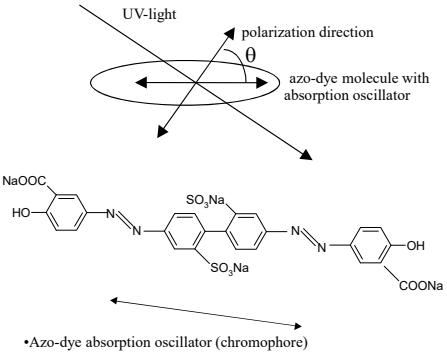
Photoaligned and photopatterned liquid crystals: new materials for displays and photonics

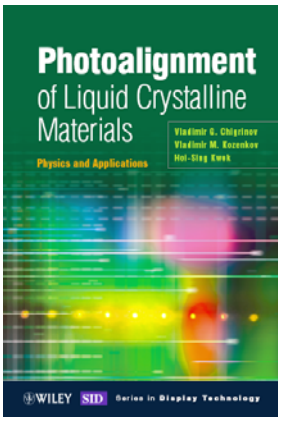
Vladimir G. Chigrinov

Emeritus Professor, Hong Kong University of Science and Technology, CWB, Kowloon, Hong Kong

Diffusion mechanism of azo-dye molecule alignment



V. Chigrinov et al. Phys. Rev. E, (2004).



Advantages of photoalignment technology

Elimination of electrostatic charges and impurities as well as mechanical damage of the surface;

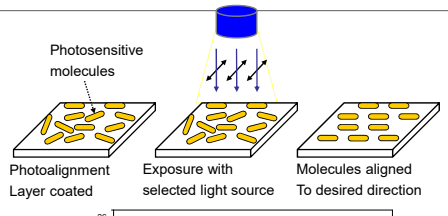
A controllable pretilt angle and anchoring energy of the liquid crystal cell, as well as its high thermo and UV stability and ionic purity;

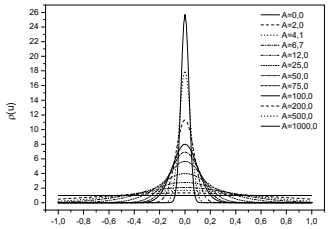
New advanced applications of LC in fiber communications, optical data processing, holography and other fields, where the traditional rubbing LC alignment is not possible due to the sophisticated geometry of LC cell and/or high spatial resolution of the processing system;

Ability for efficient LC alignment on curved and flexible substrates;

Manufacturing of new optical elements for LC technology, such as patterned polarizers and phase retarders, tunable optical filters, polarization non-sensitive optical lenses, with voltage controllable focal distance etc.

Diffusion mechanism





Summary

Liquid crystal (LC) devices for displays and photonics are dominating in the market and will be the basic technology for advanced display and electronics in the nearest 10 years.

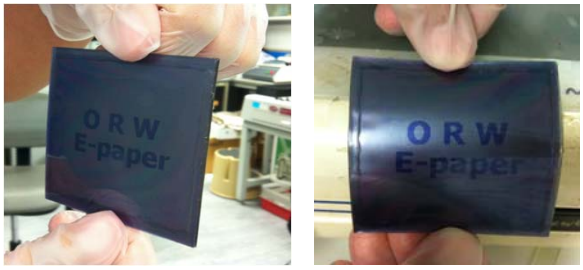
Photoalignment materials can be effectively used in LC alignment and patterning for new generations of LC devices that provide extremely high resolution and optical quality of alignment both in glass and plastic substrates, photonics holes etc.

New liquid crystal devices include ORW E-paper, field sequential color ferroelectric liquid crystal (FLC) projectors, 100% polarizers, q-plates, sensors, switchable lenses, security films, switchable antennas.

ORW E-paper

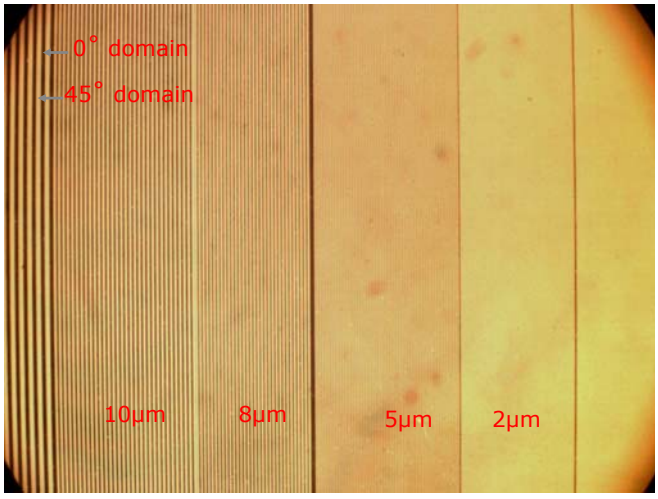
Very durable & flexible
- Light weight thin
- Good brightness
- High contrast ratio
- Wide viewing angle
- Low cost
- No electrode
- Zero power consumption
- Display & driving units are separated

Future Work: Flexible



Recent development: full gray scale image.

Future Work: Full Color

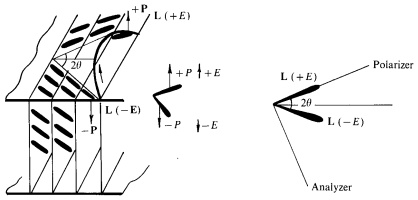


Security films

Structure is based on patterned photoalignment layer with liquid crystal polymer
Phenomenon:
1.Observe only with polarizer.
2.Change of brightness with the rotation of polarizer.
3.Picture change with the rotation of substrate.

M. Stalder, M. Ibn-Elhaj, and F. Moia, US20070196616 A1 (23 August 2007).
F.X. Delbaere, H. Seiberle, and P. Studer, US20110017838 A1 (27 January 2011).
M. Franco, WO2000029878 A1 (25 May 2000).
M. Schadt and H. Seiberle, US20100118256 A1 (13 May 2010).
弗兰克·赛拉, CN1397047 A (12 February 2003).
F. Moia, US20030035191 A1 (20 February 2003).
M.J. Escuti, C. Sanchez, C.W.M. Bastiaansen, and D.J. Broer, US20120086903 A1 (12 April 2012).

Electrooptical response of FLC cell



the switching times in linear electrooptical effects are equal and can be very small:

$\tau_{on} = \tau_{off} = \gamma_\varphi / P_s E < 50\mu s$,

γ_φ is rotational viscosity, P_s – spontaneous polarization, E- electric field

N. Clark, S.T. Lagerwall, APL, 36, 899 (1980).

FLCOS microdisplay progress

In-plane switching maintains contrast in ~f/1 optics of near-eye displays

Binary code grayscale can be achieved with LED readout providing short pulses to extend bit depth

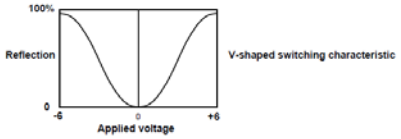
Power consumption reduced by simple pulse width modulation in 24-bit color field sequential at 360 hz, assisted by LED pulse modulation

AC operation is necessary to prevent ionic charging, but imposes 50% off-state which halves throughput. Can be defeated by synchronous counter polarity switch in output path

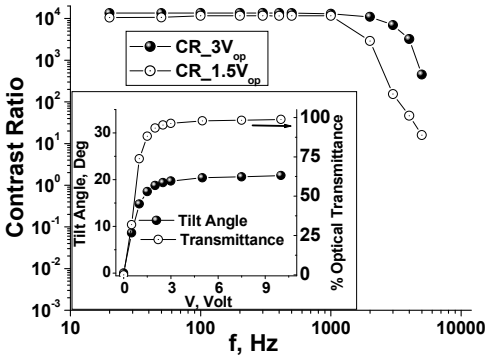
FLC LCOS microdisplays are available with up to 1280x1024 resolution and 360 hz frame rate

Color sequential camera viewfinders and near-eye viewers are dominant application

Development of fast analog switching FLC would enhance performance of color sequential projectors e.g. "V-shaped" switching is in development stage.



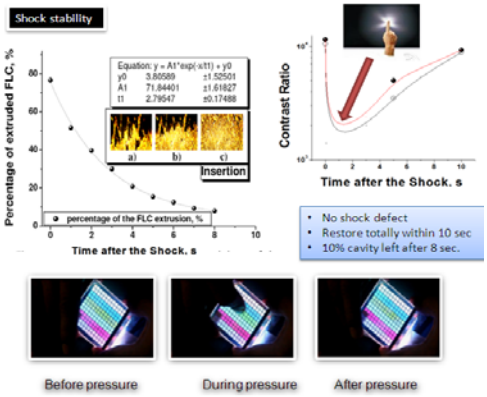
ESH mode frequency dependence

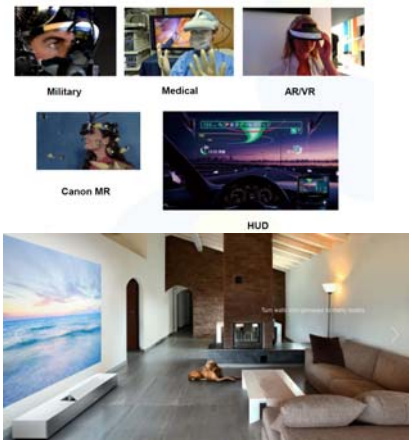


FEATURES of ESH FLC

- High contrast (~10k:1)
- Fast response time (10 μs)
- Low power consumption with 1V driving.
- Good shock stability
- 8 bit gray scale
- Color triangle 130% of the NTSC : more color
- Fast operational frequency (~3kHz)

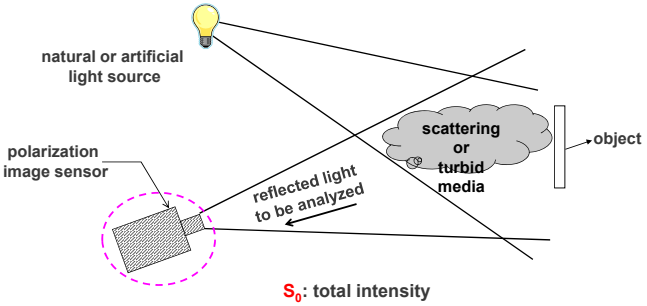
Mechanically stable FLC





Courtesy by Mr. Ken Tai (Jasper Display)

Stokes polarization imaging



Stokes parameters (S_0, S_1, S_2, S_3)

S_0: total intensity

S_1 and S_2: linearly polarized components

S_3: circularly polarized components

X. Zhao et al. Opt. Expr., (2010).

Sensor head – overview

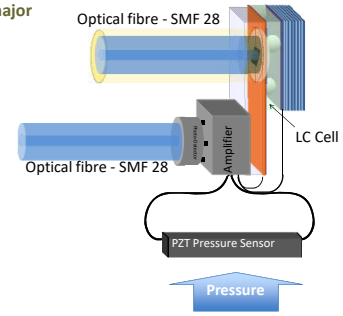
The sensor head consists in 4 major parts:

PZT pressure sensor

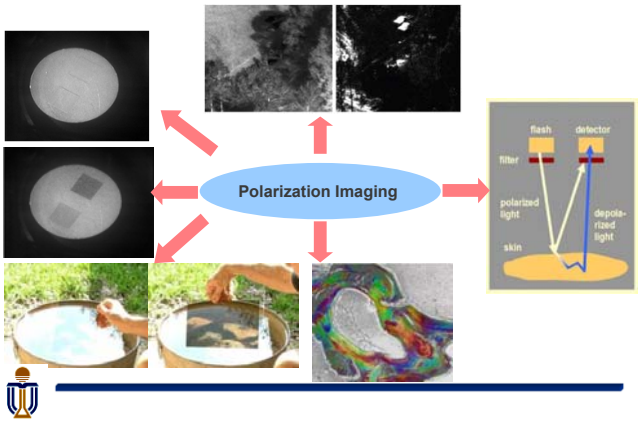
Liquid crystal cell

Optical fibre

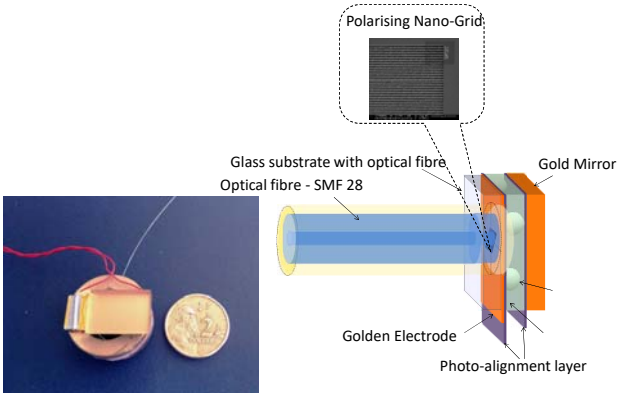
Optically powered amplifier



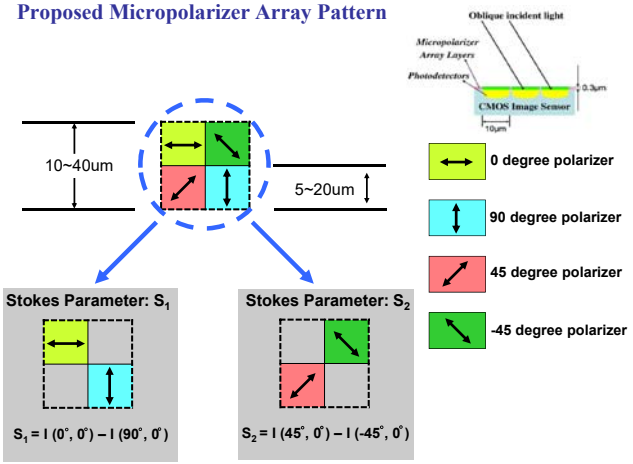
LC sensors



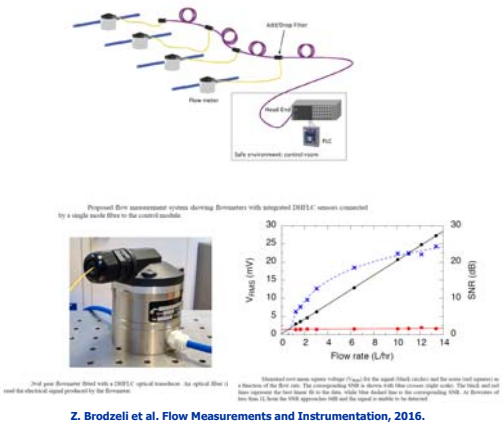
New DHF FLC based sensor



Proposed Micropolarizer Array Pattern



Flow meter network based on LC sensors



Z. Brodzeli et al. Flow Measurements and Instrumentation, 2016.