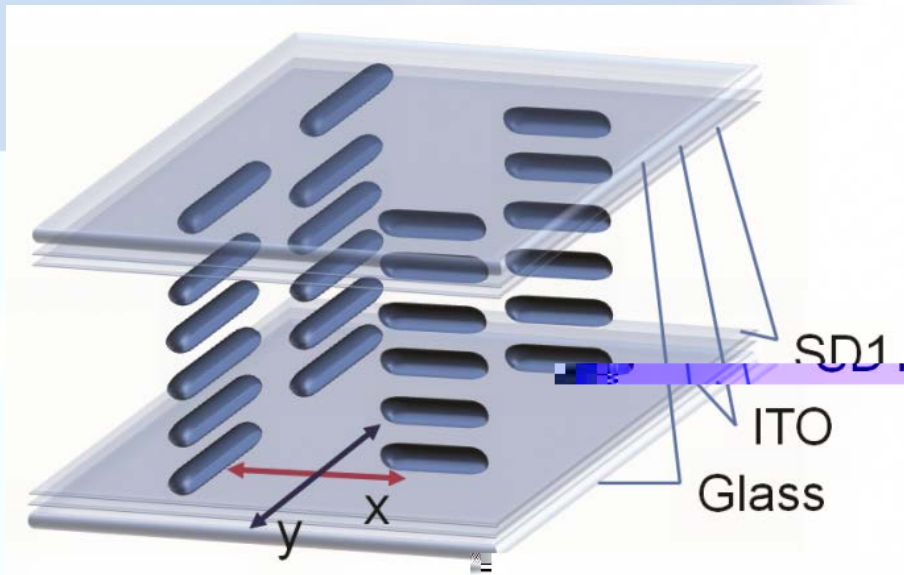


Diffusion model of SD1 reorientation



The azo dye molecules would reorient to make their absorption oscillators (chromophores) perpendicular to the polarization of the UV light and further guide the LC directors.

Orthogonally homogeneous aligned (PA) grating



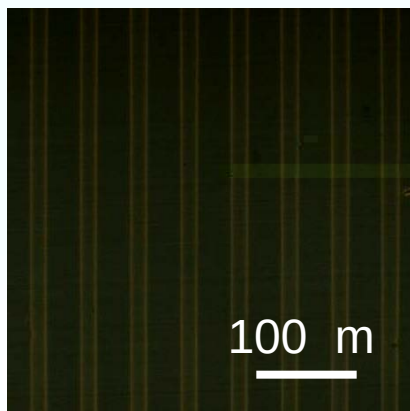
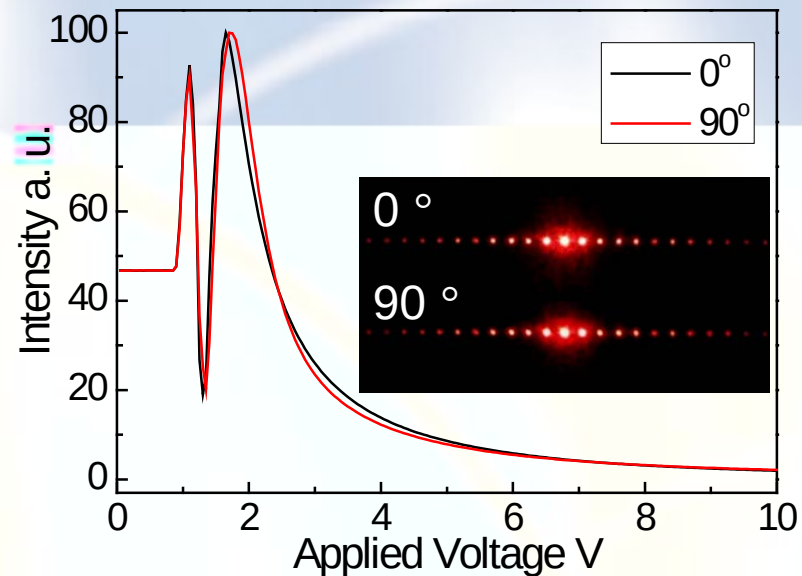
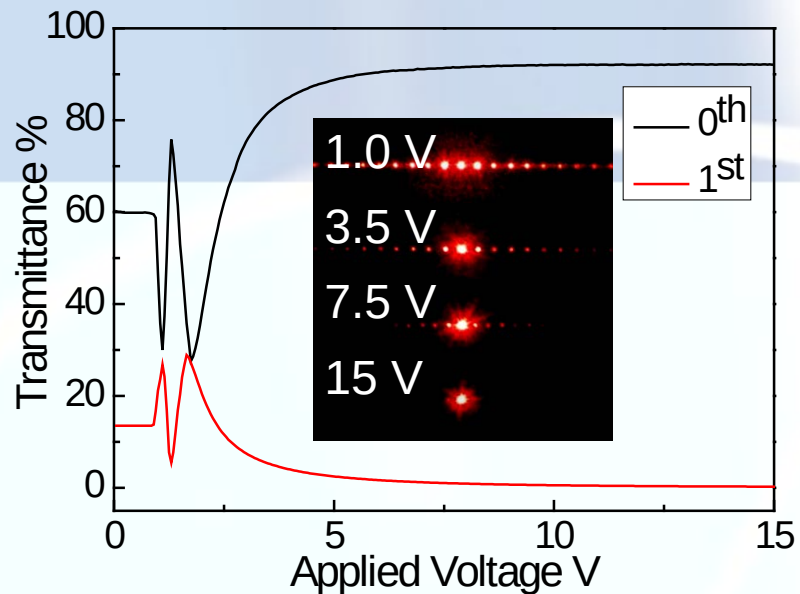
Procedure:

- SD1 spincoating ;
- Cell fabrication and then the cell is exposed under linearly polarized light with long side parallel to polarization.
- The same cell rotates 90° and is exposed again through **a grating mask**.

Hu *et al.* Appl. Phys. Lett., 100, 111116 (2012)



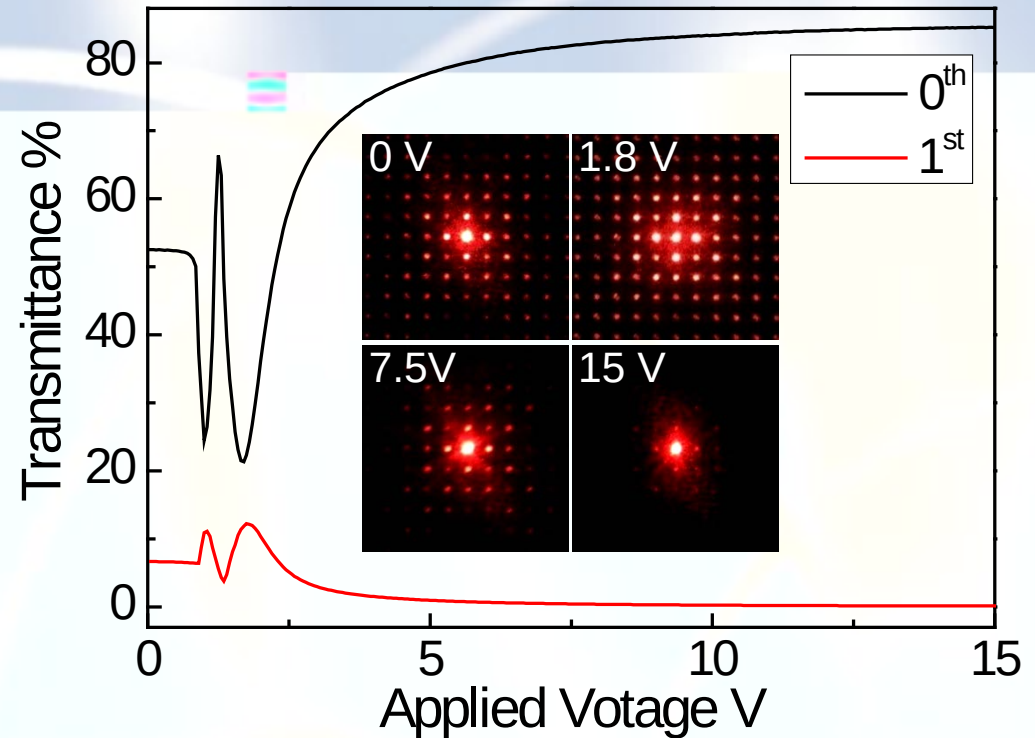
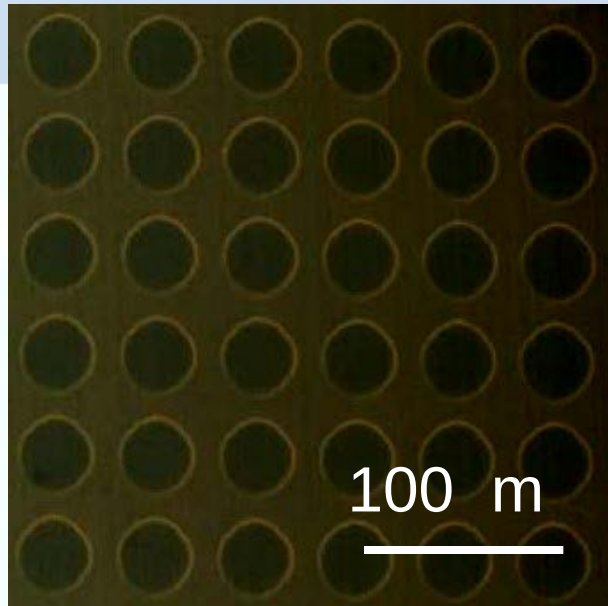
1D or-PA LC gratings



38 diffraction orders could be distinguished with naked eyes at ON state



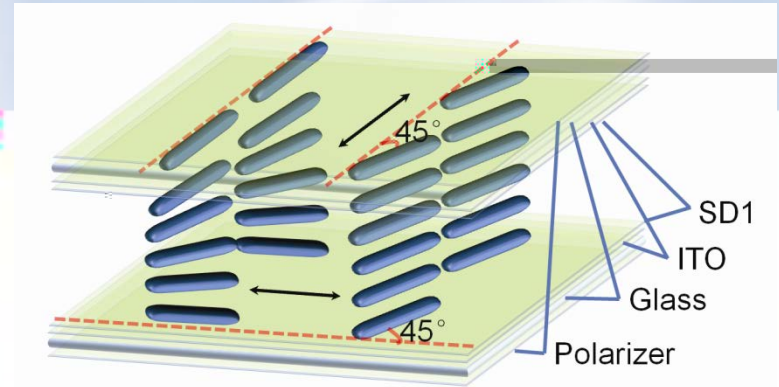
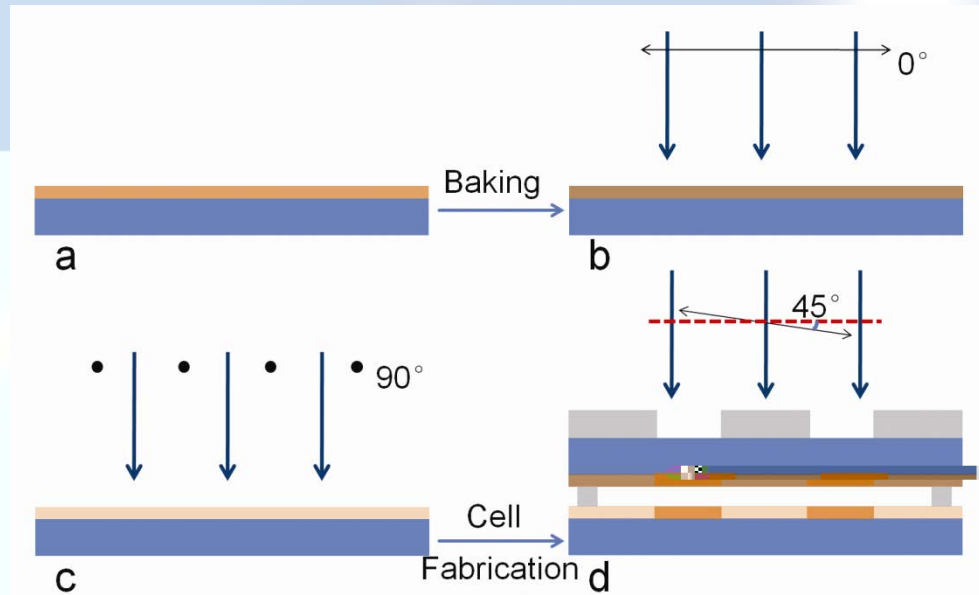
2D or-PA LC gratings



A lower transmittance of 87% is attributed to more domain boundaries and stronger scattering. The diffraction efficiency and optical contrast of 1st order is ~ 14% and over 140 respectively. 75.5% of total transmittance energy distributed to diffraction orders at on state.



Fabrication of TN/PA gratings



Cell structure of the LC gratings with TN-PA micro arrays.

Procedure:

- Spin-coating of SD1 and then baking at 100°C for 10 min
- Bottom and top substrates photoaligning under linearly polarized UV light with orthogonal directions, and then cell fabricating
- Photopatterning with a cell direction is 45 ° with respect to the polarization of incident UV light.

Hu *et al.* *Opt. Express* 20, 5384-5391 (2012)

Scheme for TN/PA grating

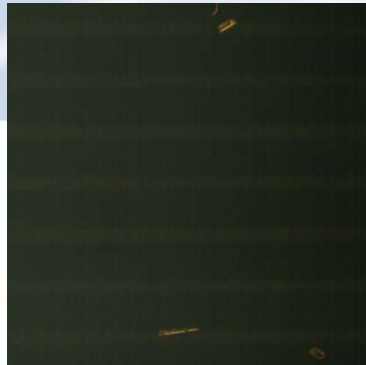
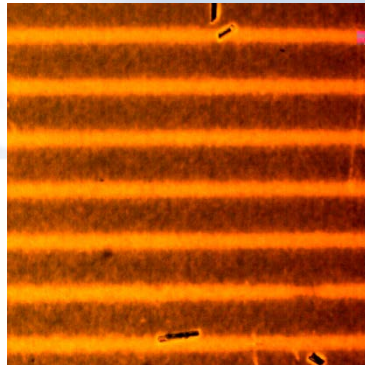
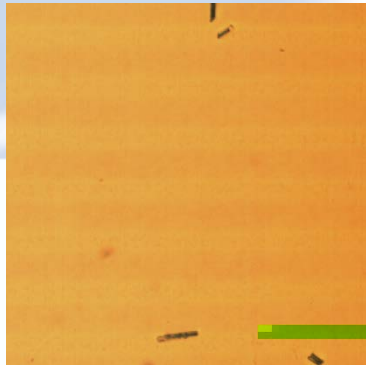
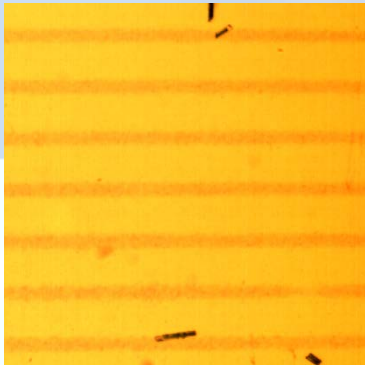


Both TN and PA are typical alignments, but they exhibit different EO properties including voltage-dependent phase changes and transmittances.

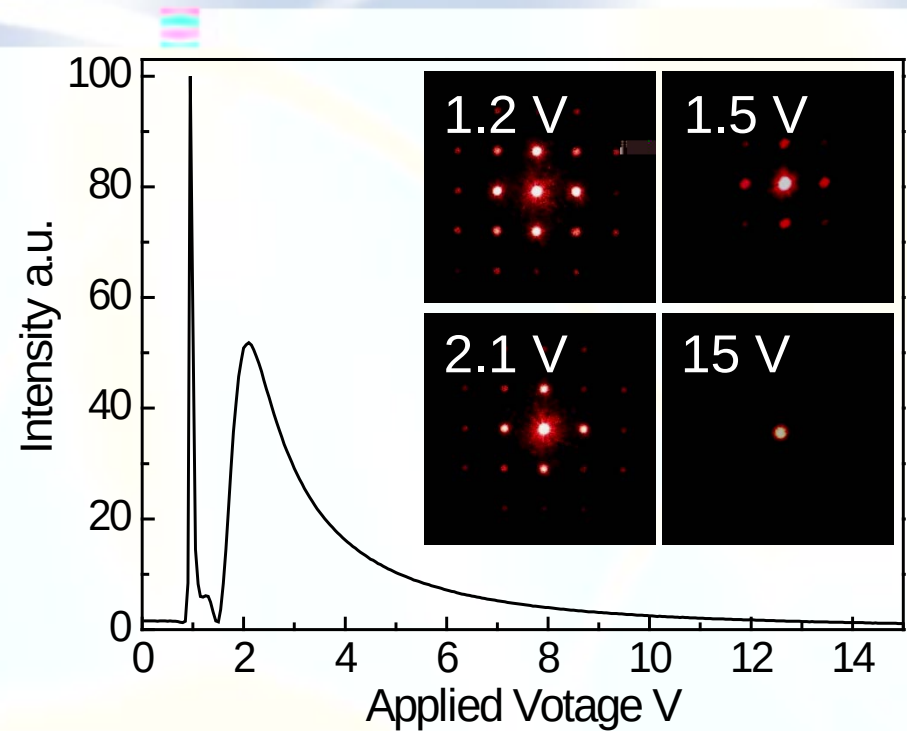
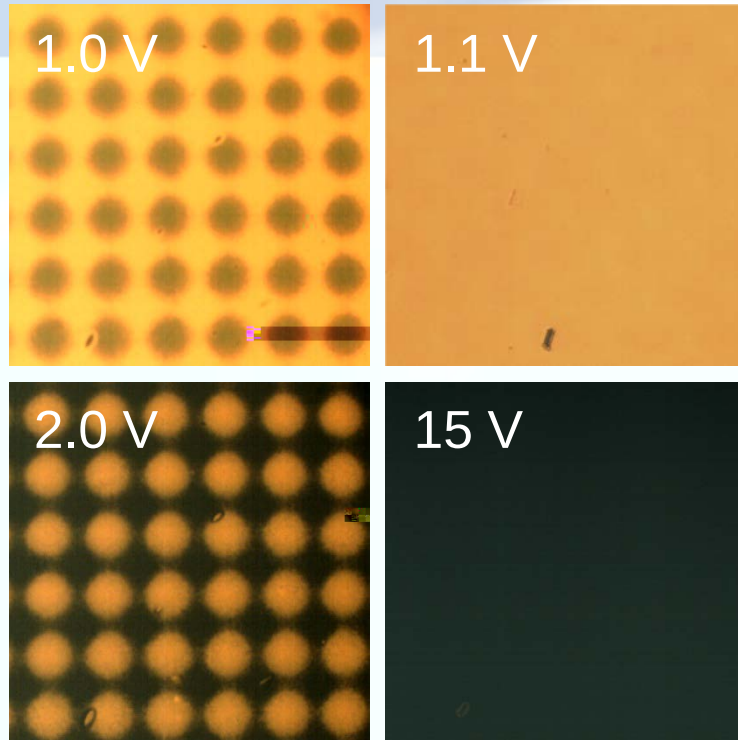
Micro 90° TN and PA (45° to the alignment direction of TN) regions are assembled alternately to form gratings. It works based on the combination of phase and amplitude modulation.

Unique four-state feature of the cell is obtained:

- I. Grating A (TN area is brighter than PA area)
- II. Uniformly bright state
- III. Grating B (PA area is brighter than TN area).
- IV. Uniformly dark state

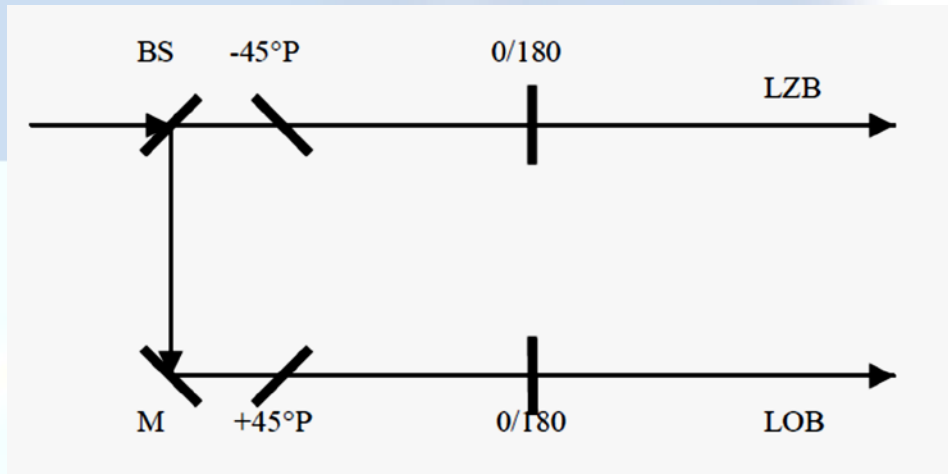


2D TN/PA LC gratings

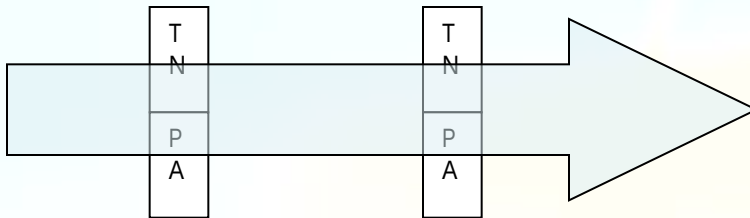




Another possible application: optical logic devices



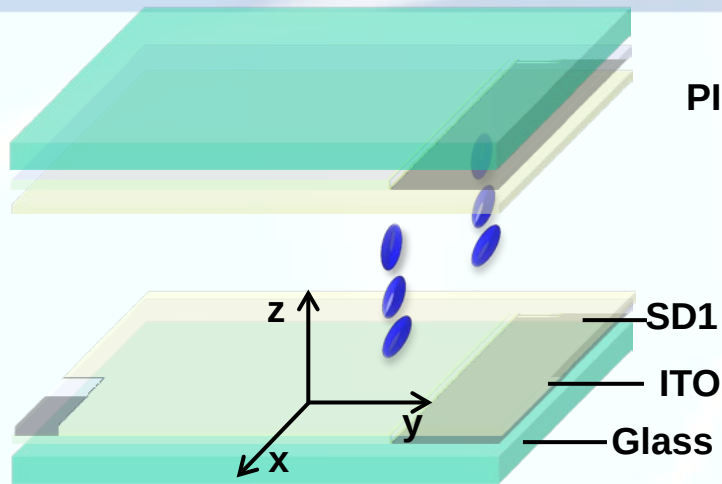
Y. A. Zaghloul, "Complete all-optical processing polarization





DFLC + HAN cell gratings

Dual frequency LC + Hybrid alignment



Cell gap: $\sim 5 \mu\text{m}$

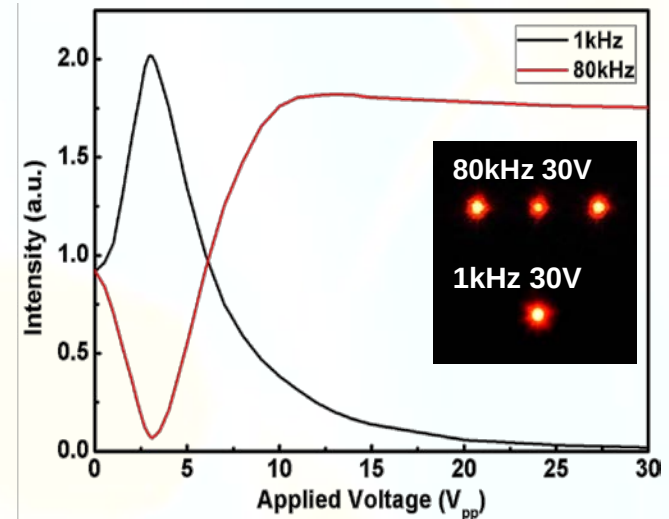
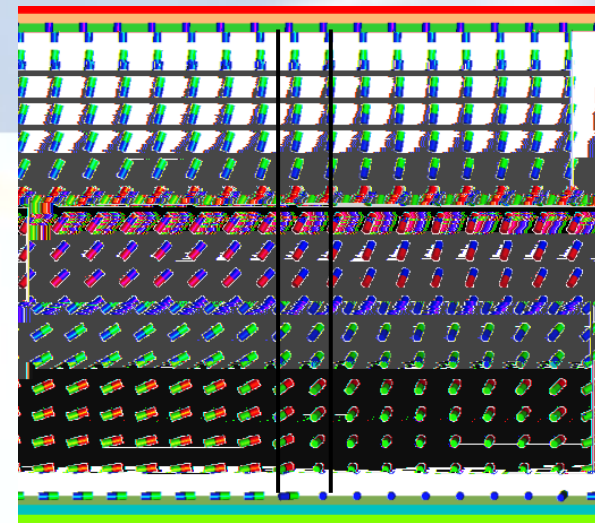
DFLC (HEF951800-100, HCCH)

$\beta \approx 0.19$ @ 632.8 nm

$\beta \approx 2.10$ @ 1KHz

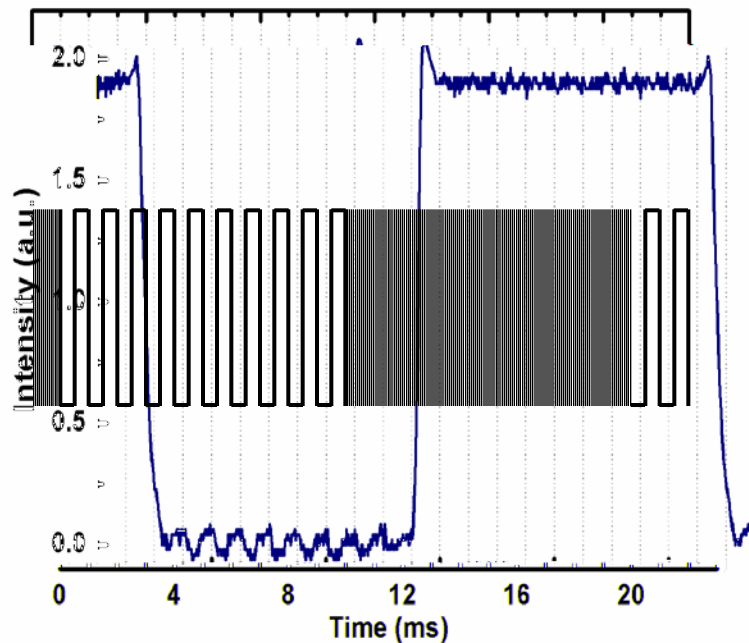
$\beta \approx 1$ # $N + 1$

fc $\approx N + 1$



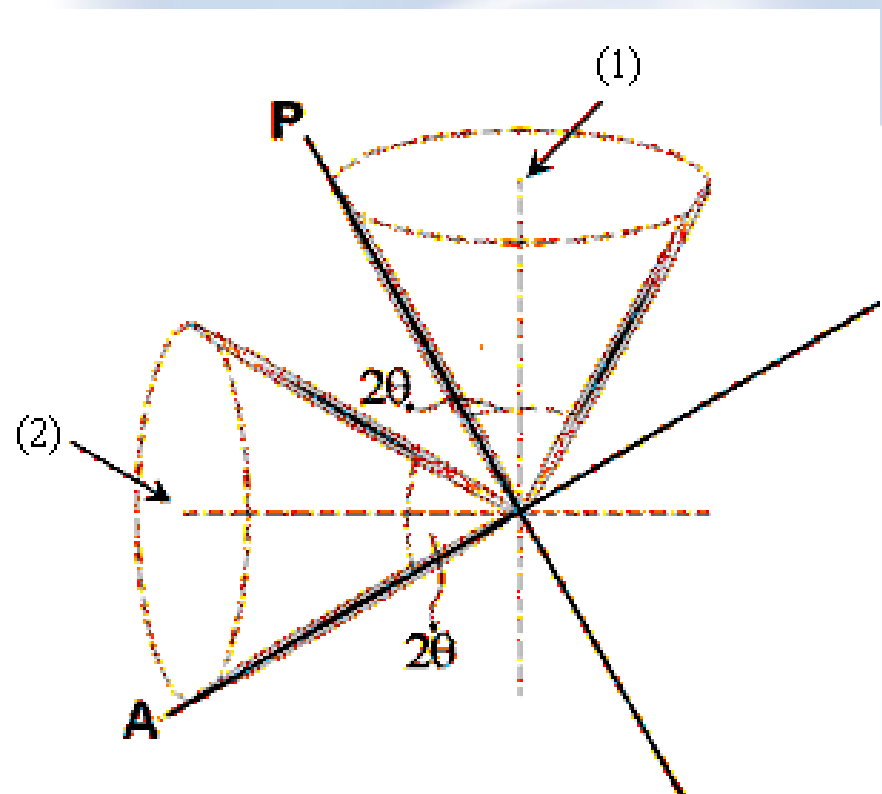
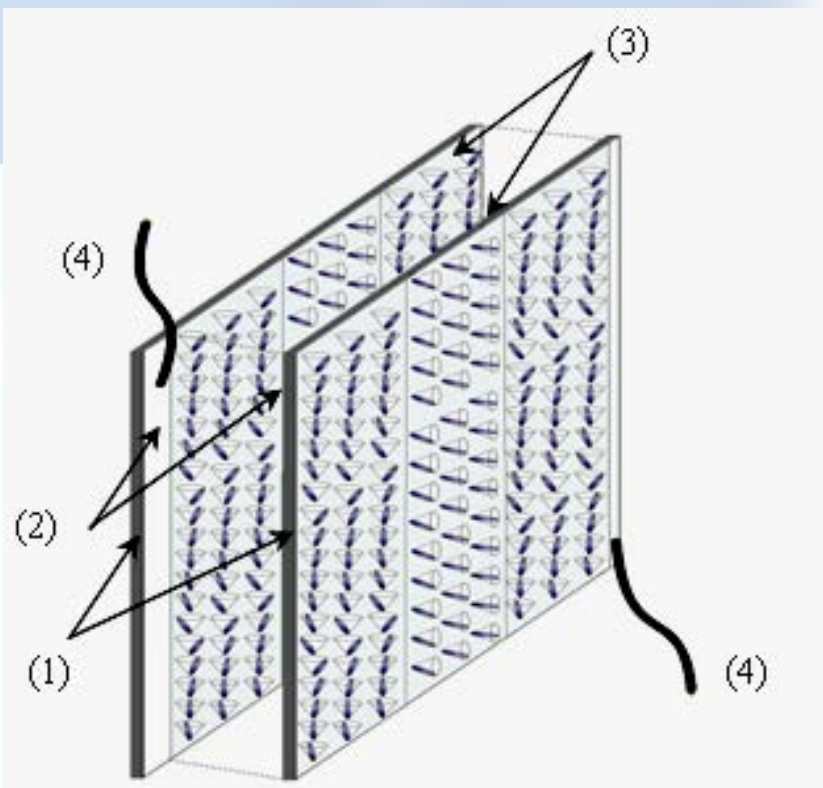
X. W. Lin et al. *Opt. Lett.* **37**, 3627 (2012)

Fast switching and Polarization independency



The switch ON/OFF time are measured to be **350 ns** and **600 ns** respectively, both of which have reached subpicosecond (so)4(i)-1.4(i)

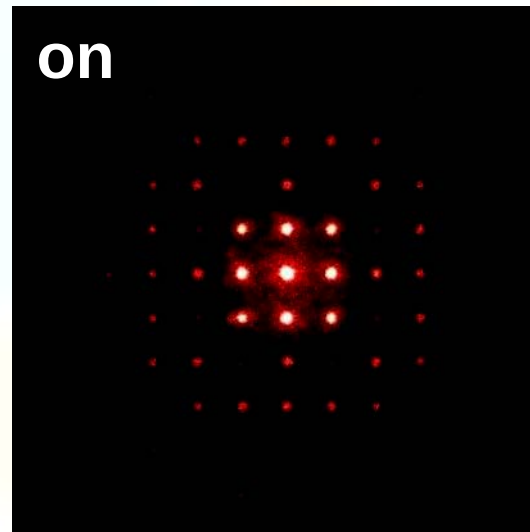
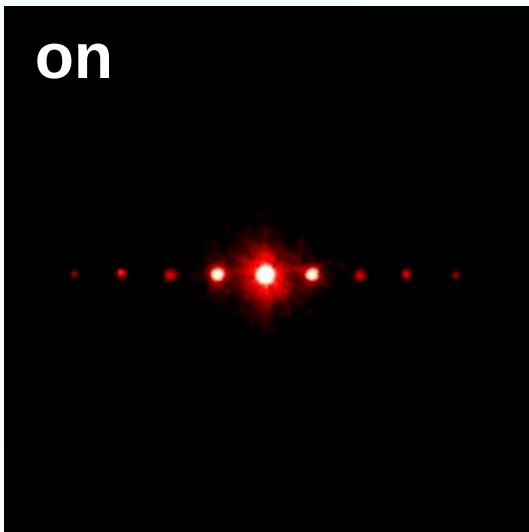
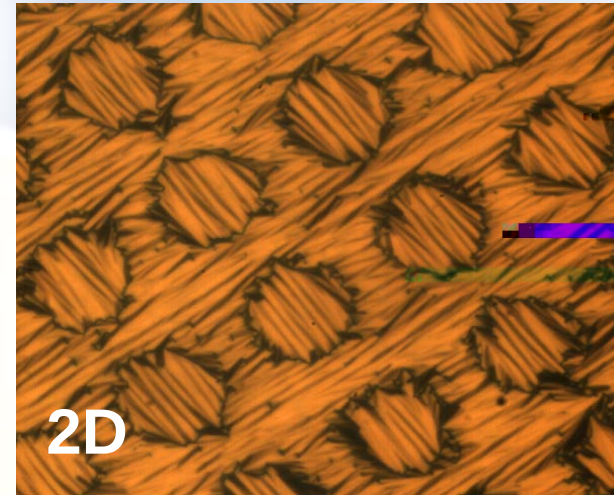
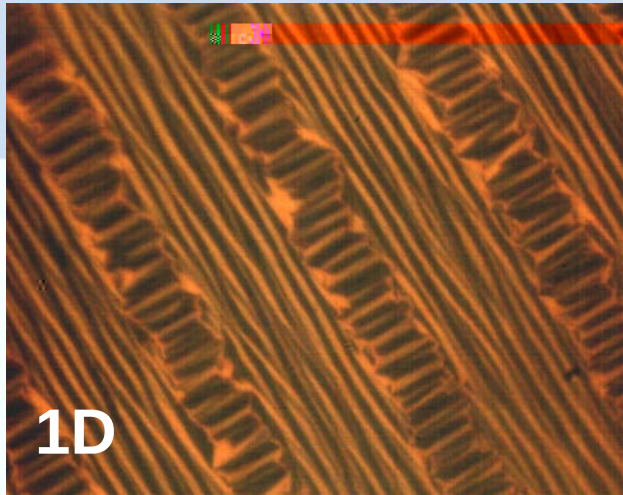
Fast switching FLC gratings



a FLC grating cell with **electrically suppressed helix electro-optical mode** with FLC pitch less than the LC cell gap.

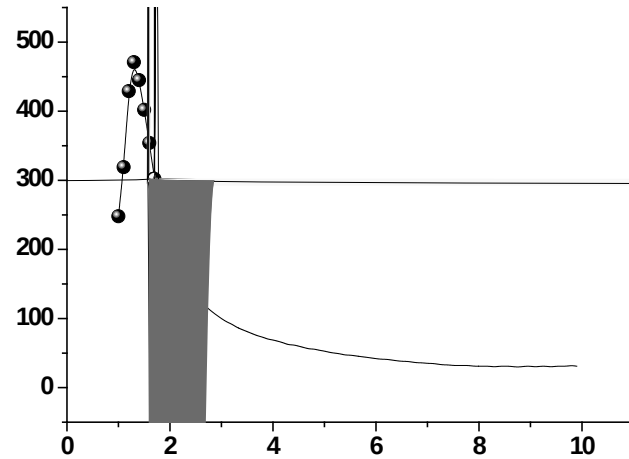
A. K. Srivastava, W. Hu, V. G. Chigrinov, A. D. Kiselev and Y. Q. Lu
Appl. Phys. Lett., **101**, 031112 (2012)

1D and 2D FLC gratings



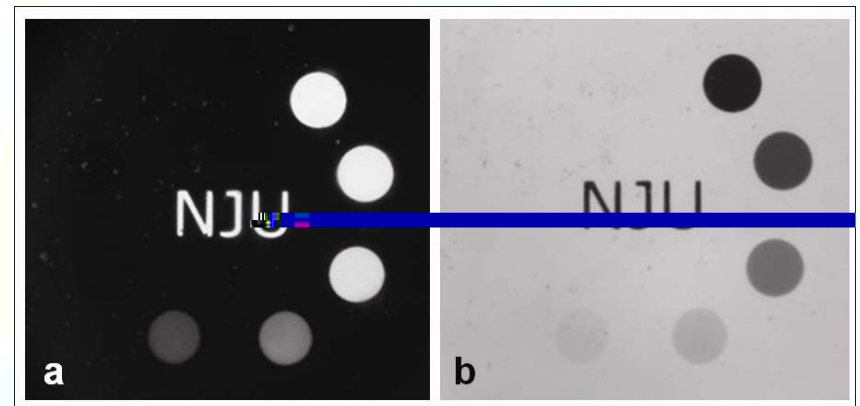
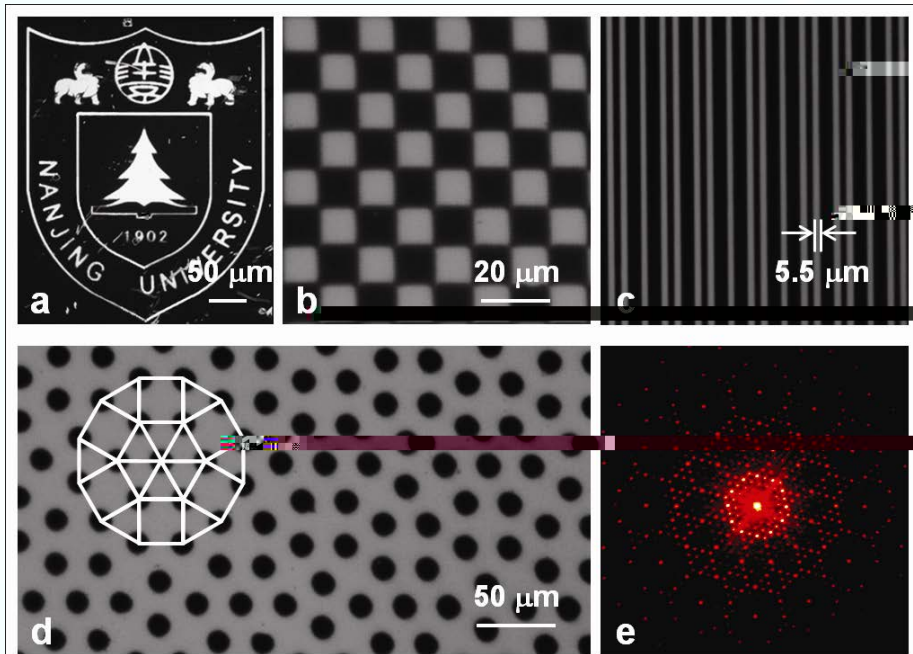
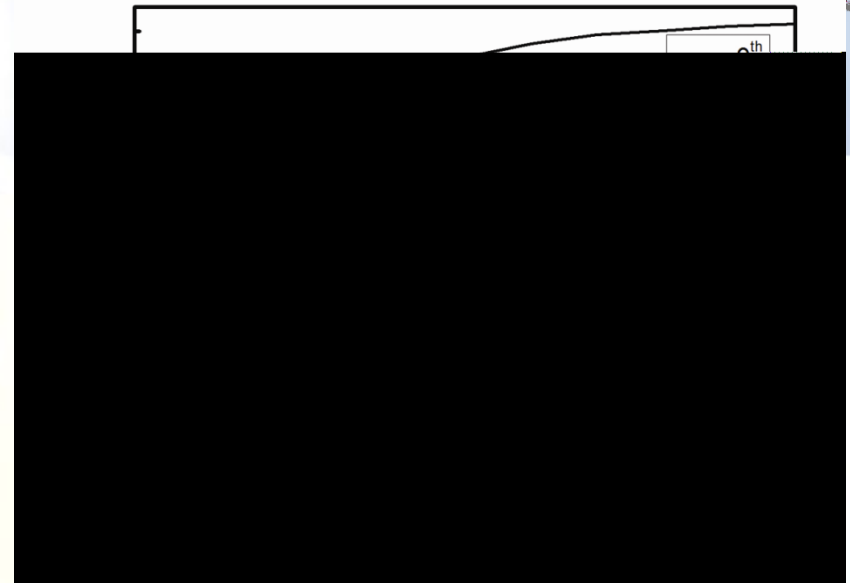
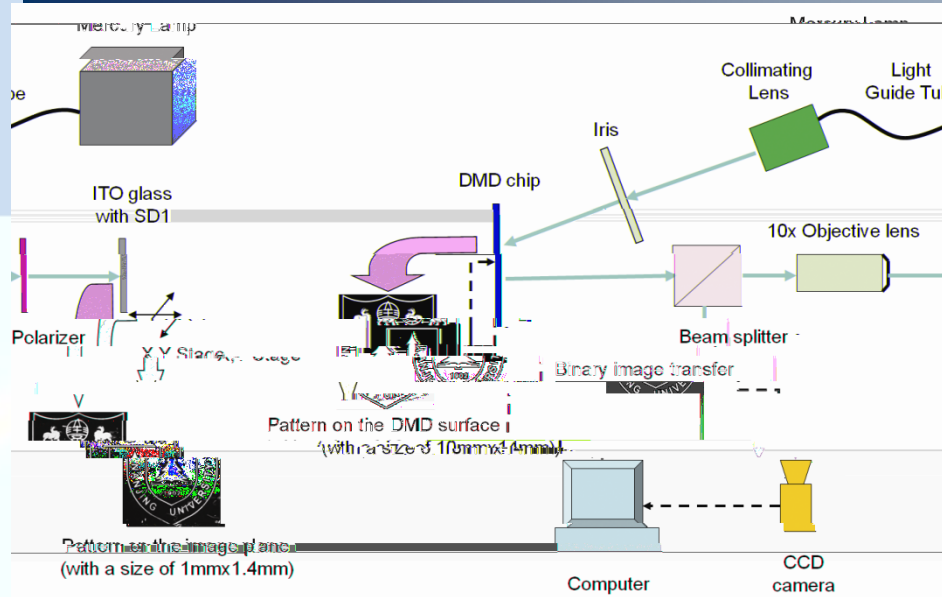
FLC FD4004N (DIC) , tilt angle : 22.05 , Cell gap: 1.5 μm , Grating period: 50 μm

Fast switching





Arbitrary photo-patterning in LC alignments

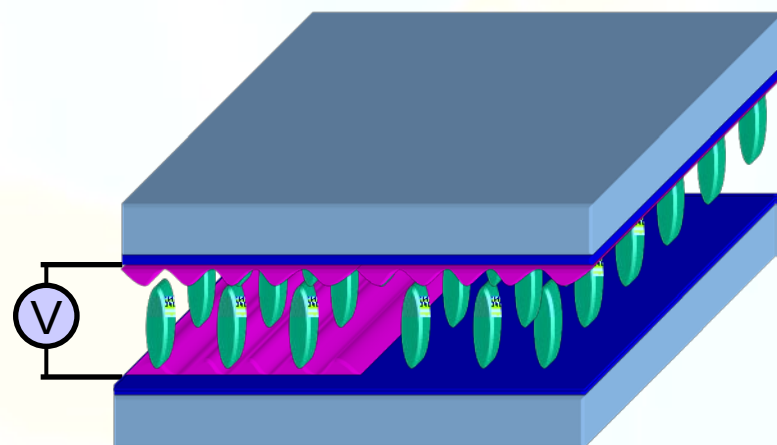
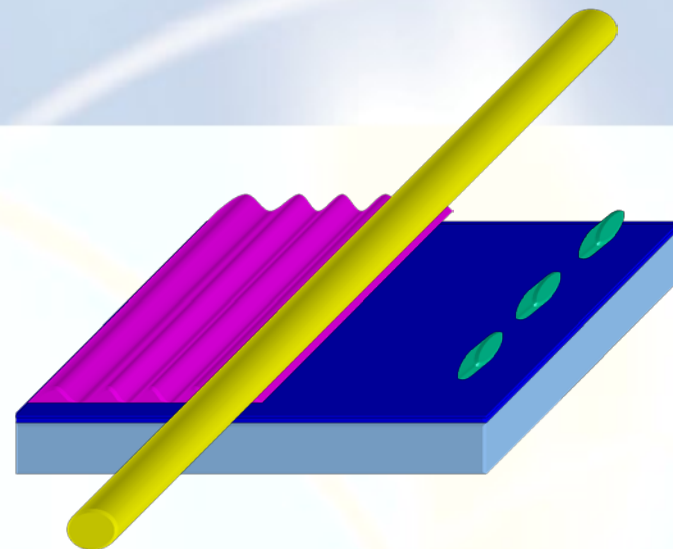


Outline



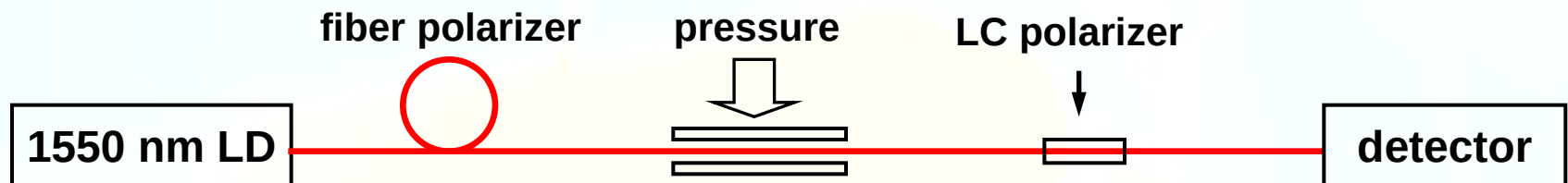
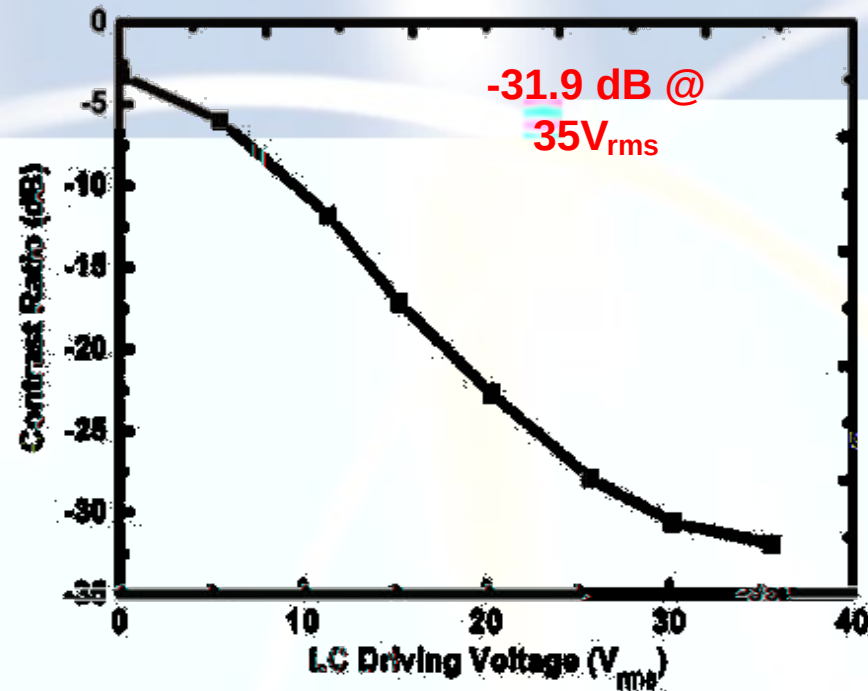
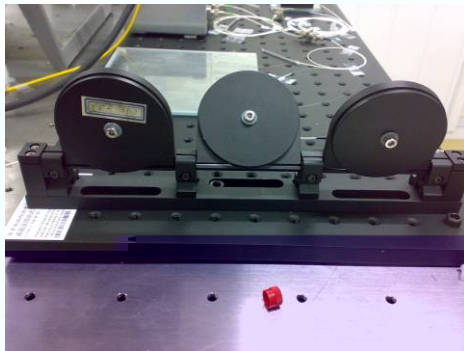
- ✓ Telecomm as an example for photonic applications
- ✓ LC based VOA (variable optical attenuator)
- ✓ LC based DWDM wavelength blocker
- ✓ LC based diffraction gratings
- ✓ LC based in-line polarizer and fiber-optic sensor
- ✓ LC for tunable THz applications
- ✓ LC for tunable optical vortex generation
- ✓ Other LC's photonic applications

LC cladding microfiber as an in-line polarizer





LC cladding microfiber as an inline VOA & polarizer



J. Feng et. al., IEEE Photonics Journal, 2, 292-298 (2010)



LC cladding fiber for pressure sensing

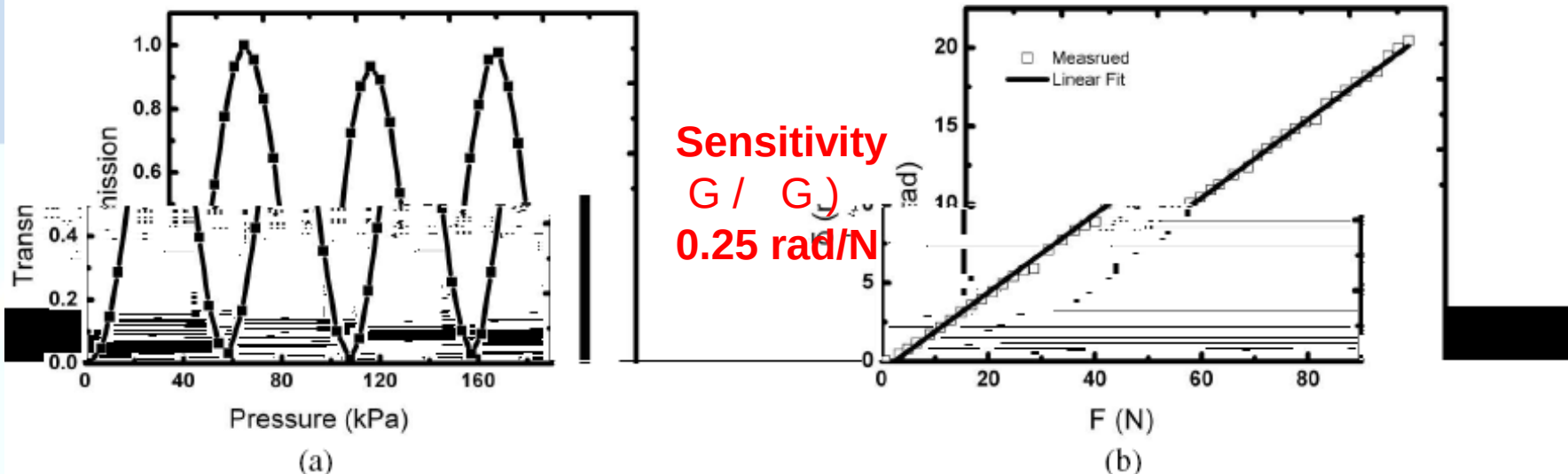
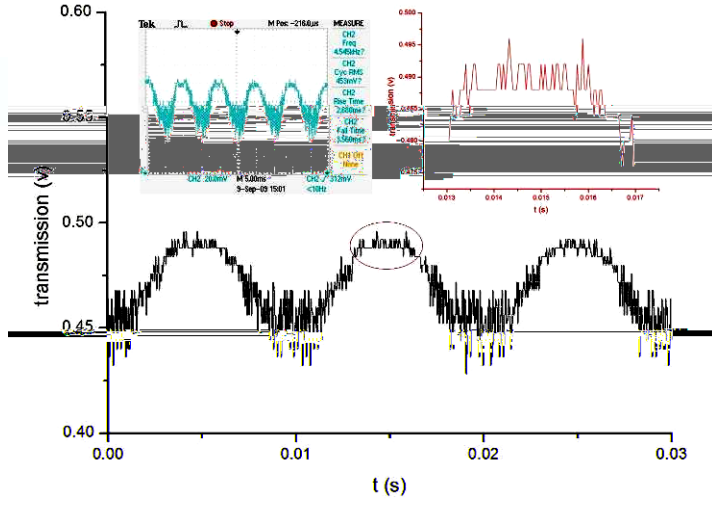
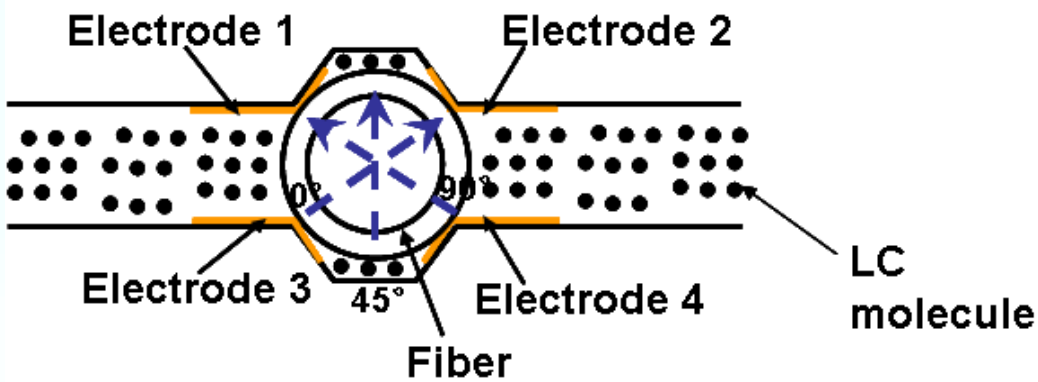


Fig. 5. (a) The pressure induced transmission change. (b) The measured phase retardation as a function of the applied force. The solid line is a best-fit curve..



Outline



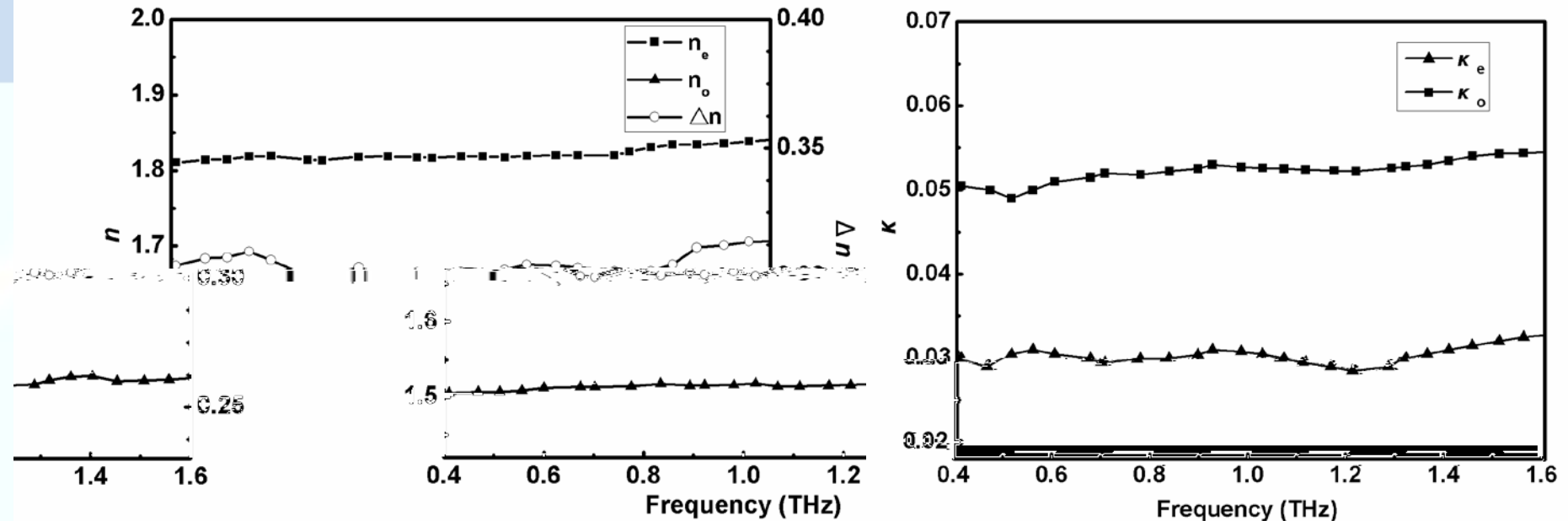
- ✓ Telecomm as an example for photonic applications
- ✓ LC based VOA (variable optical attenuator)
- ✓ LC based DWDM wavelength blocker
- ✓ LC based diffraction gratings
- ✓ LC based in-line polarizer and fiber-optic sensor
- ✓ LC for tunable THz applications
- ✓ LC for tunable optical vortex generation
- ✓ Other LC's photonic applications



Challenges of tunable LC devices for THz apps.

- The commonly used conductive ITO layer is highly absorptive in THz range.
(New transparent conductive electrodes in THz band)
- The dispersion of LC induces a comparatively low birefringence.
(New highly birefringent LC mixture in THz band)
- Cell gap should be much larger than that in visible region, large operation voltage, slow response and poor pre-alignment.
(New cell structure, new LC alignment)
(e.g., *Prof. CL Pan's group: 570 nm-thick cell, QWP @ 1THz, - Opt. Lett. 31, 1112 (2006).*)

Self-developed large birefringence LC in THz range



Collaborated with Prof. Xiao Liang in Tsinghua Univ.

Frequency-dependent birefringence Δn and refractive indices: real part n (a) and imaginary part (b) of a fluorinated phenyl-tolane based nematic mixture NJU-LDn-4.

Wang, *Opt. Mater. Express*, **2**, 1314 (2012)



Large birefringence LC material in terahertz range

LaserFocusWorld

International Resource for Technology and Applications in the Global Photonics Industry

HOME | BROWSE BY TOPIC | BUYERS GUIDE | PRODUCTS | BUSINESS CENTER | EDUCATION | RESOURCES

ence-for

ial Media Tools

Print Email Save

Tweet

Liquid-crystal material has large-birefring

tenahertz-radiation

10/25/2012
By John Wallace
Gang Liang

Liquid crystals (LCs) are commonly used in visible wavelengths, but it turns out that these materials can be used for optical devices at terahertz frequencies too. A group at Nanyang University (Singapore, China) and Tsinghua University (Beijing, China) is using a fluorinated phenyl-tolane-based nematic LC mixture between two thin fused silica plates (rubbed for LC orientation) as a birefringent material for radiation in the 0.4 to 1.8 THz range. The material has a mean birefringence of 0.008 over that range, reaching a peak of 0.014 at 1.0 THz.

The gap between the two fused silica plates was 0.12 mm, used for testing the absorption of the material with the terahertz time domain spectroscopy (THz-TDS) technique. With the refractive index values of the fused silica plates measured first and the subsequent data, both real and imaginary components of the ordinary (n_o) and extraordinary (n_e) refractive indices were obtained (the real portion is shown here). The imaginary part of birefringence, which is a coefficient, showed low absorption over the whole testing range. The LC material has potential for terahertz waveguide.

Subject: Top Downloads in Liquid Crystals from Optical Materials Express

Print This

[View Online](#) | [Share](#) | [Forward](#)

OSA | The Optical Society

Optical Materials EXPRESS

Find out what your colleagues are reading about Liquid Crystals in *Optical Materials Express*

OSA's open-access, rapid-publication journal, *Optical Materials Express*, publishes high-quality, peer-reviewed content on the synthesis, processing, and characterization of materials for applications in optics and photonics. One of the Journal's most active topic areas is Liquid Crystals. To help you stay on top of the most read articles in this topic area, we have pulled together a collection of the top downloaded papers over the past year in this content area.

We hope that you enjoy this collection.

Large birefringence liquid crystal material in terahertz range

[Abstract](#) | [Full Text: PDF](#) | [Enhanced HTML](#) ⓘ

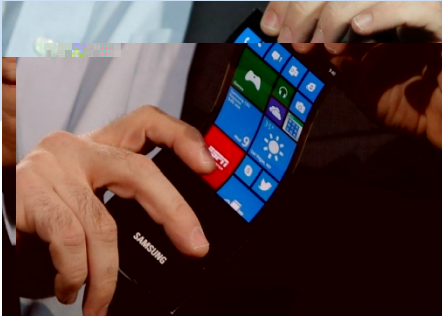
Optical Materials Express, Vol. 2 Issue 10, pp.1314-1319 (2012)
Wang, Lei; Lin, Xiao-wen; Liang, Xiao; Wu, Jing-bo; Hu, Wei; Zheng, Zhi-gang; Jin, Biao-bing; Qin, Yi-qiang; Lu, Yan-qing

We develop a fluorinated phenyl-tolane based nematic mixture NJU-LDn-4 and evaluate its frequency-dependent birefringence utilizing terahertz time domain spectroscopy (THz-TDS). A large birefringence 0.008-0.014 is obtained in the whole range from 0.4 to 1.8 THz. With a

Top downloads in Liquid Crystals from *Optical Materials Express*

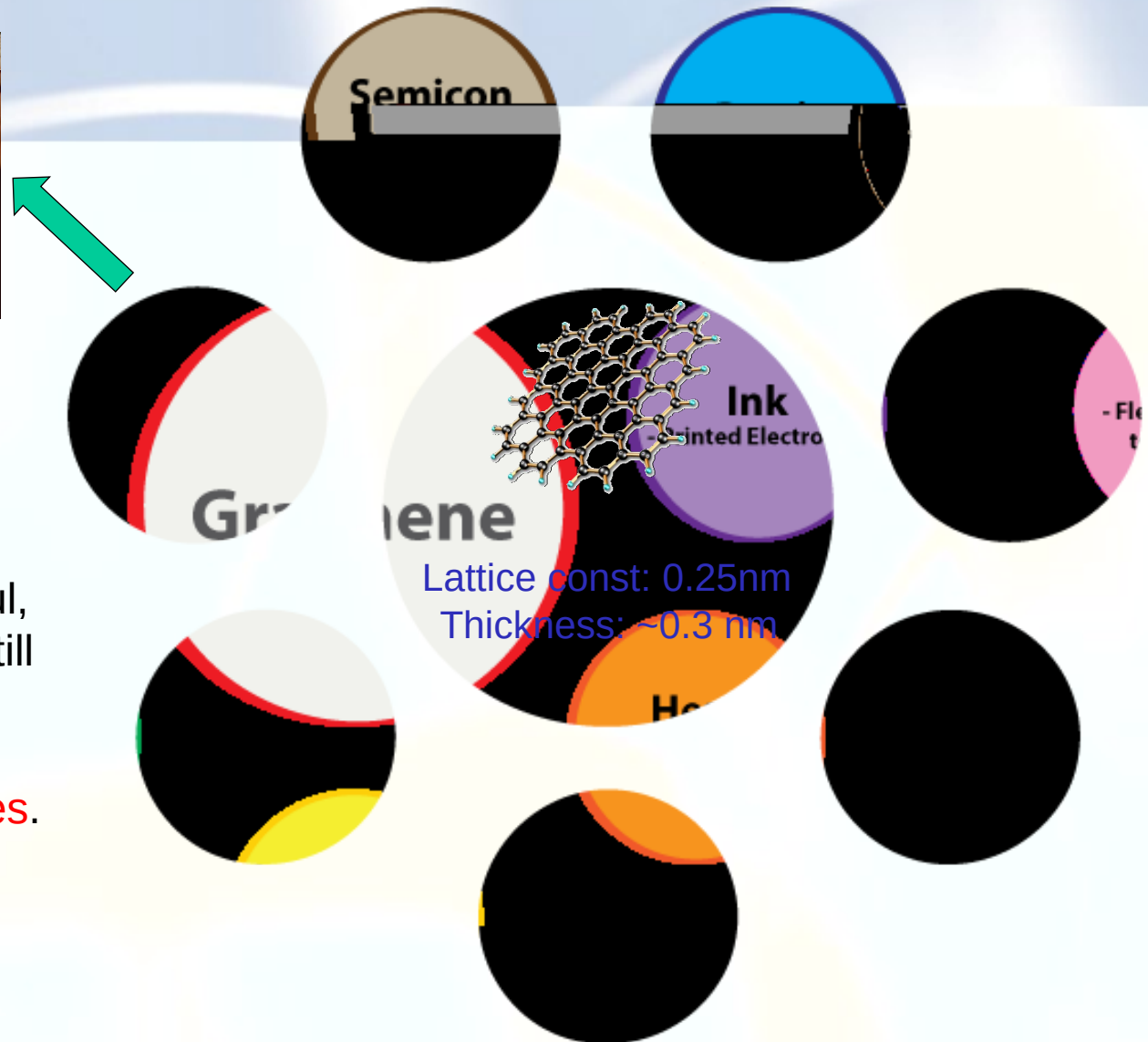


New electrode material: Graphene

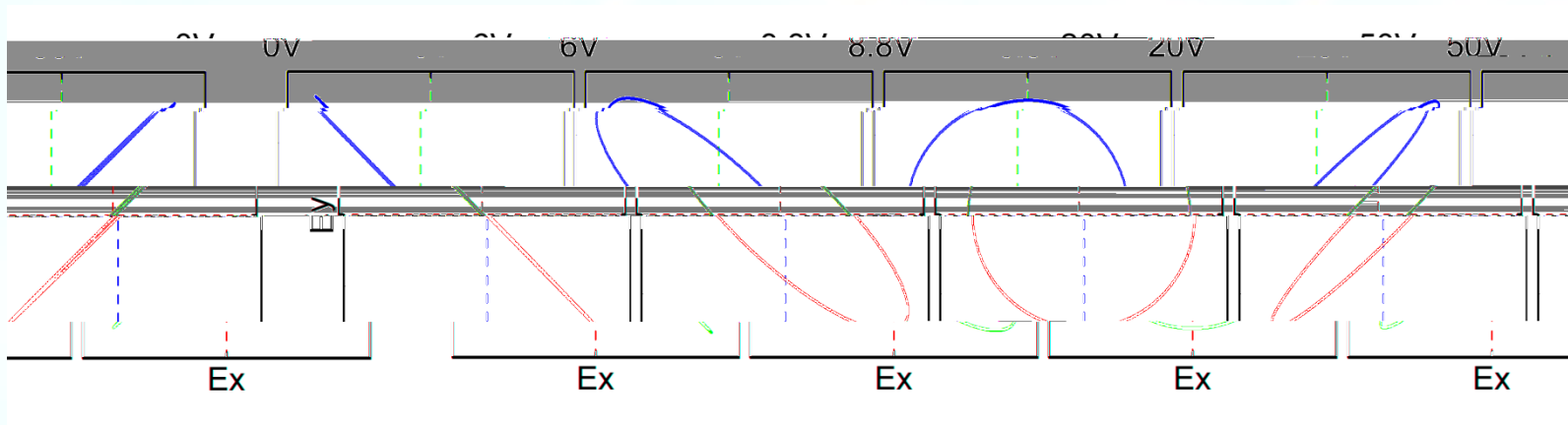
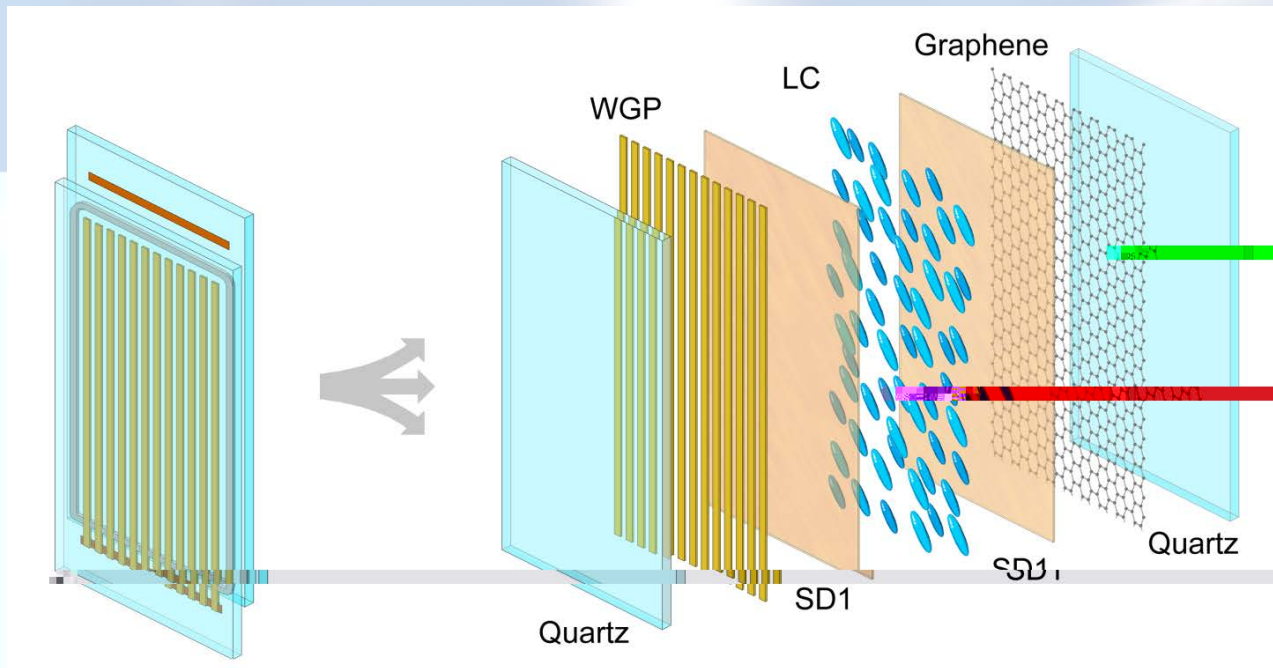


The self-polarizing function of **sub-wavelength metallic gratings** is very useful, but, sometimes we still need **polarization independent transparent electrodes**.

A new candidate:
Graphene



Our tunable THz LC waveplate with graphene electrode



Outline

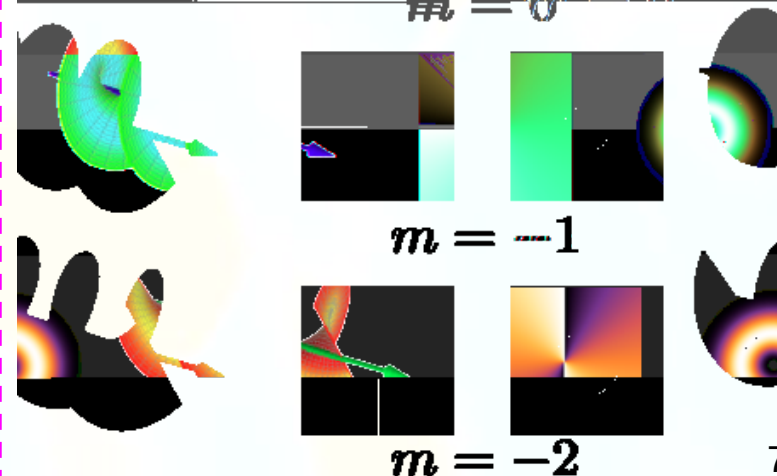
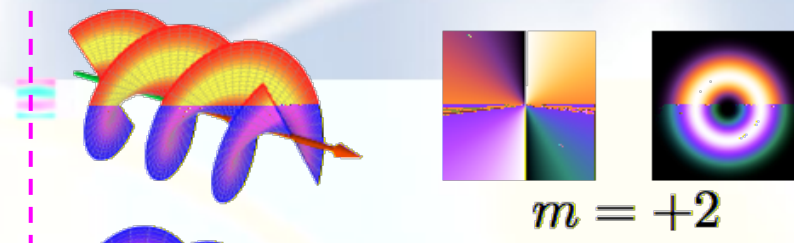


- ✓ Telecomm as an example for photonic applications
- ✓ LC based VOA (variable optical attenuator)
- ✓ LC based DWDM wavelength blocker
- ✓ LC based diffraction gratings
- ✓ LC based in-line polarizer and fiber-optic sensor
- ✓ LC for tunable THz applications
- ✓ LC for tunable optical vortex generation
- ✓ Other LC's photonic applications

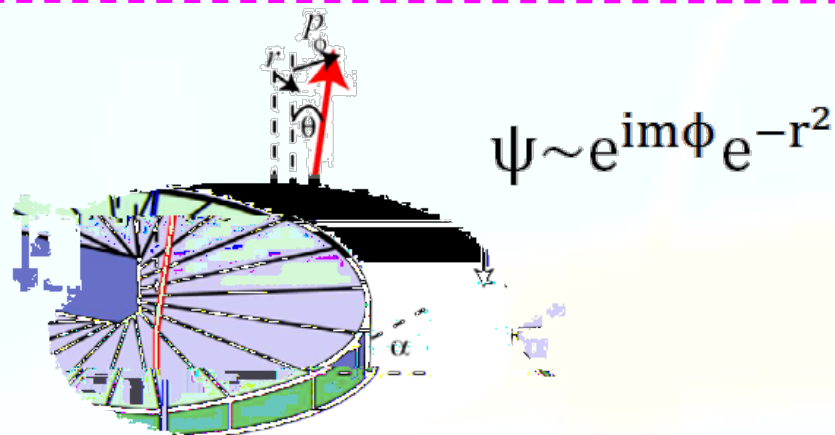
Optical vortex and orbital angular momentum



Optical Vortices with OAM



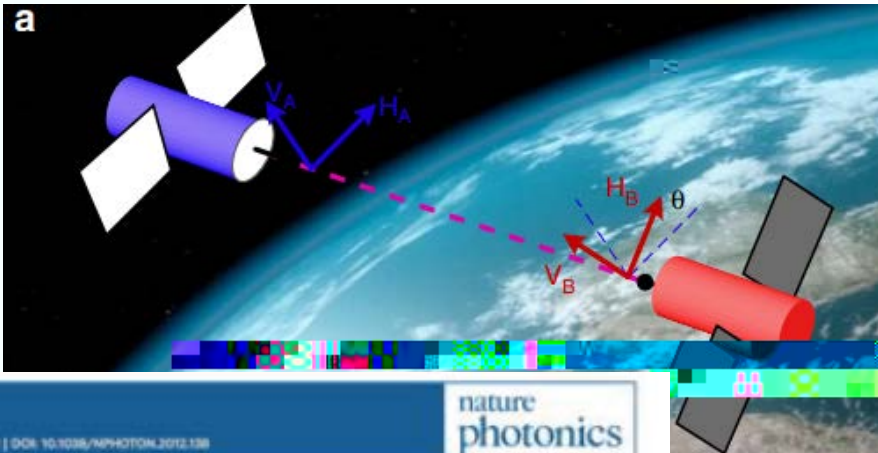
SAM: spin angular momentum



OAM: orbital angular momentum

Interesting applications of optical vortex beams

- ✓ Optical tweezers: trapping and rotation
- ✓ OAM multiplexed optical communications
- ✓ Satellite-based quantum communication
- ✓ Fast data manipulation in quantum computing
- ✓ Extrasolar planets observation
- ✓ Cryptography
- ✓ Fundamental tests of quantum mechanics
- ✓ ...



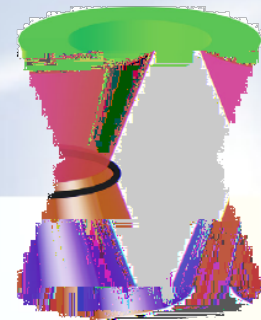
ARTICLES

PUBLISHED ONLINE: 24 JUNE 2012 | DOI: 10.1038/NPHOTON.2012.138

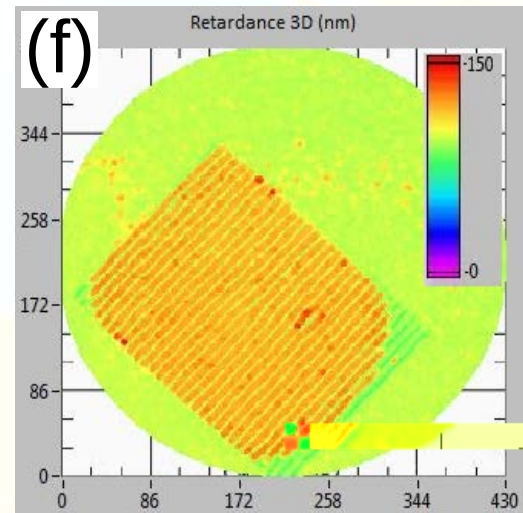
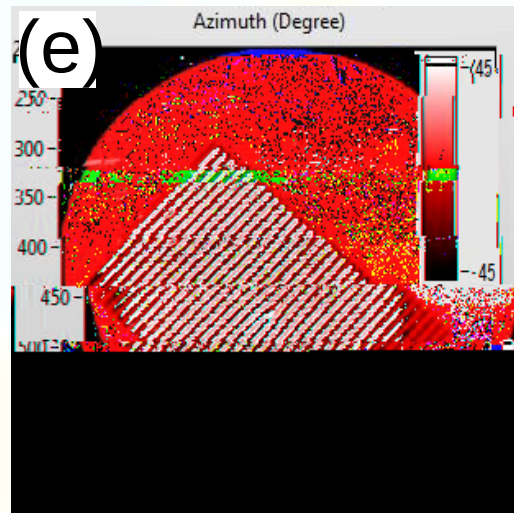
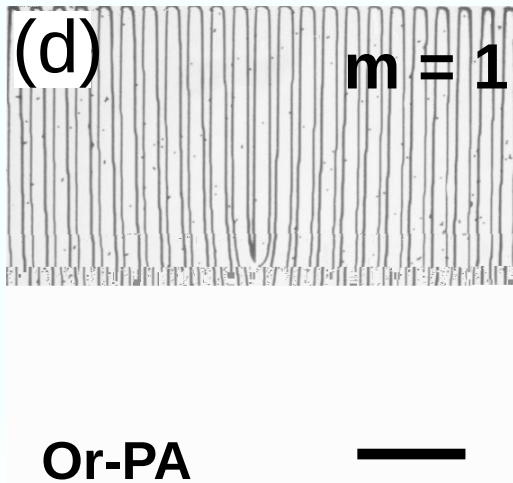
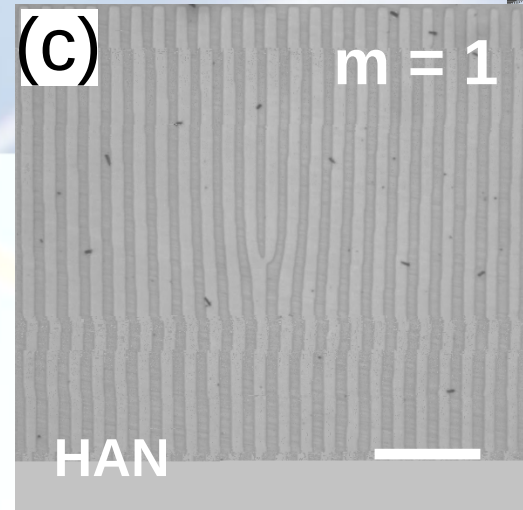
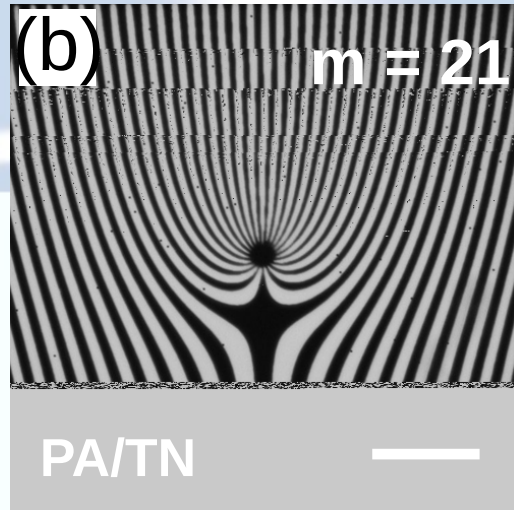
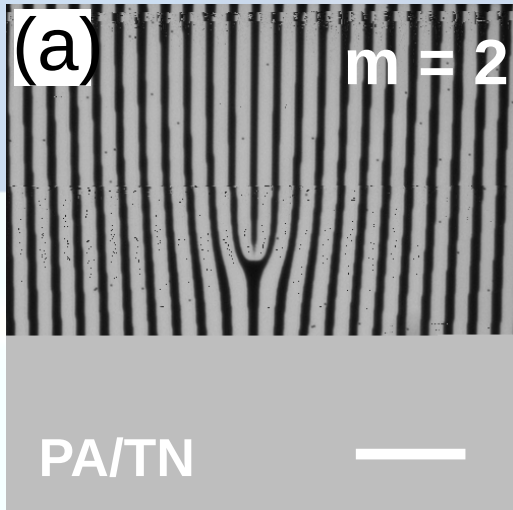
nature
photonics

Terabit free-space data transmission employing orbital angular momentum multiplexing

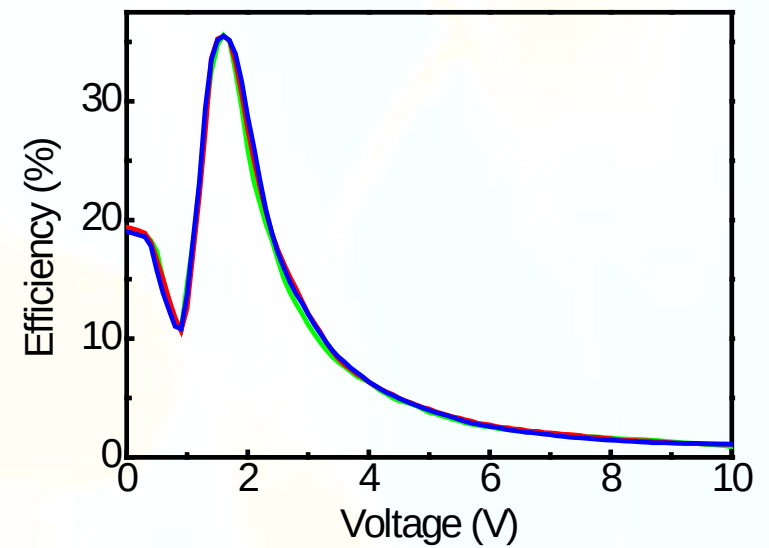
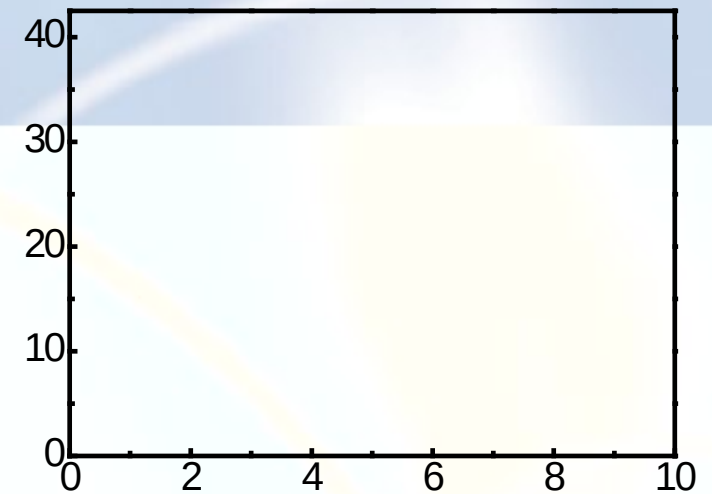
Jian Wang^{1,2*}, Jeng-Yuan Yang¹, Irfan M. Fazali¹, Nisar Ahmed¹, Yan Yan¹, Hao Huang¹, Yongxiong Ren¹, Yang Yue¹, Samuel Dolinar³, Moshe Tur⁴ and Alan E. Willner^{1*}



LC fork grating with various alignments

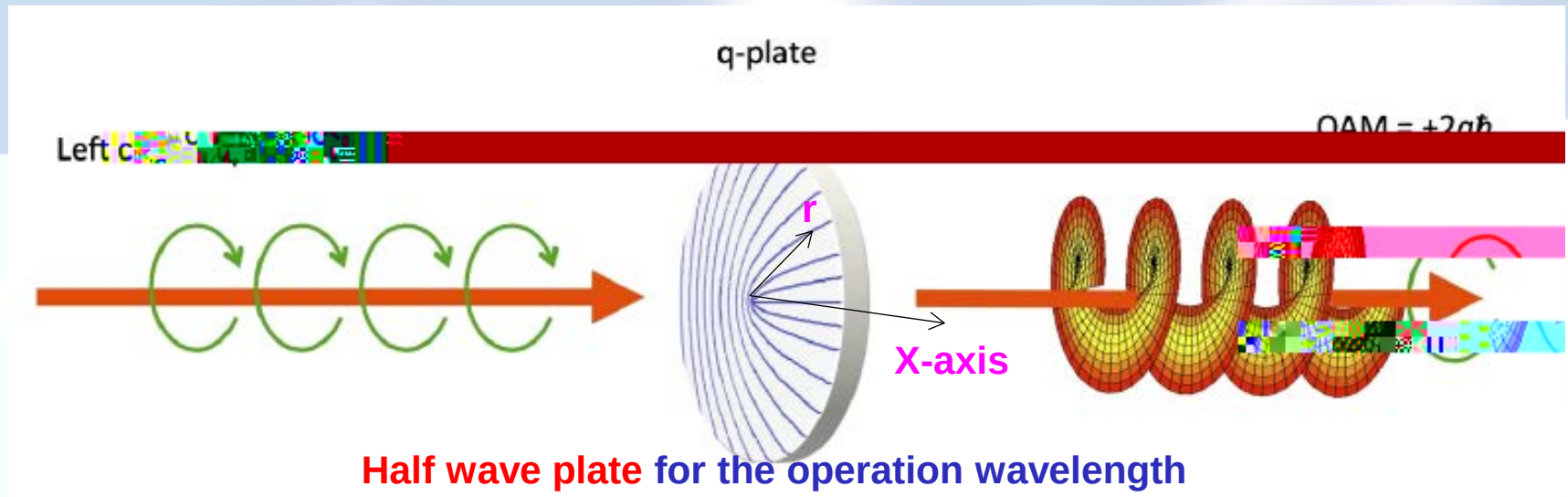


LC: E7 Cell gap: 4 μm Scale bar: 100 μm

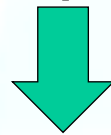




Liquid crystal Q-plate for tunable vortex generation



For a specific Q-plate pattern: $\alpha(r, \varphi) = q\varphi + \alpha_0$



$$\Delta\phi(x, y) = \alpha = q\varphi + (\alpha_0 + m\varphi + \text{const.})$$

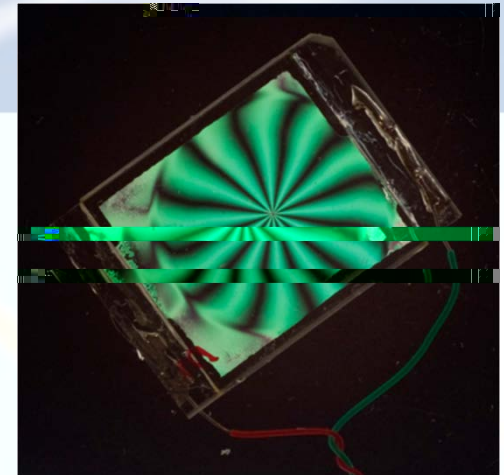
Vortex phase with $m = 2q$

Fabrication of Liquid crystal Q-plates

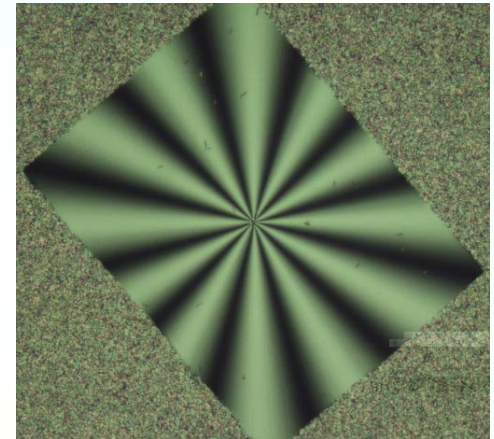
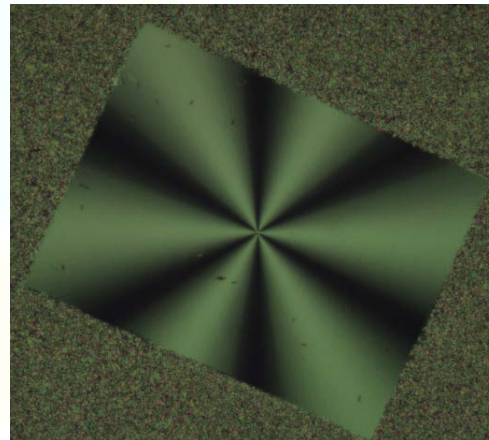


lens polarizer mask cylindrical lens sample

Opt. Express, 19, 4085 (2012)



UV Lamp



Outline



- ✓ Telecomm as an example for photonic applications
- ✓ LC based VOA (variable optical attenuator)
- ✓ LC based DWDM wavelength blocker
- ✓ LC based diffraction gratings
- ✓ LC based in-line polarizer and fiber-optic sensor
- ✓ LC for tunable THz applications
- ✓ LC for tunable optical vortex generation
- ✓ Other LC's photonic applications



LC's other photonic applications

- ✓ LC tunable FP filter/laser
- ✓ LC based random laser
- ✓ LC tunable metamaterials
- ✓ LC based soliton
- ✓ LC based nonlinear optical frequency converter
- ✓ LC tunable plasmonic devices in different bands
- ✓ LC based electrocaloric effect
- ✓ ...



1991年诺贝尔物理学奖得主、法国著名的物理学家**P. G de Gennes**教授在《液晶物理学》的中译本（1990年）序言中写道：“液晶最初是**100**年前由德国学者发现的，后来法国的**Georges Friedel**建立了结构分类的基本方案，美国人最先注意到液晶在显示器件应用的潜在重要性，今天的液晶的应用技术大部分掌握在日本人手中.....”

几十个 韩国 台湾 中国大陆?!

寻找液晶产业的新蓝海！



Acknowledgements

All group members in NJU.

Financial support: China's "973" and NSFC projects.

감사합니다 Natick
Danke Ευχαριστίες Dalu
Thank You Köszönöm
Tack
Спасибо Dank Gracias
谢谢 Merci Seeé
ありがとう

<http://light.nju.edu.cn>