

Supramolecular Stereochemistry in Liquid Crystals

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- ◆ ***Introduction to thermotropic liquid crystals***
 - *What's a liquid crystal?*
 - *What's a liquid crystal texture (birefringence)?*
- ◆ ***Some applications of ferroelectric liquid crystals***
 - *LC electro-optics*
 - *The SSFLC light valve and LCOS microdisplays*

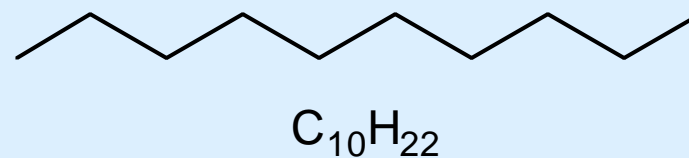
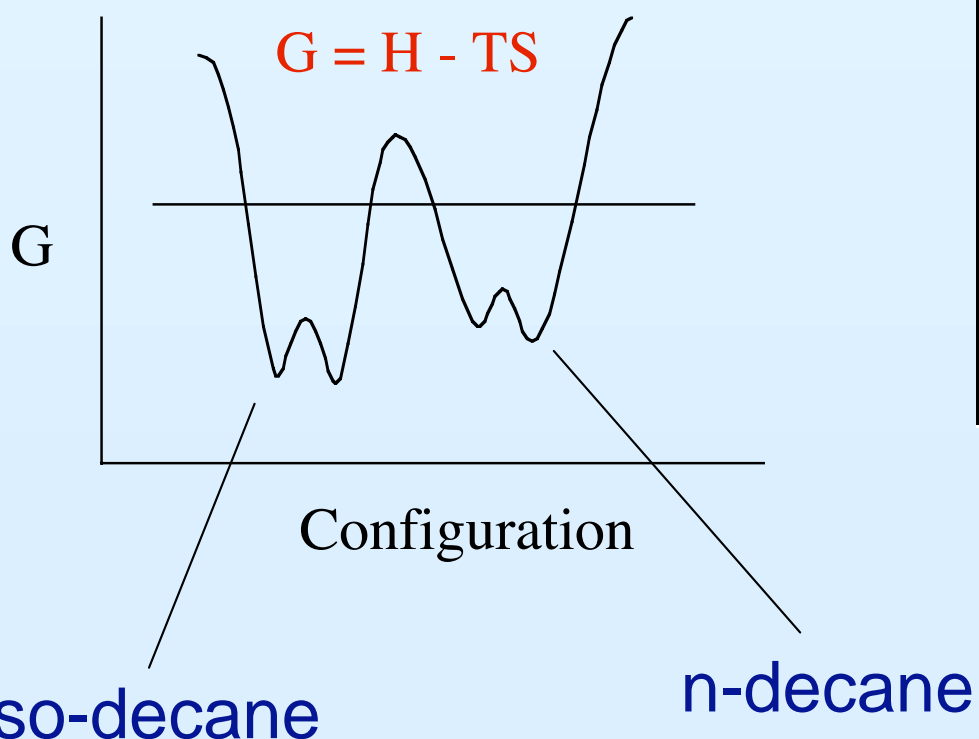
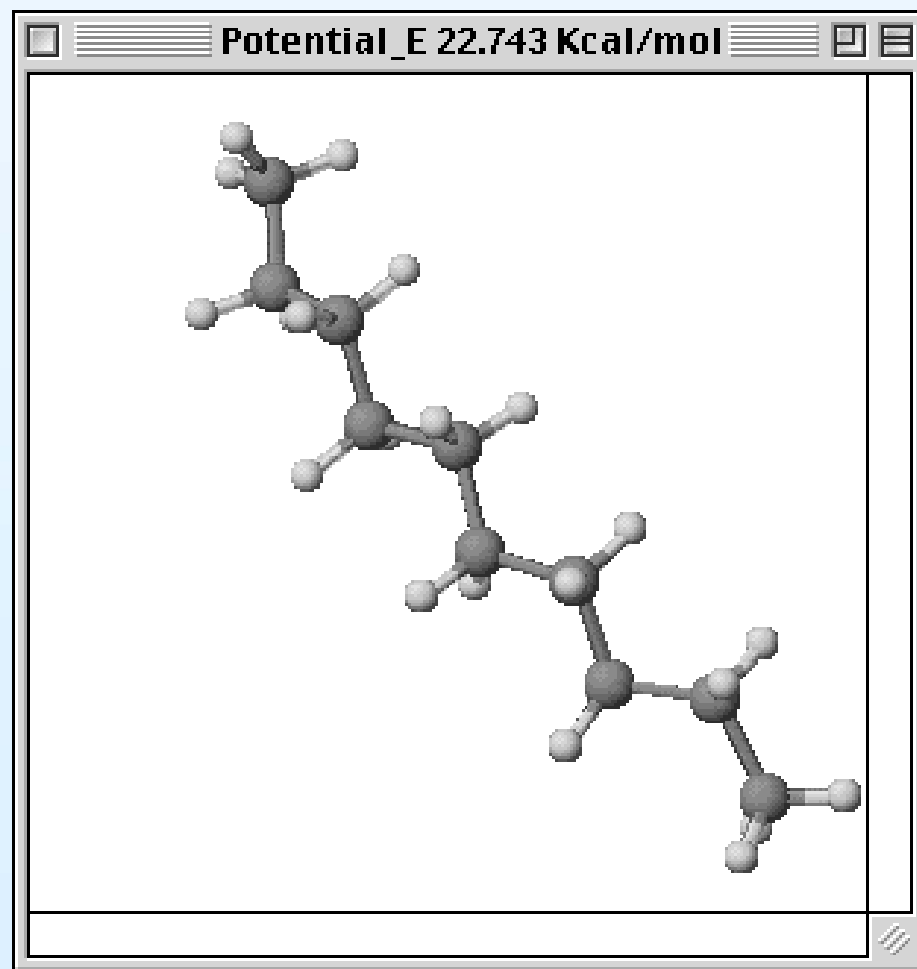


Stereochemical Aspects of Novel Materials
UCSB, August 2005

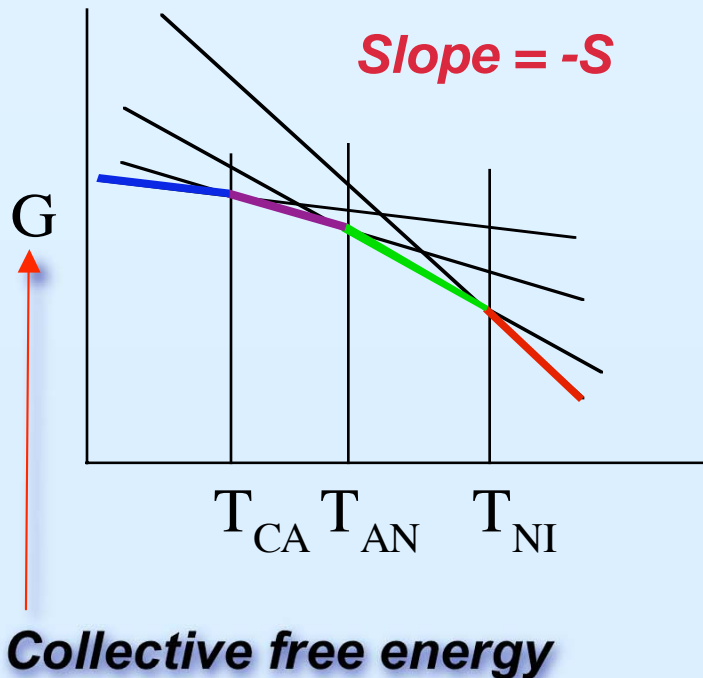
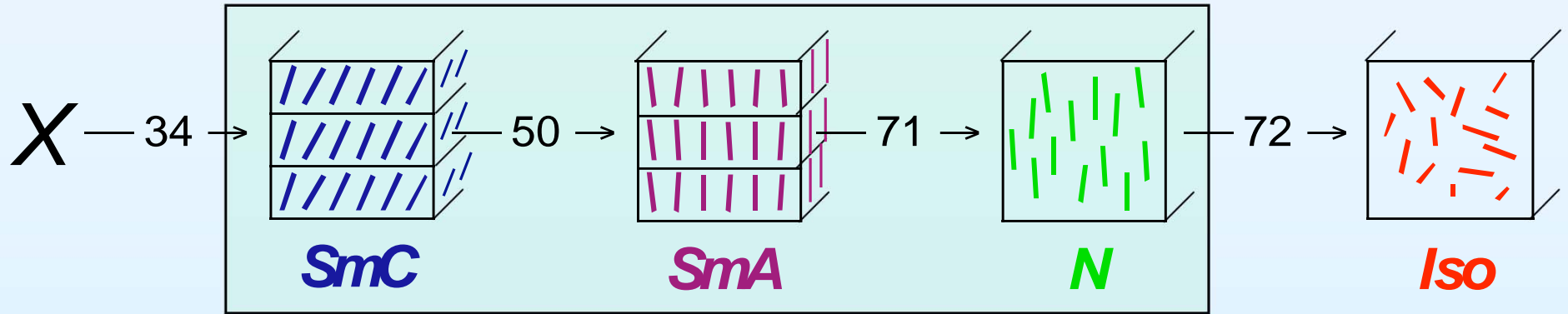
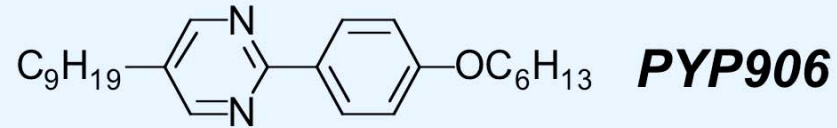


Molecules can be Very Dynamic

- ◆ Lots of molecules are very **FLOPPY** in the gas or liquid phase - **time-average structure and symmetry**.
- ◆ The structure of these molecules in the liquid phase is inherently dynamic in nature.



What's a Liquid Crystal?

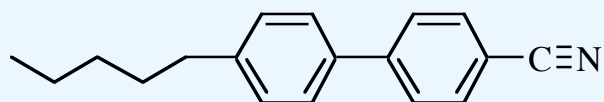


The classic INAC phases
The SmC is the most ordered, with
 C_{2h} symmetry \Rightarrow Nonpolar


 $C_{\infty v}$ or lower

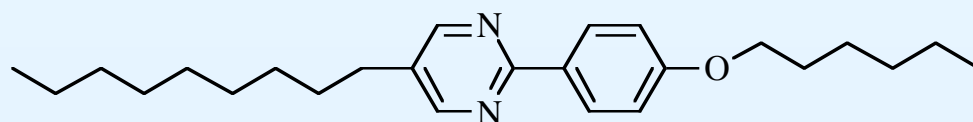
Potpourri of LC Mesogens

N and SmA

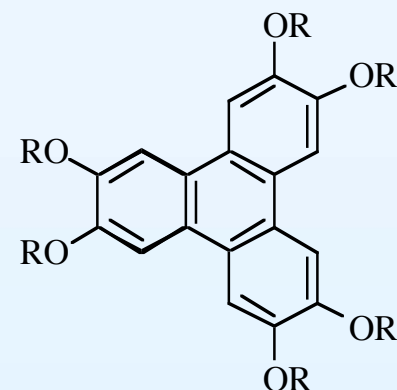


Cyanobiphenyls (Nematics)

INAC

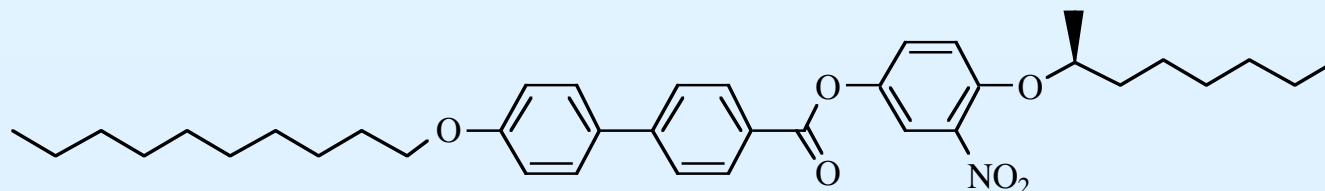


Phenylpyrimidines (Tilted Smectics)



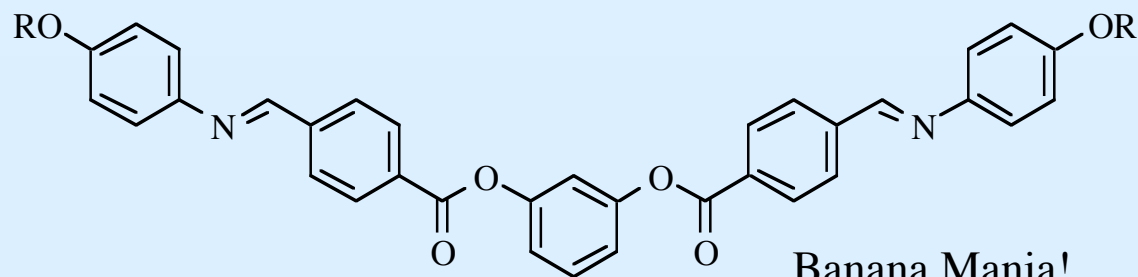
Discotics (Columnar)

IAC



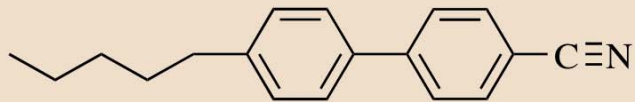
o-Nitrophenyl-biphenylcarboxylates (Chiral Tilted Smectics for NLO)

I-N-“Bn”



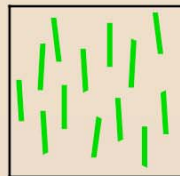
Banana Mania!

Nematic and Smectic LCs

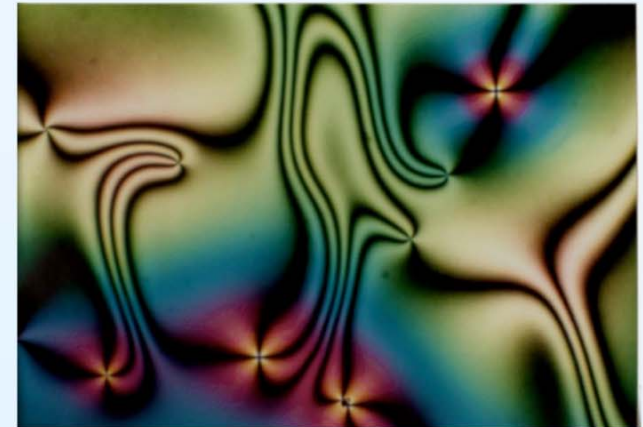


5CB (nematic)

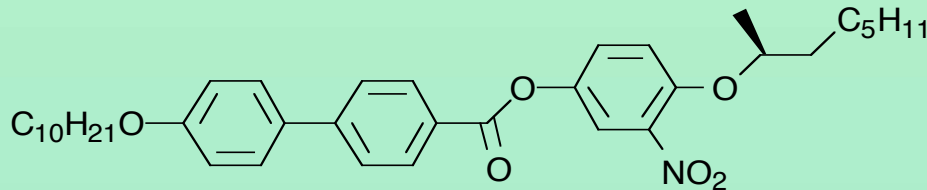
Cr — 24.0 → N — 35.3 → I



N



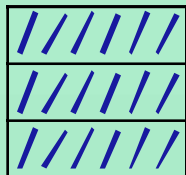
Nematic Schlieren texture
(Photo by Mary Neubert)



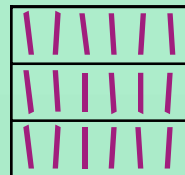
W314 (SmC* - SmA*)

Cr — 63.5° → SmC* — 93.7° → SmA* — 116° → I

Cr ← (20°) — SmC* ← 93.7° — SmA* ← 116° — I



SmC

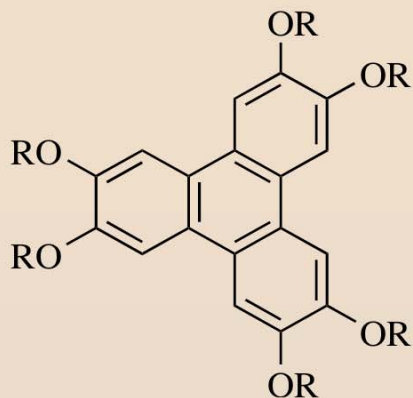


SmA

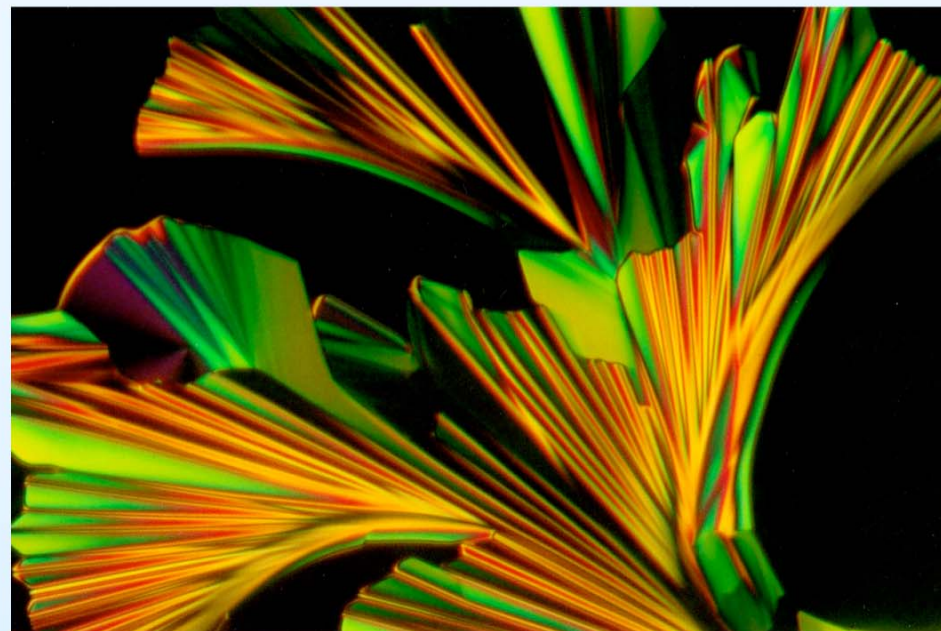


Smectic A focal conic texture

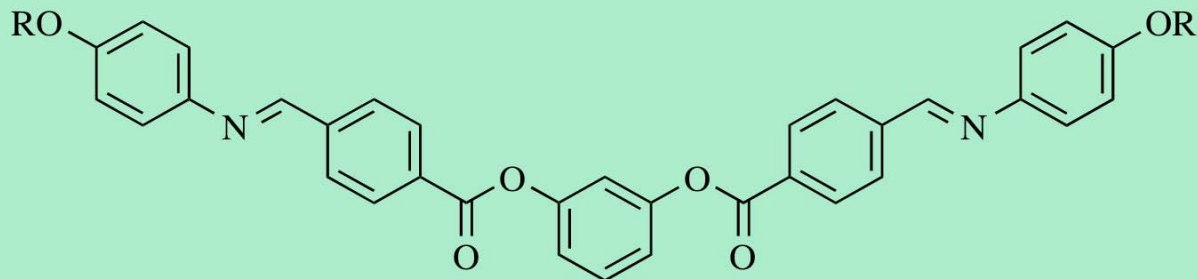
Columnar Phases



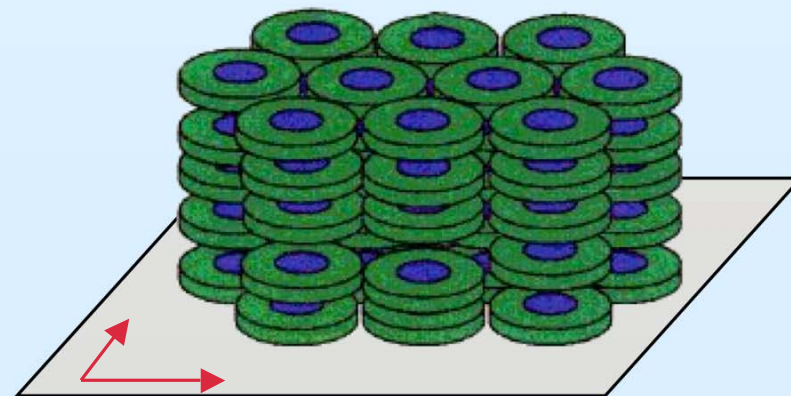
**Discotic Mesogens
(columnar phases)**



**The B1 columnar banana phase
(Photo by Renfan Shao)**



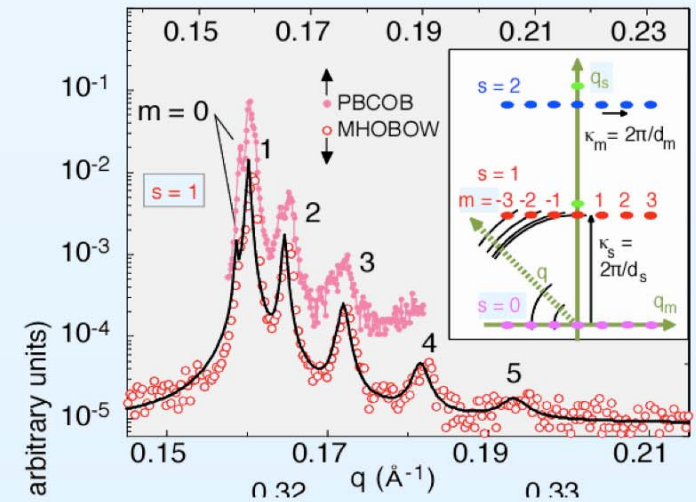
**Bent-core Mesogens
(smectic and columnar banana phases)**



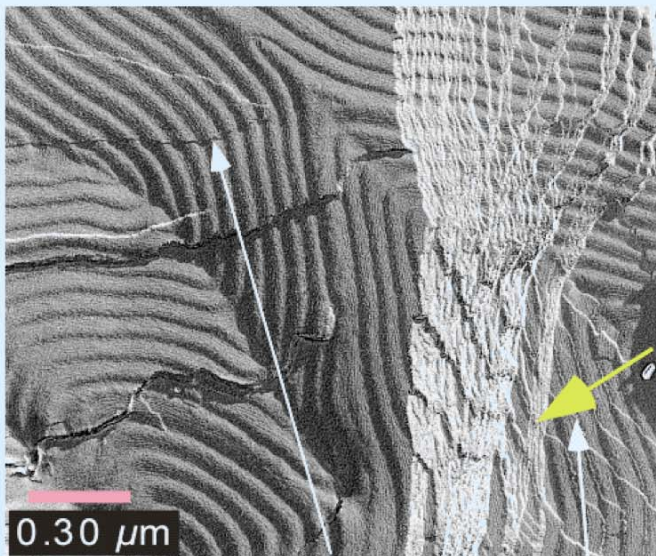
**Long-range positional order
in two dimensions**

Some Techniques used to Study LCs

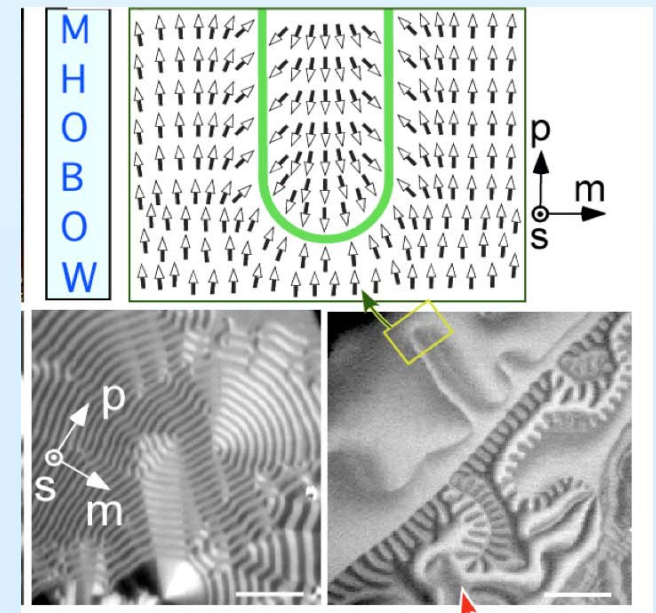
- ◆ Polarized light microscopy (PLM)
- ◆ Electro-optics
- ◆ Cross-polarization magic angle spinning ^{13}C NMR (CP-MAS)
- ◆ Dielectric spectroscopy
- ◆ X-ray diffraction (XRD)
- ◆ Depolarized reflected light microscopy from freely suspended films (DRLM)
- ◆ Freeze fracture transmission electron microscopy (FFTEM)



Powder XRD



FFTEM
Zasadzinski
and Clark



DRLM from freely suspended films

A Polarized Light Microscope

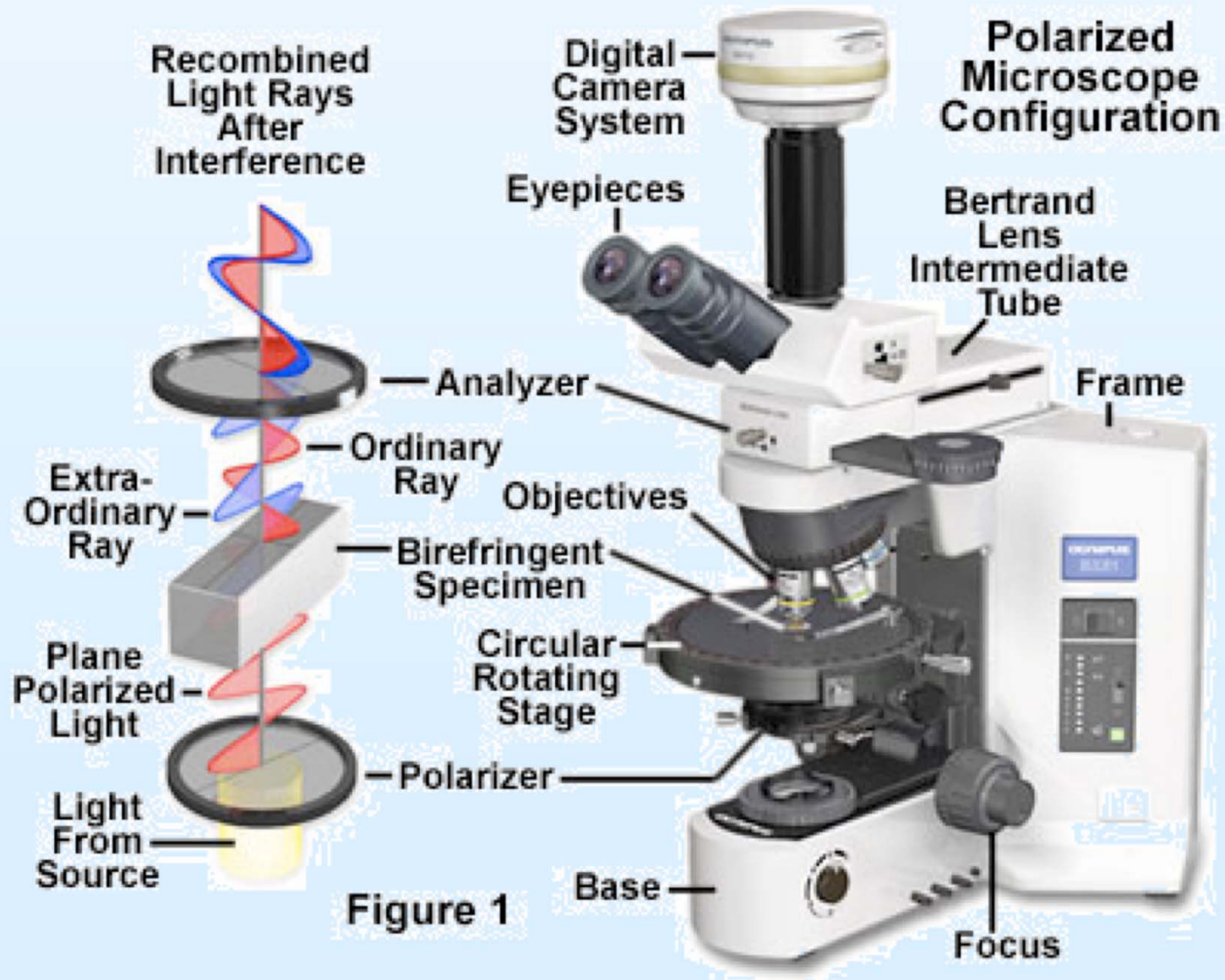
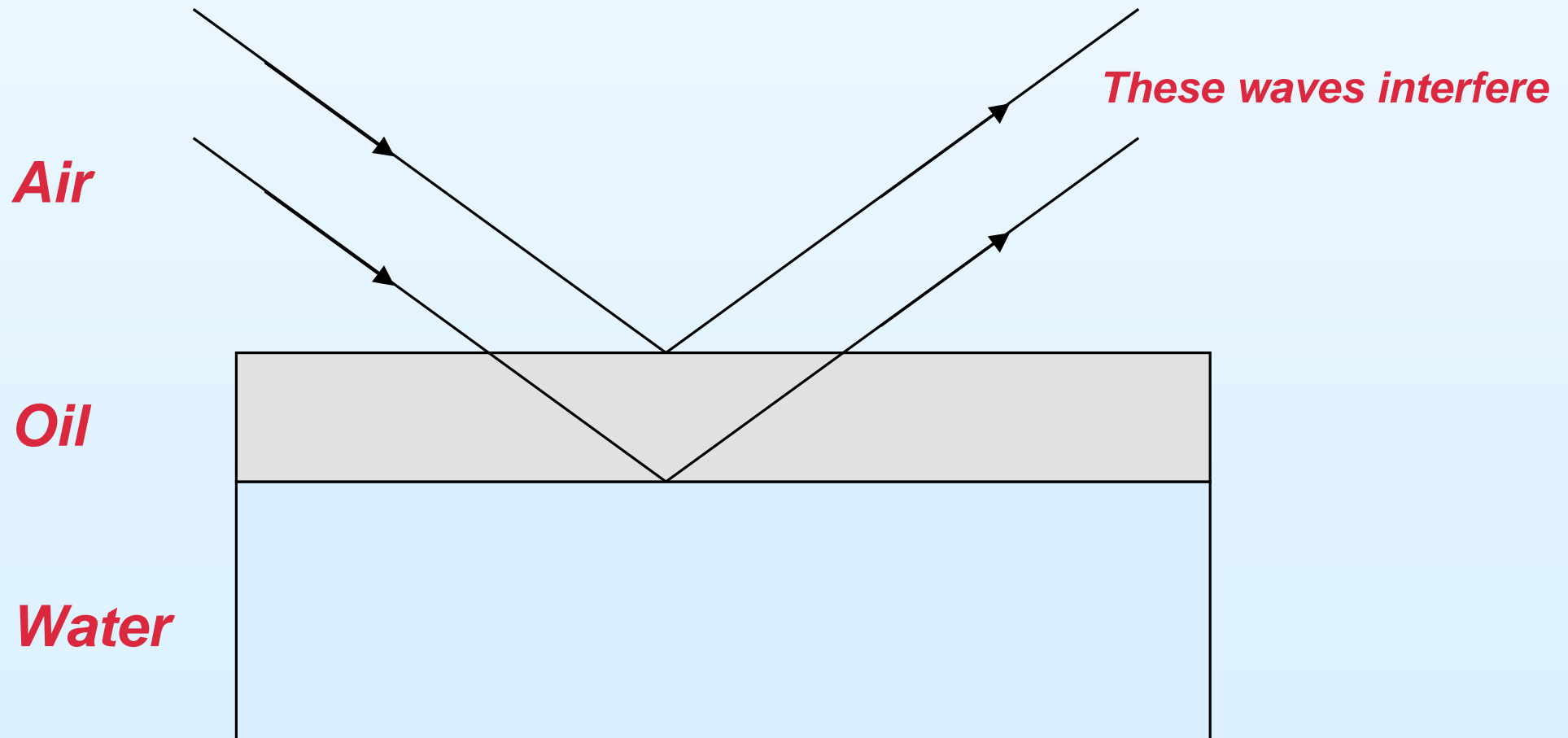


Figure 1

Interference Colors



Since the speed of light (refractive index) in air and oil are different, a thin film of oil causes a retardation of one wave with respect to the other

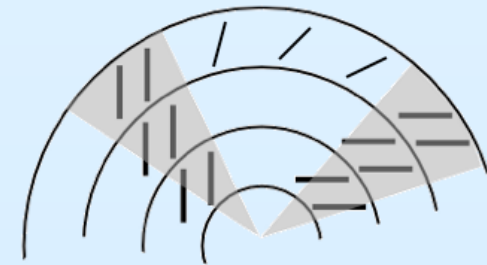
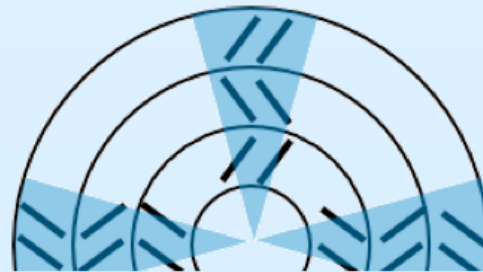
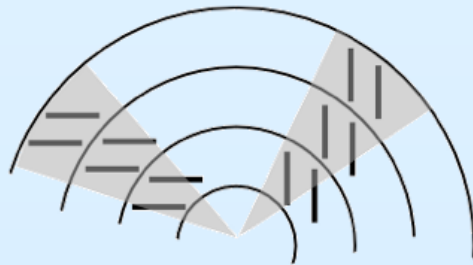
Birefringent Materials Give Interference Colors in the PLM

- ◆ All birefringent materials have something in common: They are all anisotropic
 - Piece of stretched plastic (**LC polymers** are a special kind of plastic which can have very special properties, like **kevlar**)
 - Mica crystal
 - Organic crystals
 - **Liquid crystals** - the only birefringent liquids
- ◆ The color you see is related to the birefringence (Δn) and the thickness of the sample (d)



Birefringence Color and Extinction Brushes

When the optic axis of the birefringent sample is parallel or perpendicular to the polarizer in the PLM, you see dark features known as extinction brushes



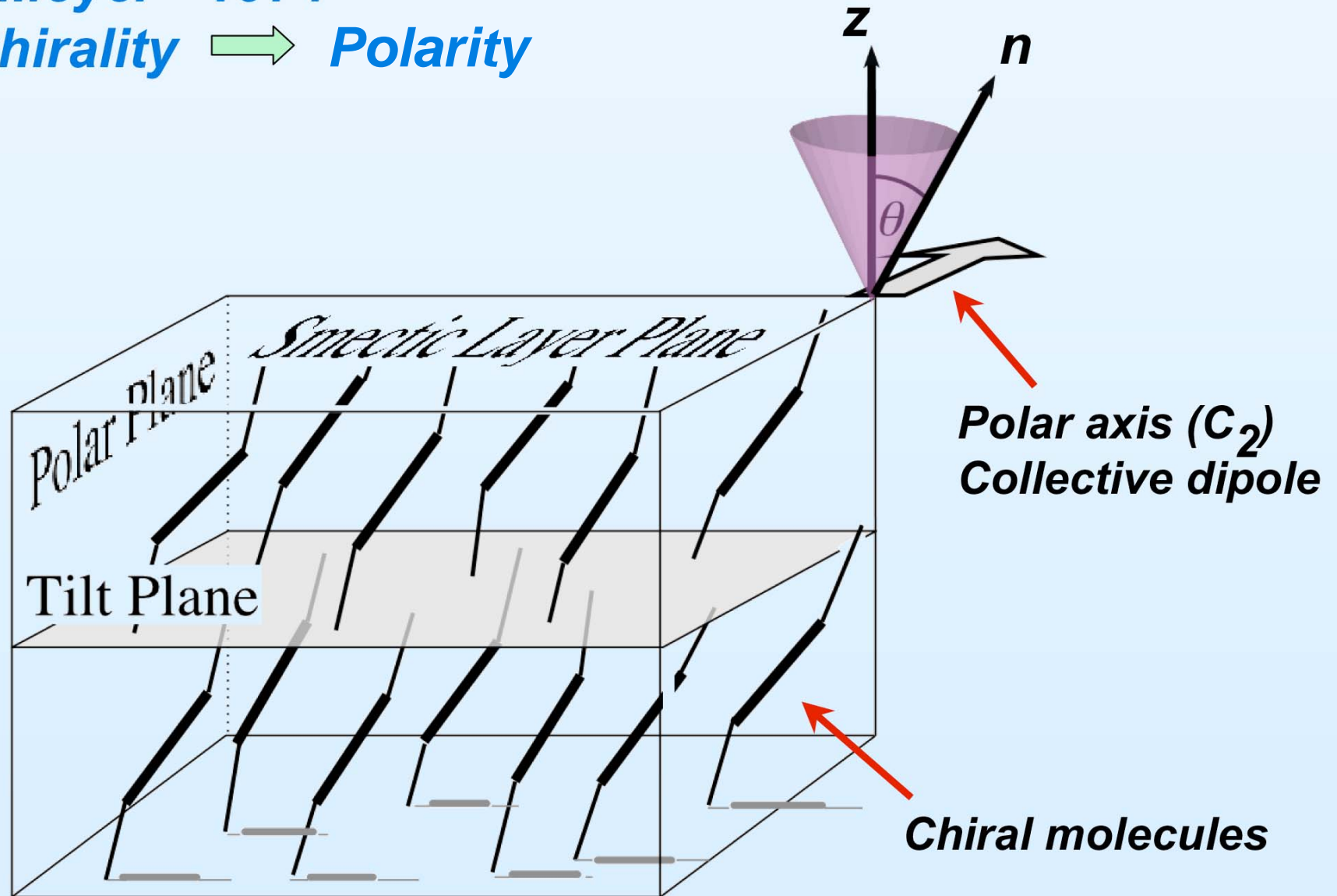
Electro-optics - Birefringence Changes and Brush Rotation



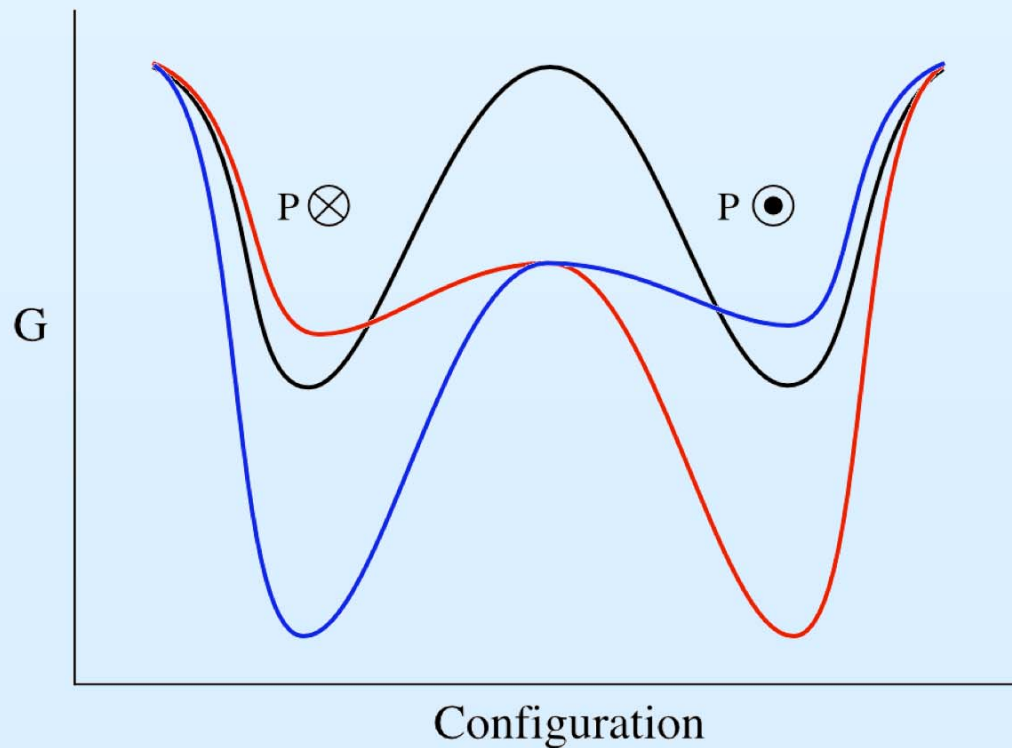
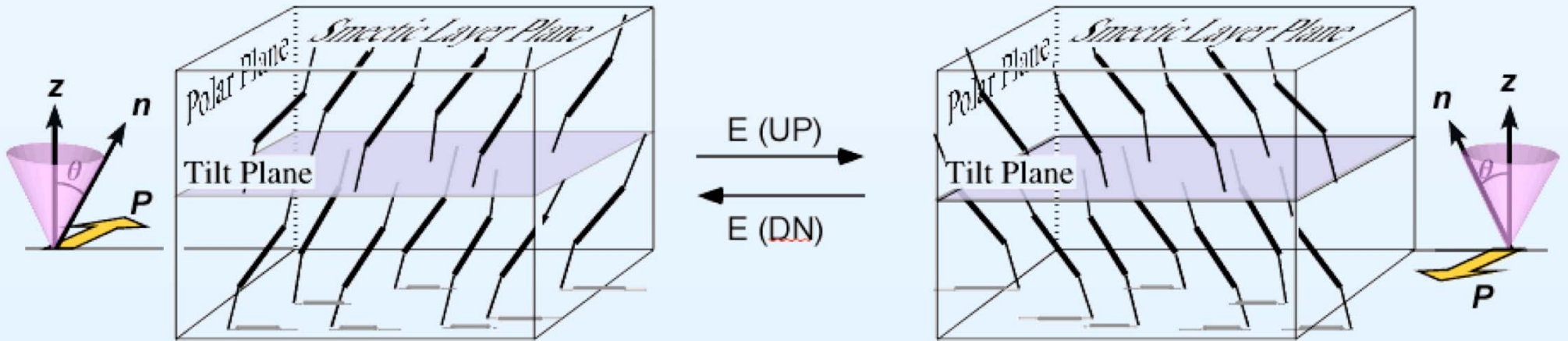
The SmC* Polar Fluid

Robert Meyer - 1974

Tilt & Chirality \rightarrow Polarity

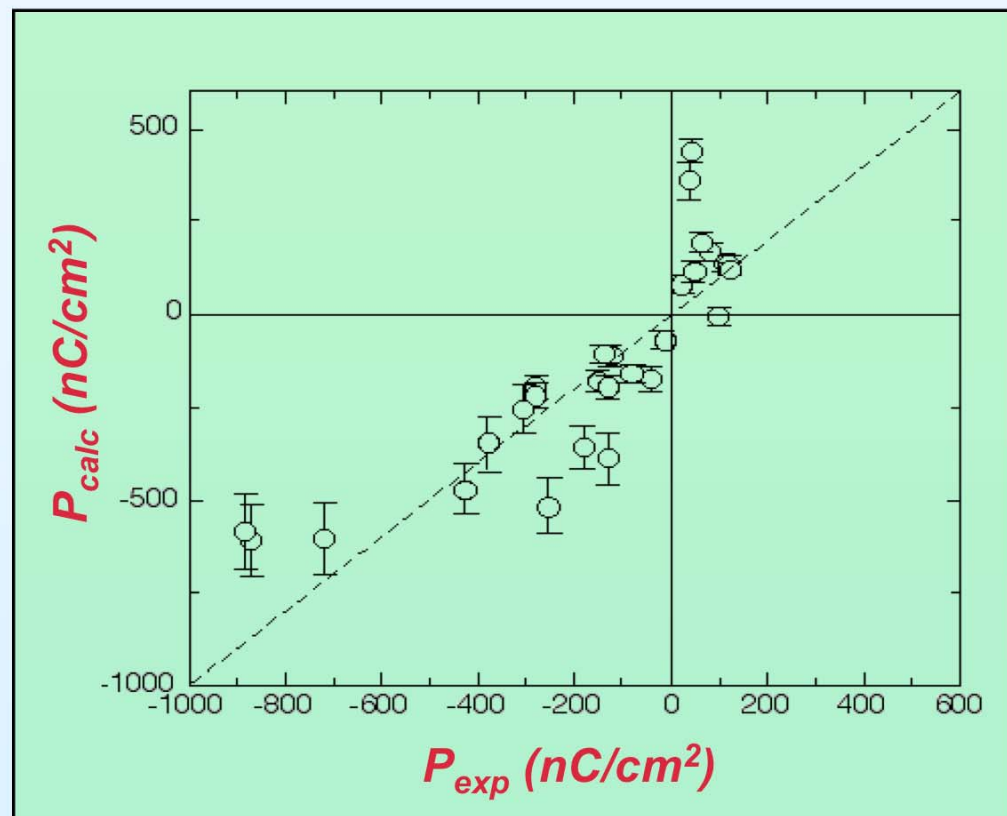
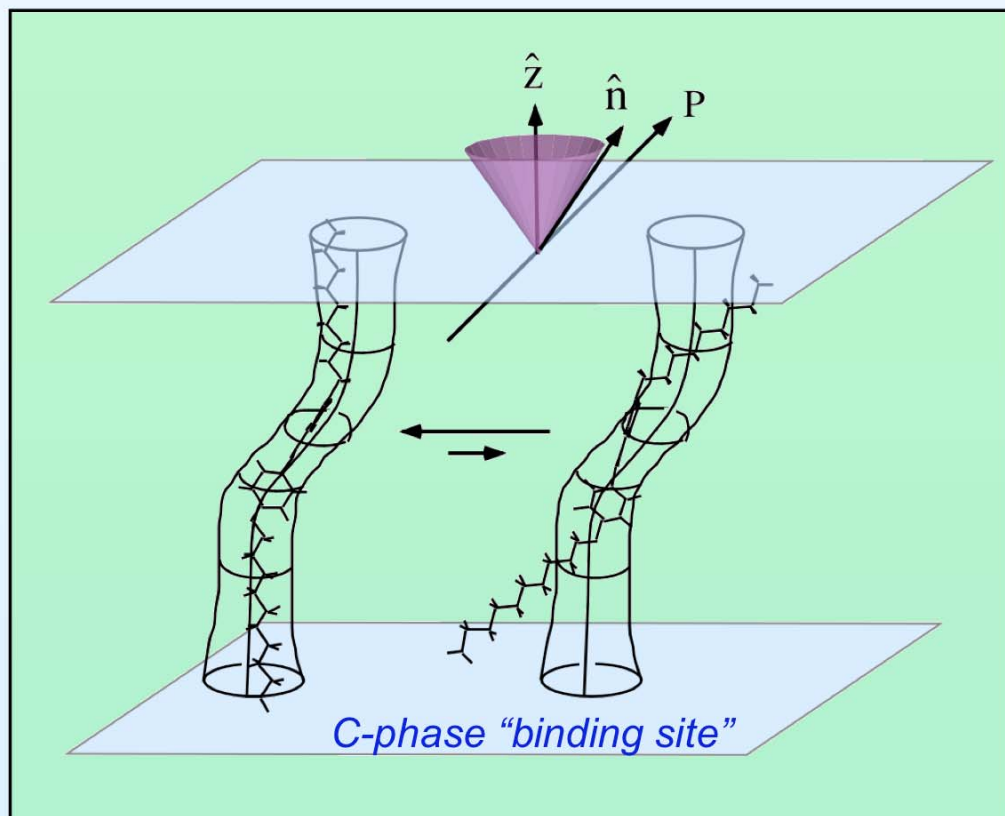


Between Glass Plates the SmC^* is Ferroelectric



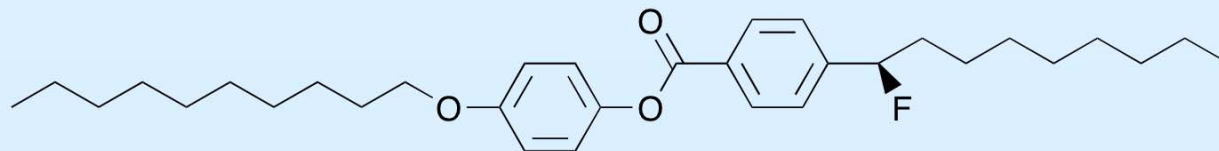
$$\tau = \frac{\eta}{P * E}$$

“Single Molecule in a Binding Site” Model for P



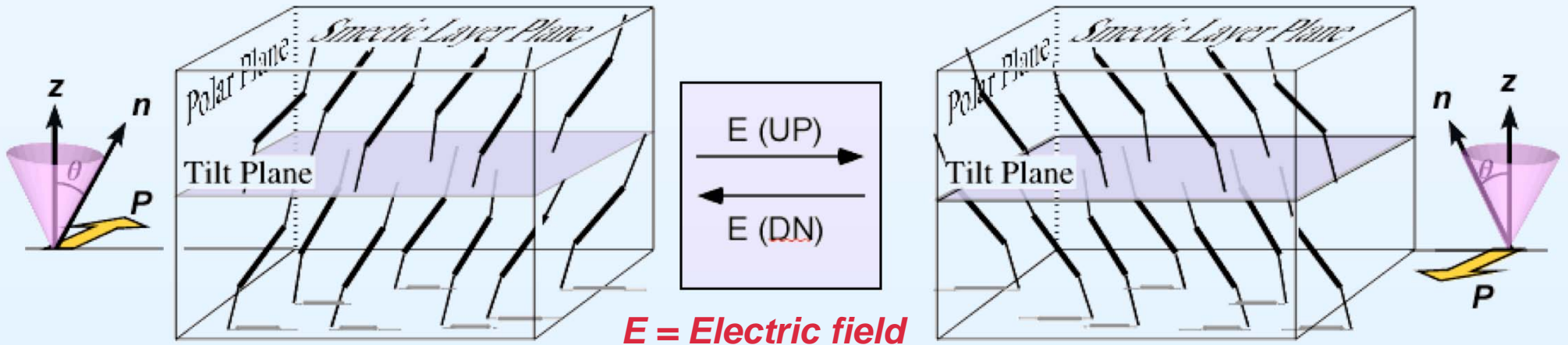
$$P = \sum_{i \text{ conformations}} P_i * D_i$$

$$P_i = \mu_i \langle \cos \alpha \rangle$$



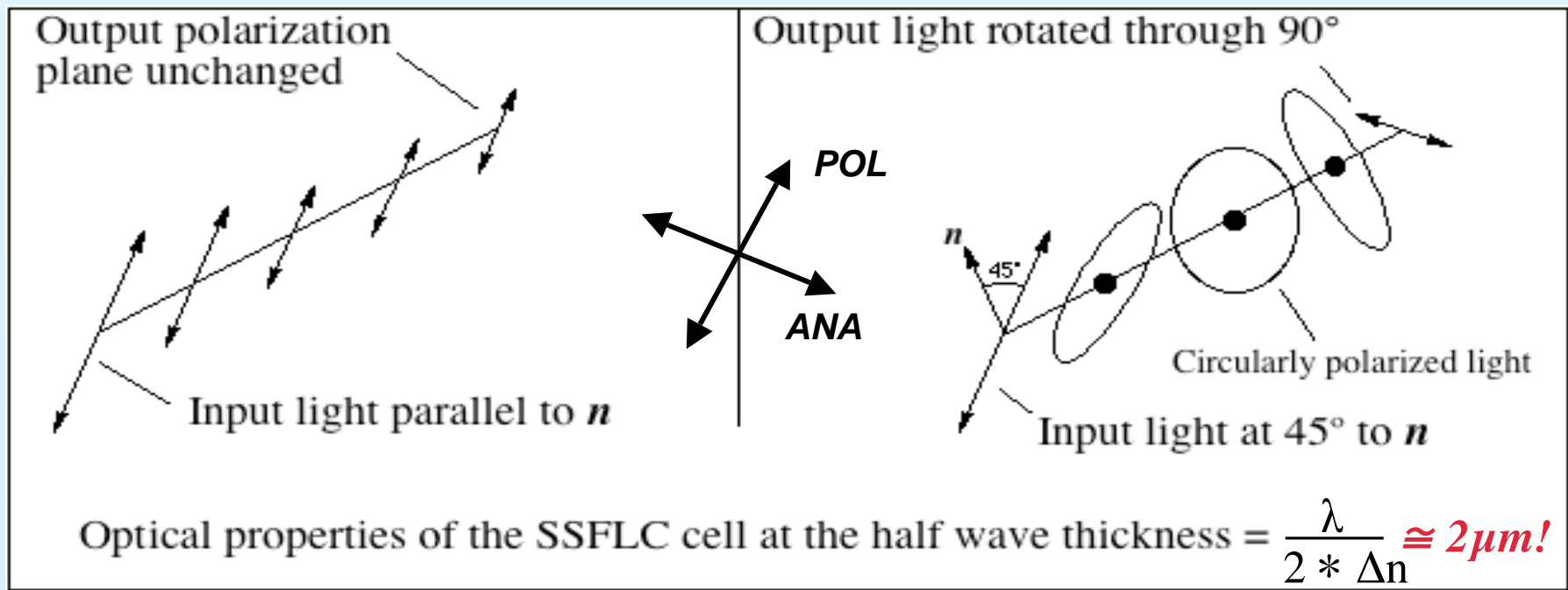
$P > 0 \Rightarrow (R) \text{ configuration}$

SSFLC Electro-optics

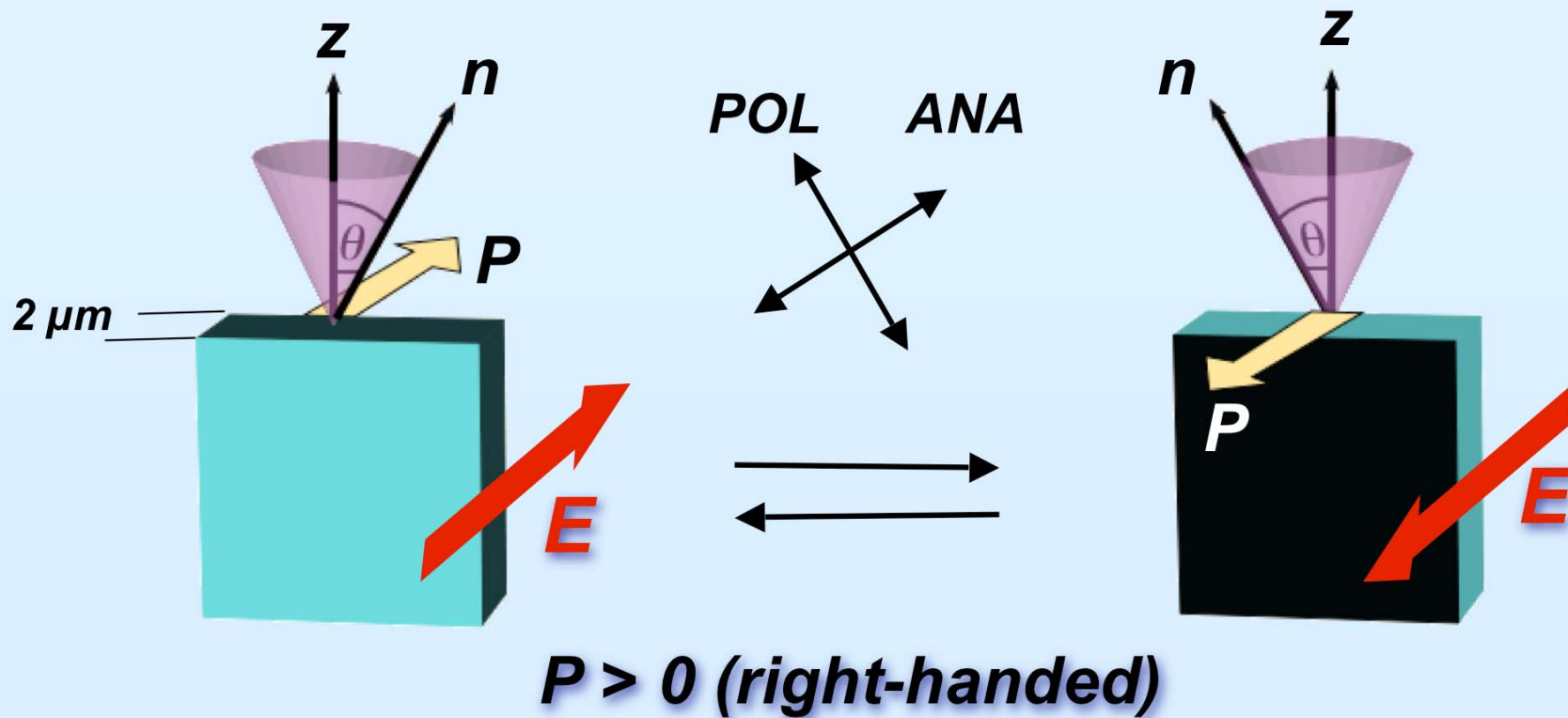
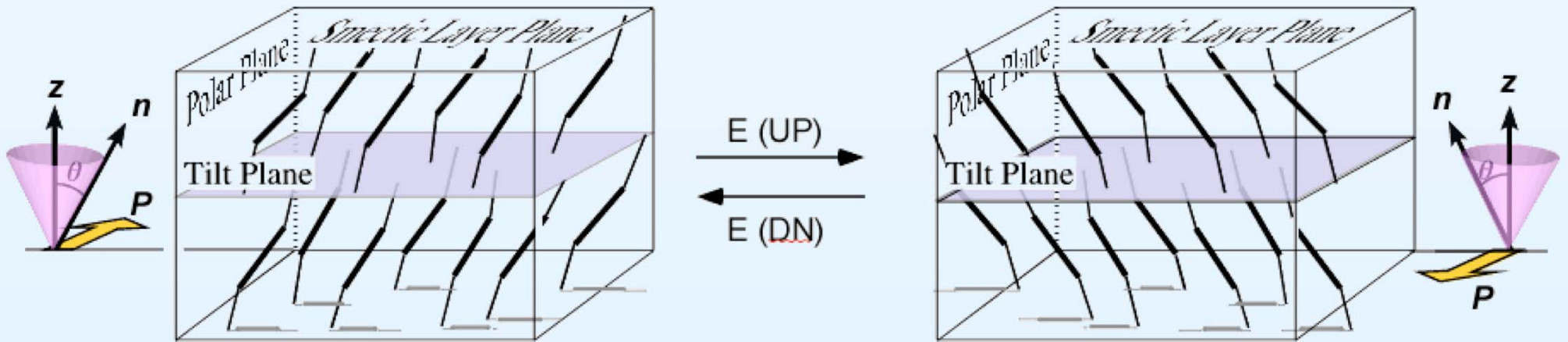


Dark State

Bright State

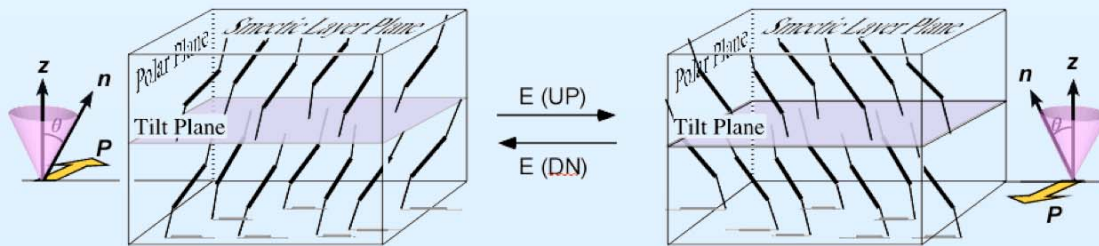


SSFLC EO is Unichiral

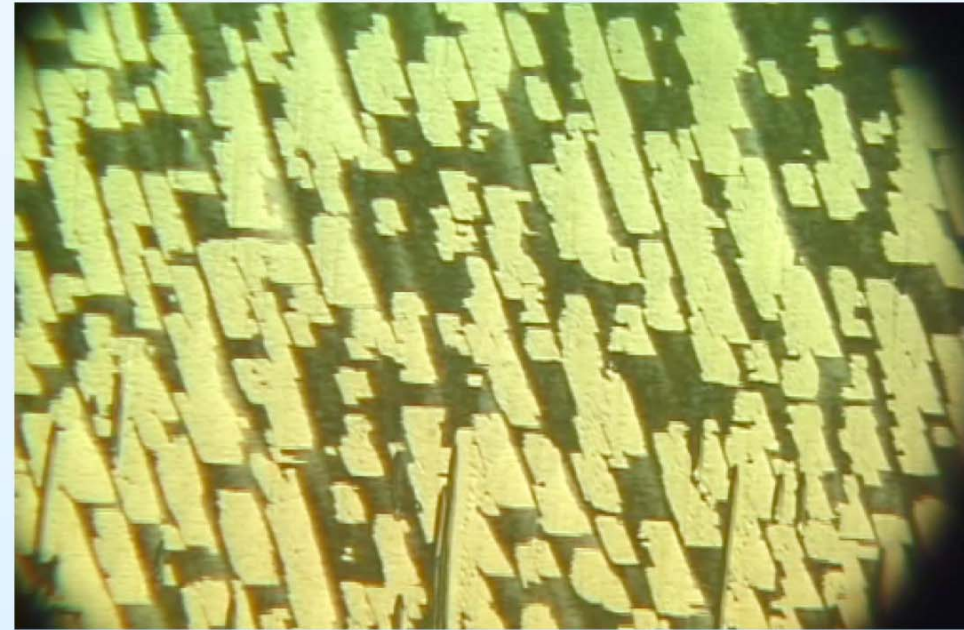


SSFLC Switching

**Bright and Dark
ferroelectric domains**

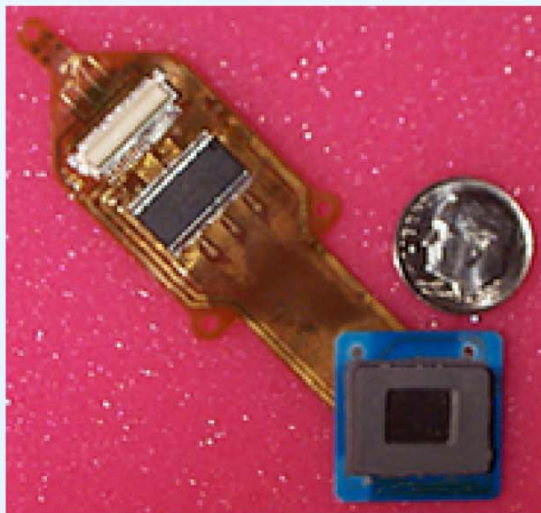


**Chiral EO response to an
applied triangular driving
waveform (the material has
a very small P)**



FLC on Silicon (FLCOS) Microdisplays

SSFLC on Silicon
Integrated
Optical
Chip



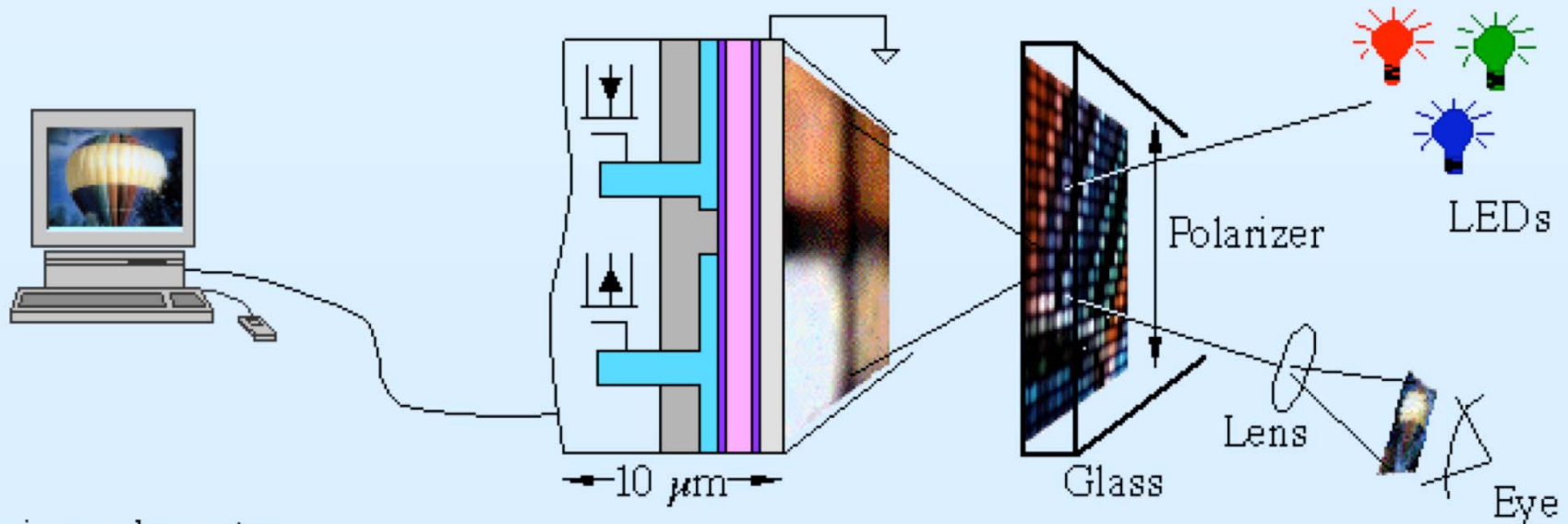
300K Channels
@ 10 KHz ~ 3 Gbits/sec



7 mm

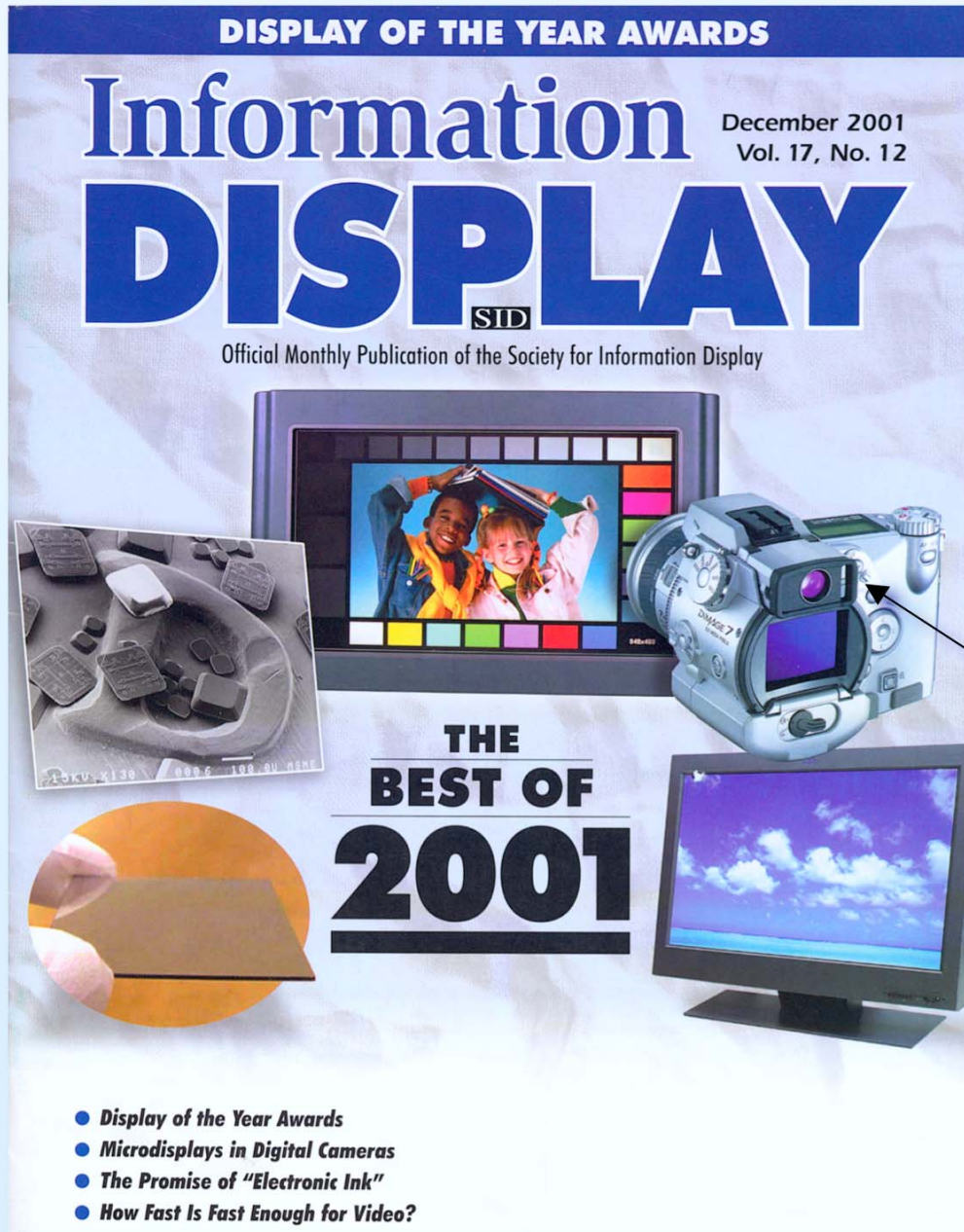


425 μ m



Photomicrographs courtesy
Displaytech, Inc.

Unichiral Electro-optics can be Useful

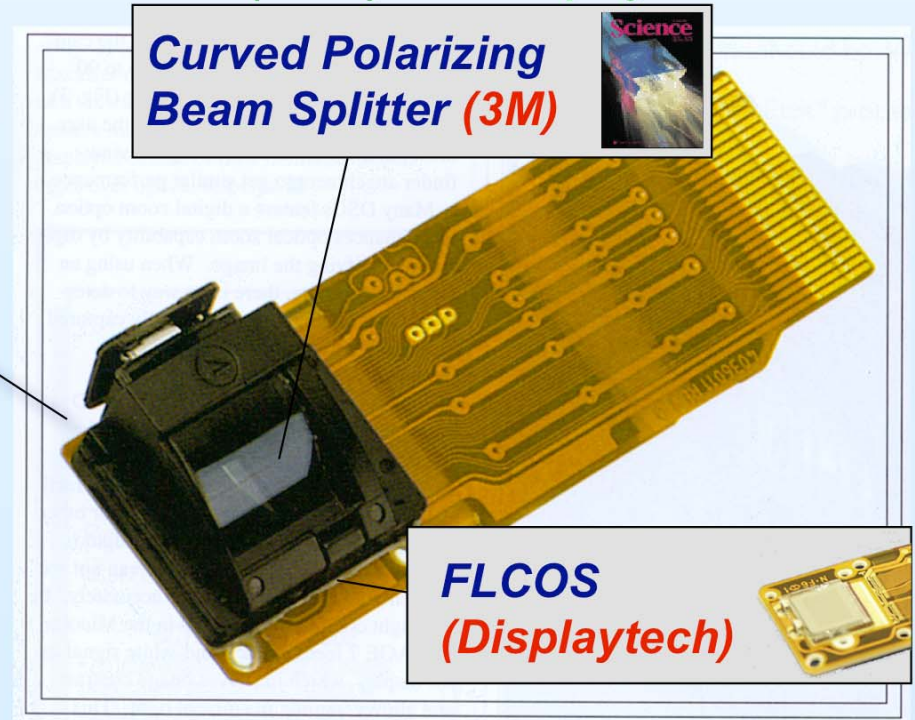


"Display Product of the Year

Gold Award:

Minolta's DiMAGE 7 Digital Still Camera

In its 5-Mpixel DiMAGE 7, Minolta Corp. has pioneered the use of a liquid-crystal-on-silicon (LCoS) microdisplay..."



8 Millionth shipped (Feb, 2005)

Displaytech/Samsung FLCOS HDTV

One 0.78" Displaytech FLCOS Chip for each color channel



Be the first in the U.S. to see Samsung's breakthrough technology -
FLCD HDTV!

SAMSUNG

High-Definition TVs

50" 16 x 9 wide

Only 18" Deep

Introducing a TV for the future that radically alters your notion of TVs of the past. Stunning brings you closer to life with the Tanta FLCD technology. So real, you can take a magnifying glass to its screen and all you'll see is picture - like a photograph. The secret to the Tanta FLCD's phenomenal clarity is a powerful combination of ferro-electric liquid crystal (FLCD) display panels and Samsung's FIRE optical technology. Together they create a razor-sharp, 720i high-definition viewer experience never EVER before seen in an ultra-compact, slim and lightweight design. Sporting of slim and lightweight, the heaviest of these TVs, the 50", weighs in at a mere 80 lbs and is only 18" deep. Your FLCD TV could protrude through a wall or even hang weightlessly from the ceiling. It simply fits the way you live. And it has all the features you've come to expect: Up-conversion System to HDTV, Dolby® Pro Logic, 3-D digital comb filter, MP Wide screen cinema format and 2-Tuner HD. The FLCD TV captures the future of television and delivers it to you in stunning simplicity.

HDTV
 HIGH-DEFINITION TELEVISION

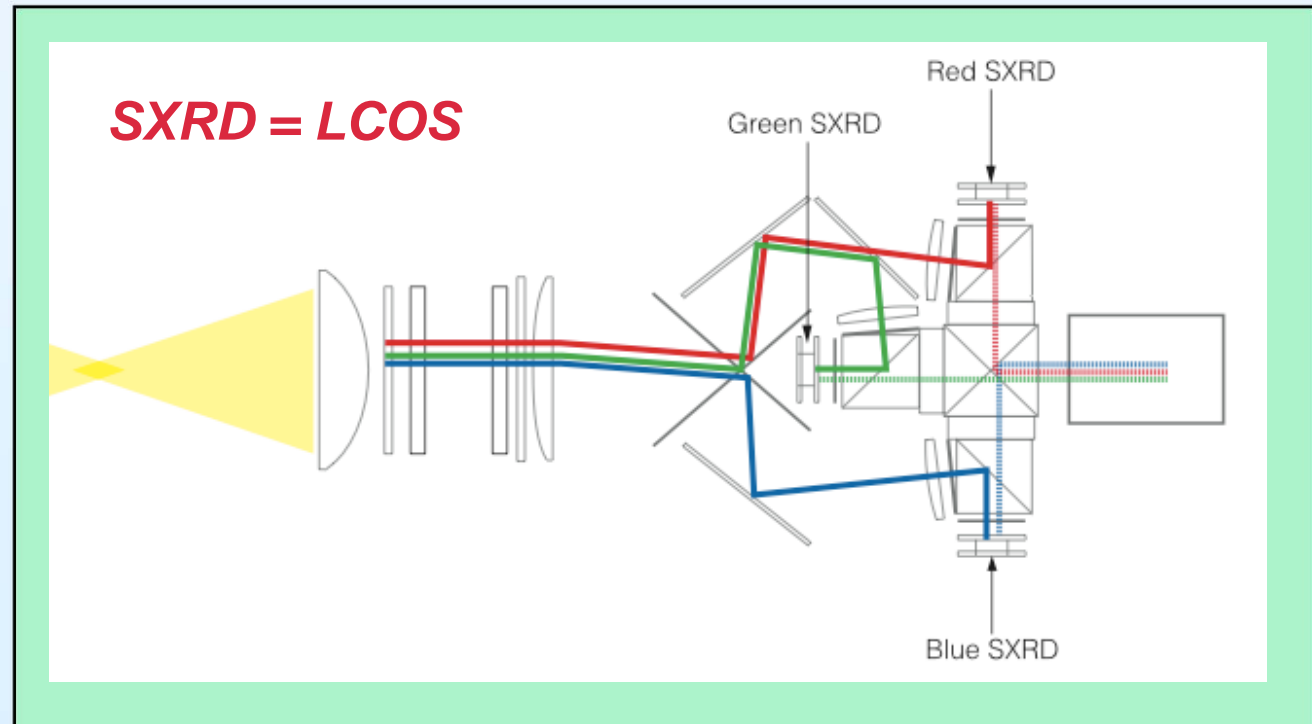
\$5999⁹⁵ ▲

The SAMSUNG 50" wide-screen FLCD HDTV-ready TV's streamlined form and highly functional technology captures the future of TV and delivers it to you in stunning simplicity.

- Forward Tanta FLCD optical system - produces 16:9 like picture
- Complete built-in DTV & HDTV compatible video source selector - capable of receiving any digital broadcast source
- NTSC to 720i Progressive Scan Lines up-conversion system - makes your TV look smoother and sharper
- 30-Watts 4 speaker Dolby® Pro Logic® audio system w/ Universal remote control
- 16:9 cinema format display & 2-Tuner picture-in-picture system
- Only 18" deep - perfect

Boulder SoundTrack brochure, Fall 2000
 Failed due to manufacturing problems

Sony VAN-LCOS HDTV - 2005



70" Rear-Projection 1080 p (!) HDTV @ ~\$10K
Vertically-Aligned Nematic LCOS
Apparently shipping in US as of June 2005

A Liquid Crystal Conglomerate?

- ◆ *Next time - the liquid crystal version of the most famous experiment in organic stereochemistry!*

