

Alternation of Alignments in Thin Cells Made by Overlaying Channels

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Outline

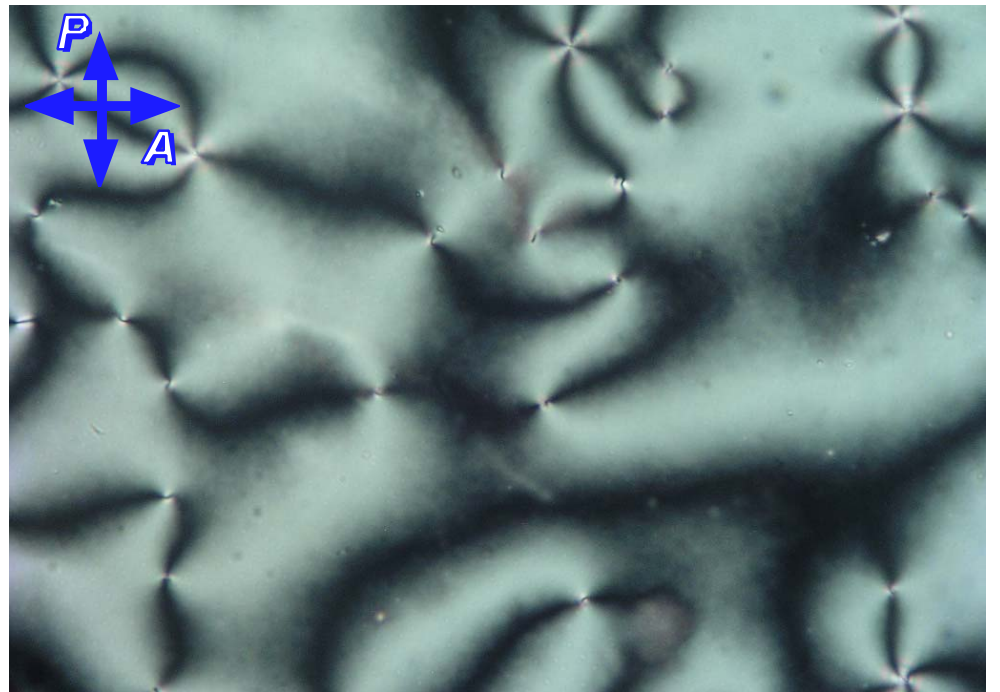
- Introduction
- Theory of liquid crystal alignment
 - Berreman's Theory
 - Beyond Berreman's Theory
- Nanoimprint
- Alignment of a smectic LC confined by overlaid channels
 - Uniform alignment in a relatively thick cell
 - Alternating alignment in a thin cell
- Summary

Defects in a Nematic LC Cell

A **depolarizing transmission optical microscope** image of a nematic liquid cell typically shows defects.

Bright area: director is in nearly diagonal directions

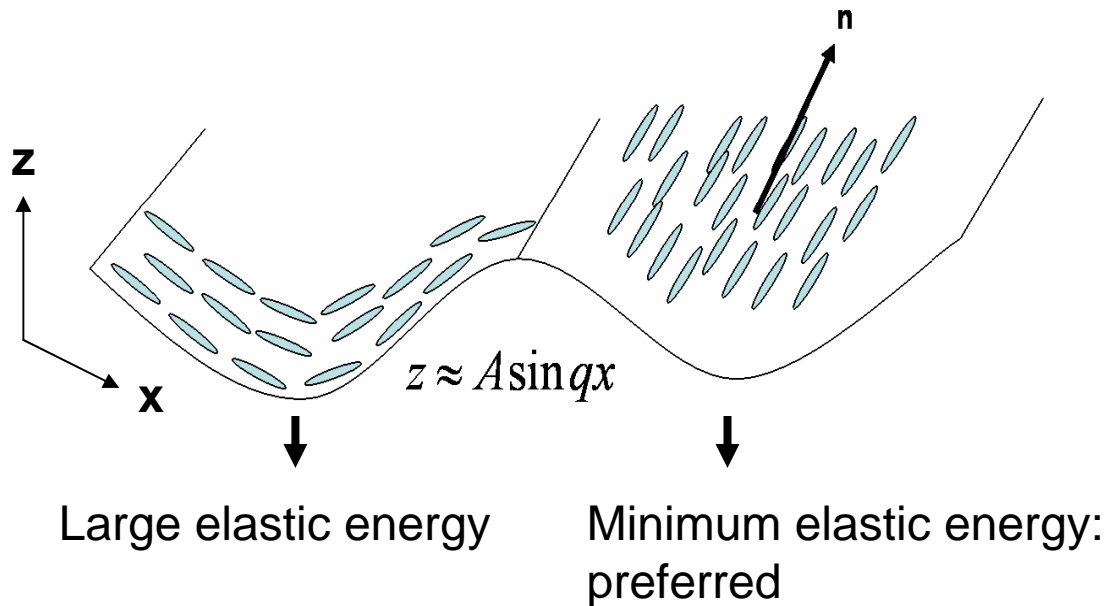
Dark area: director is nearly parallel or perpendicular to the analyzer.



~250 μm

Schlieren texture of 5CB in a glass cell coated with GLYMO

Berreman Theory



Assumptions

1. Sinusoidal surface with small Aq ($\ll 1$)
2. Infinite polar anchoring (director on the surface)
3. $K=K_1=K_3$
4. No azimuthal distortion of directors

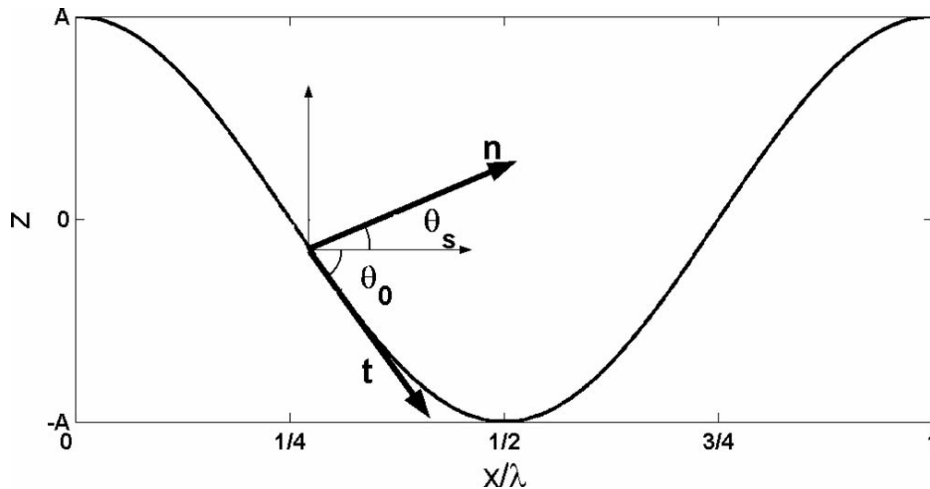
surface elastic energy: $\frac{1}{4}k_3 (Aq)^2 q$

k_3 : bend elastic constant

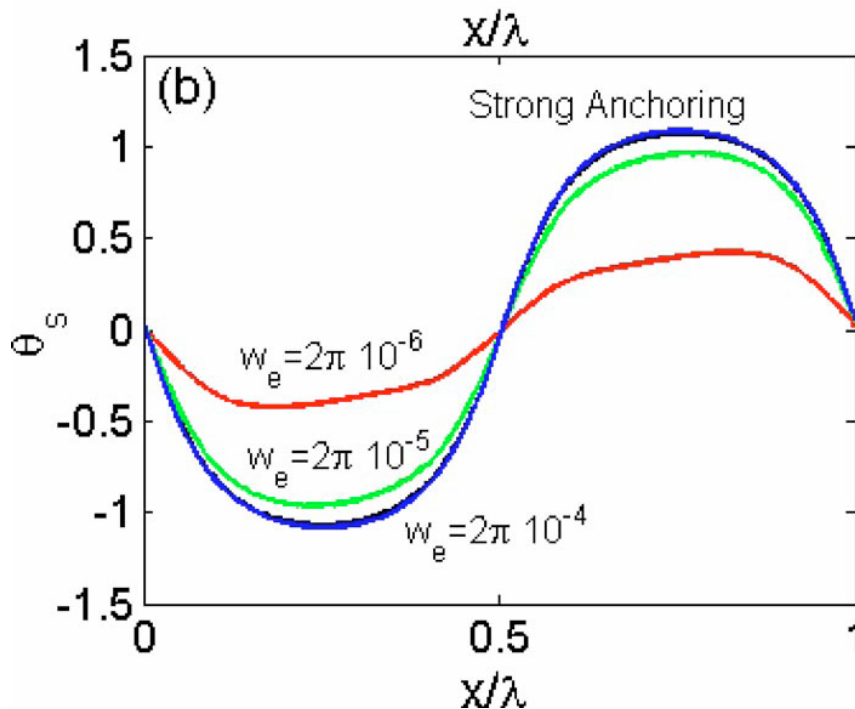
q : wave vector ($2\pi/\lambda$)

To minimize elastic energy, LC align parallel to the grooves

Beyond Berreman Theory (Finite anchoring with large Aq)



Profile of the surface
and definition of θ_s



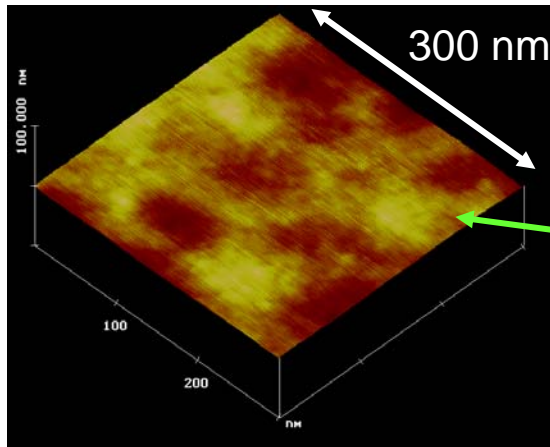
Distribution at equilibrium of the tilt
angles on the surface for different
values of the anchoring energy.

$Aq=1.9$.

Nanoimprinted Polymer Replica

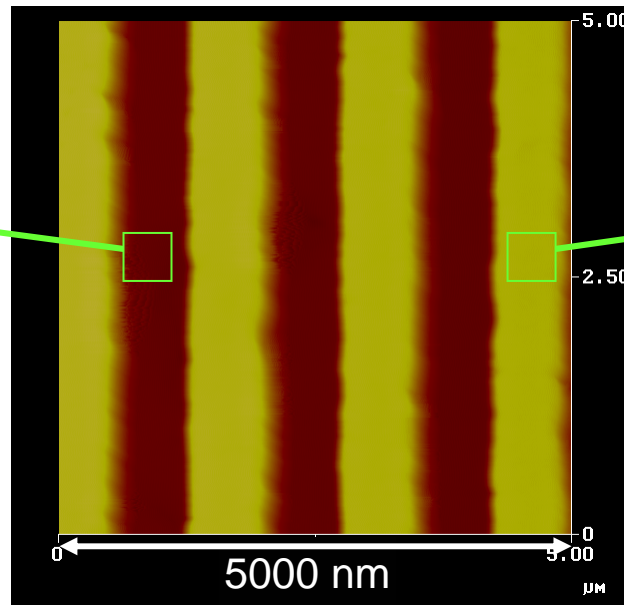
- **Mold:** e-beam writing and reactive ion etching on fused silica substrates
- **Polymerizable Materials:** UV-curable material: Thiol-ene (~ planar, Polar anchoring energy: $9 \times 10^{-5} \text{ J/m}^2$)

AFM image of a replica of a line pattern: period $1.5 \mu\text{m}$, height $0.5 \mu\text{m}$

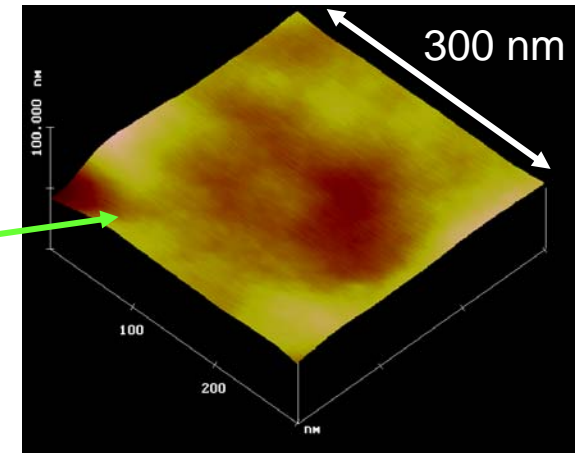


Trench

Roughness: 1 nm



Period 1500 nm, Height 480 nm

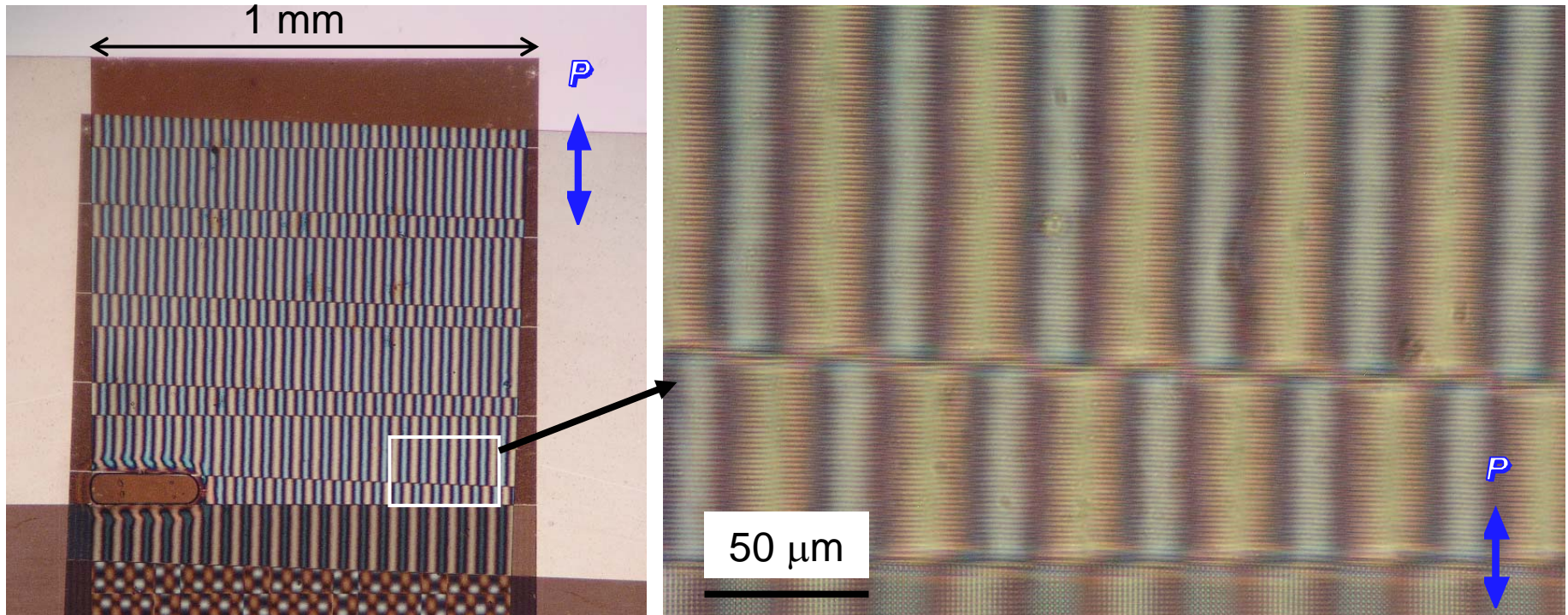


Ridge

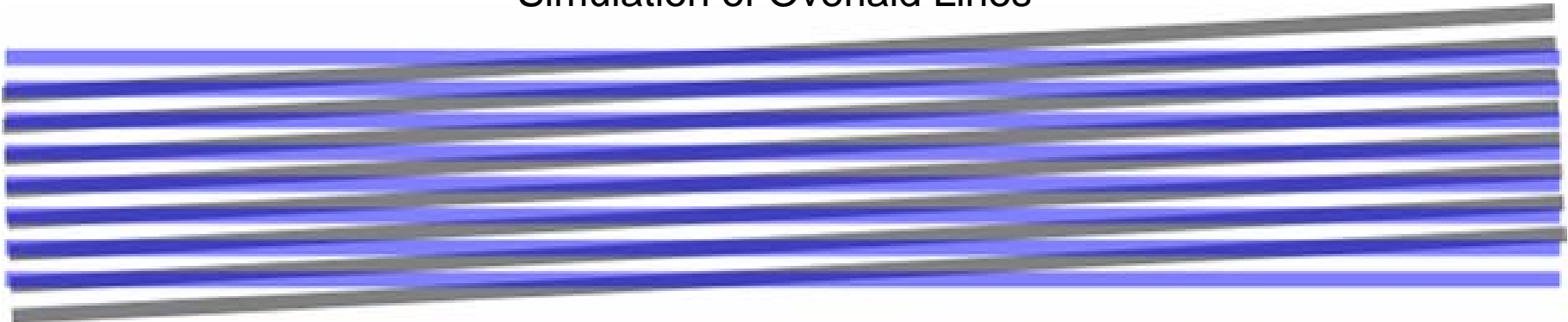
Roughness: 2 nm

The polar anchoring energy at the ridges will be smaller than at the trenches

Overlaid Empty Cell and Moiré Pattern

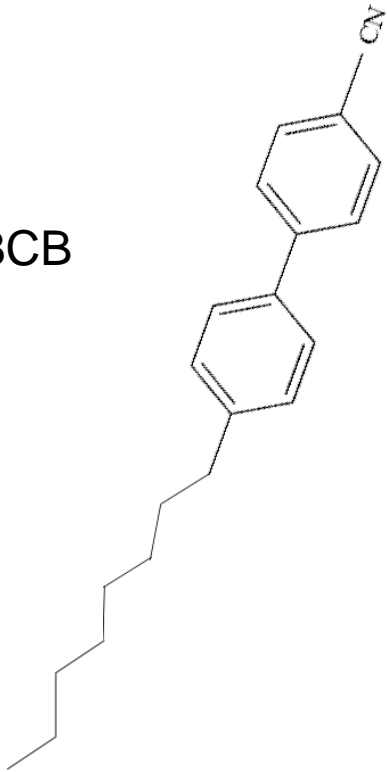


Simulation of Overlaid Lines



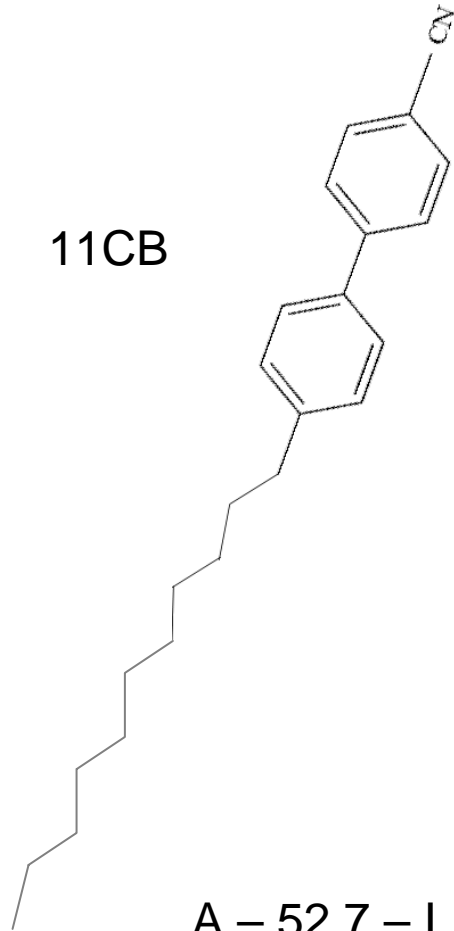
Smectic Liquid Crystals

8CB



A – 33.5 – N – 40.5 – I

11CB

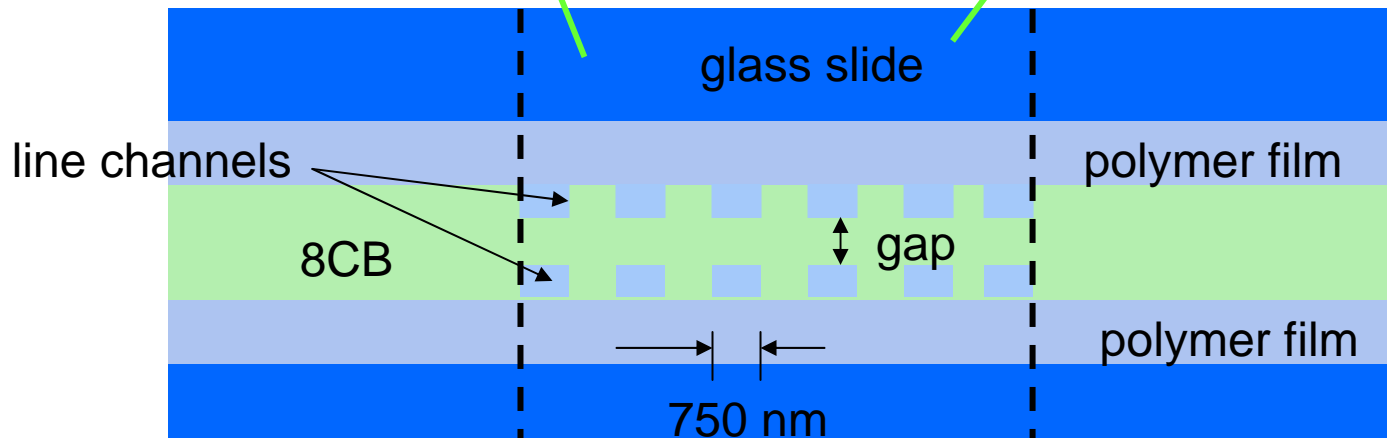
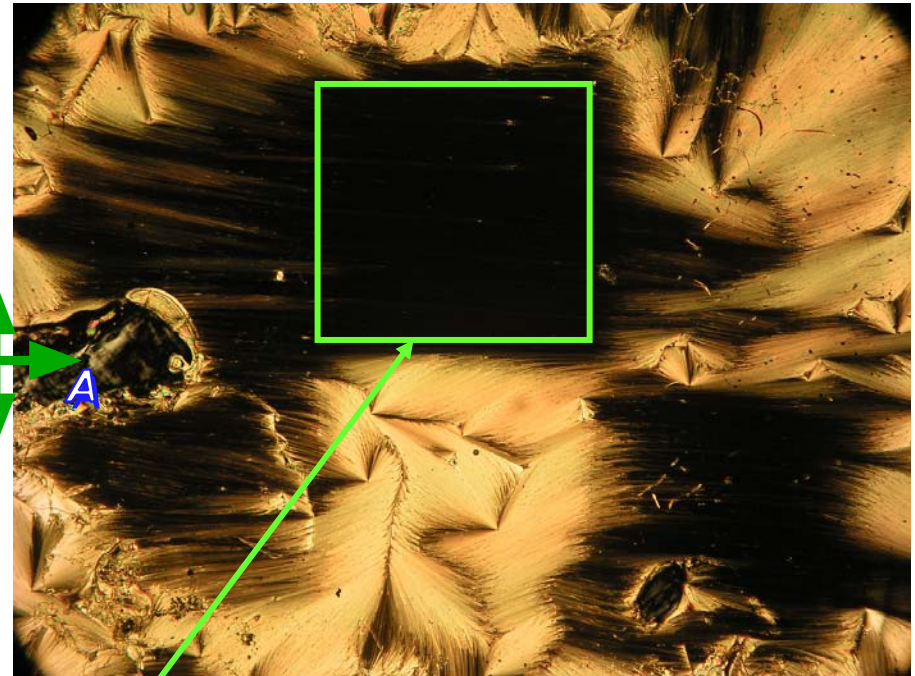
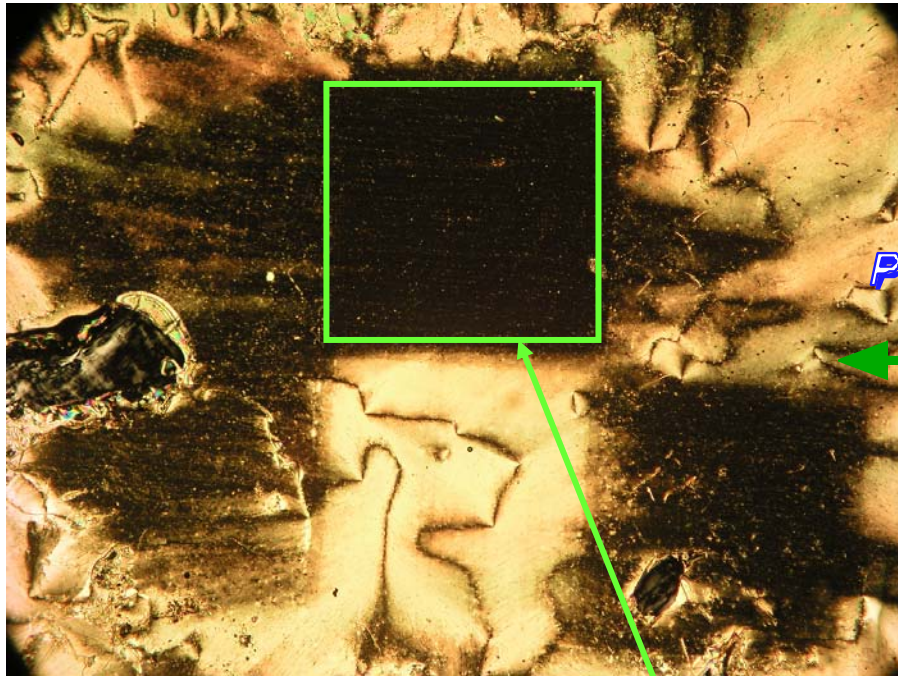


A – 52.7 – I

Overlaid 8CB (I-N-A) Cell

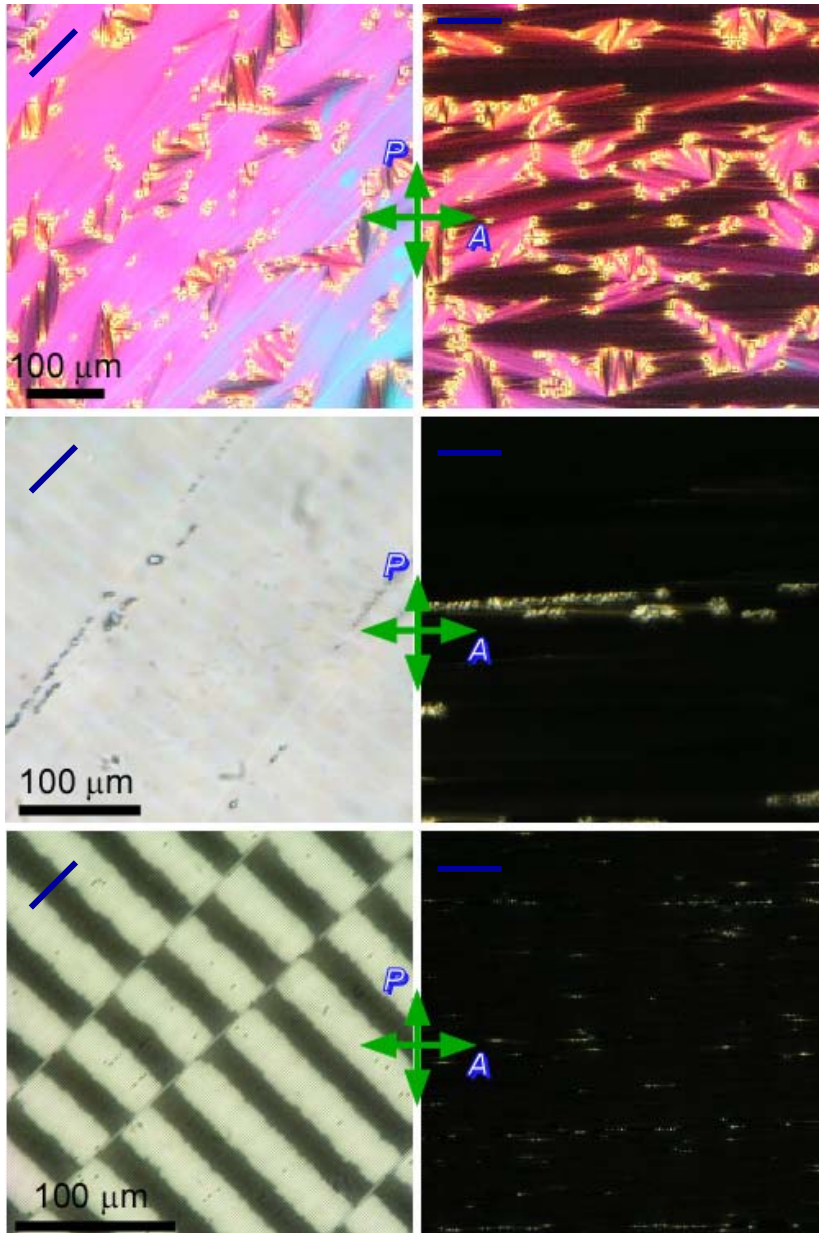
nematic

smectic



Overlaid 11CB (I-A) Cells with Various Thicknesses

Blue lines represent channel directions

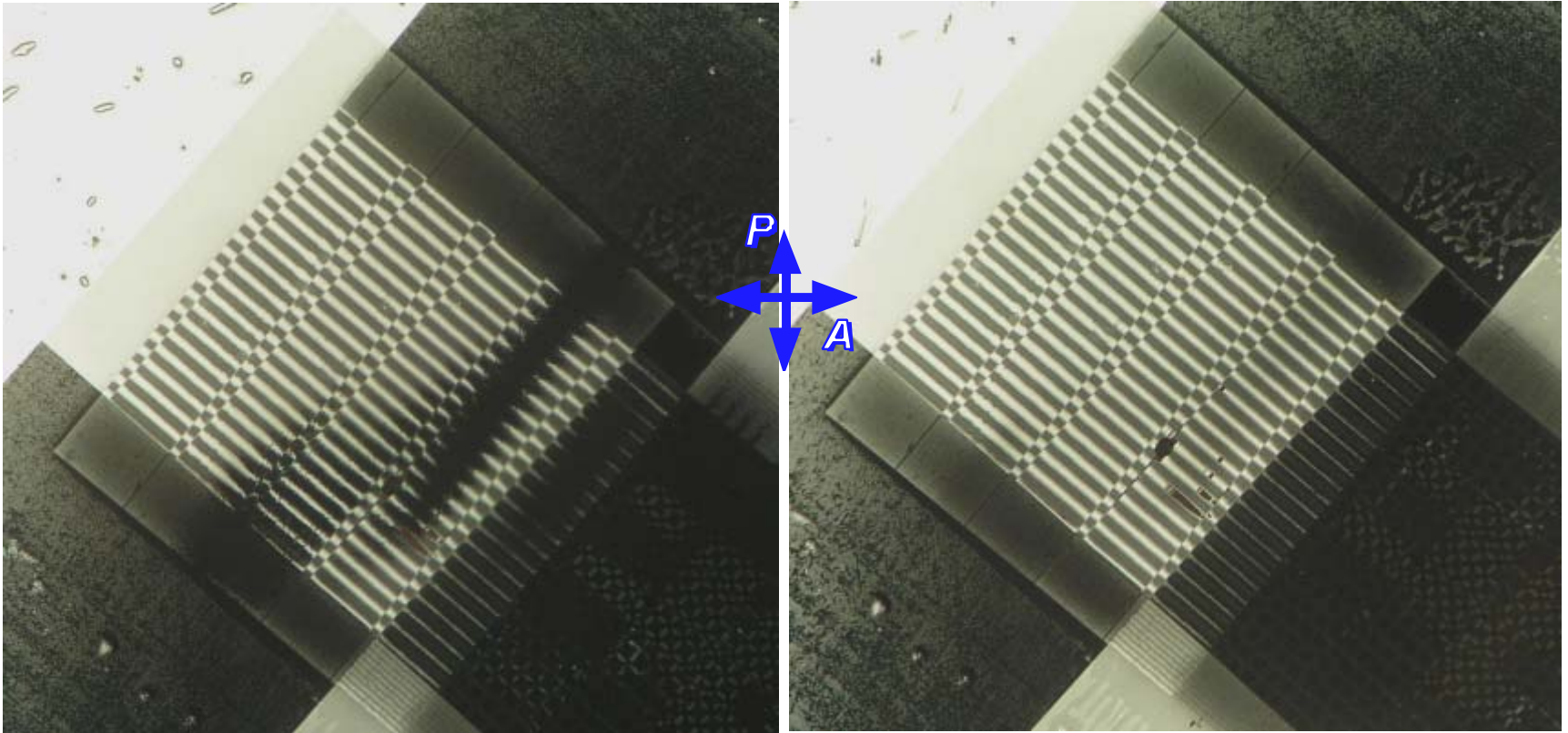


Retardation ($\Delta n d$)	Average thickness (gap)
697 nm (thick)	4100 nm (3620 nm)
196 nm (medium)	1153 nm (673 nm)
99 nm at bright bands	582 nm (102 nm)

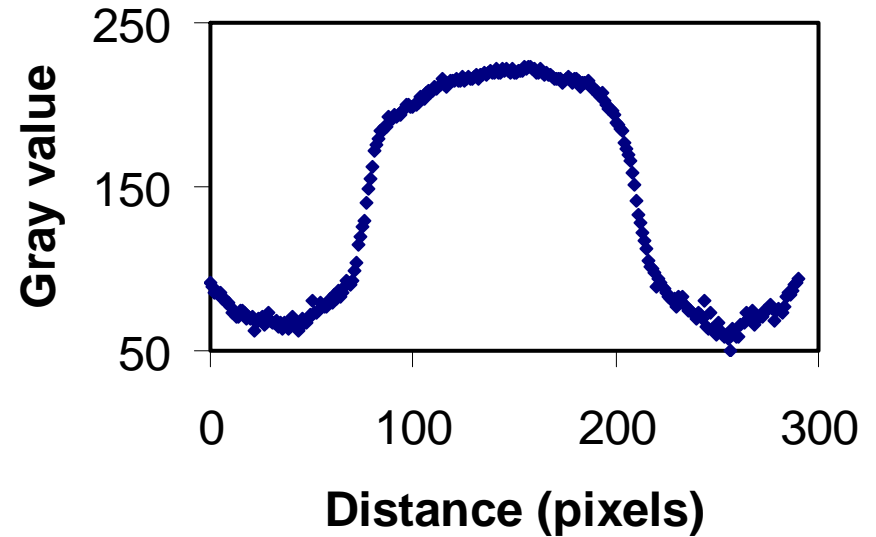
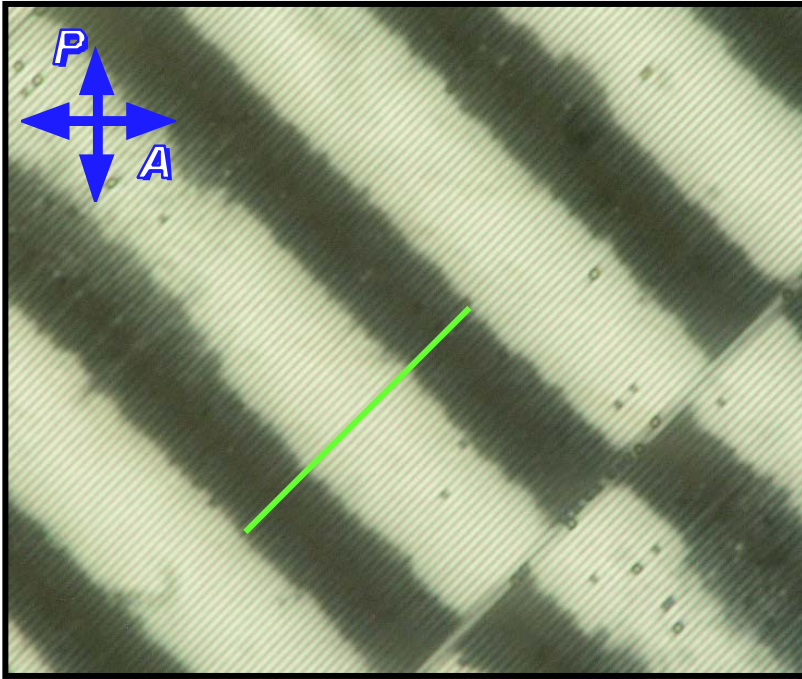
Overlaid Thin 8CB (I-N-A) Cell

Nematic

Smectic



Contrast between the two bands



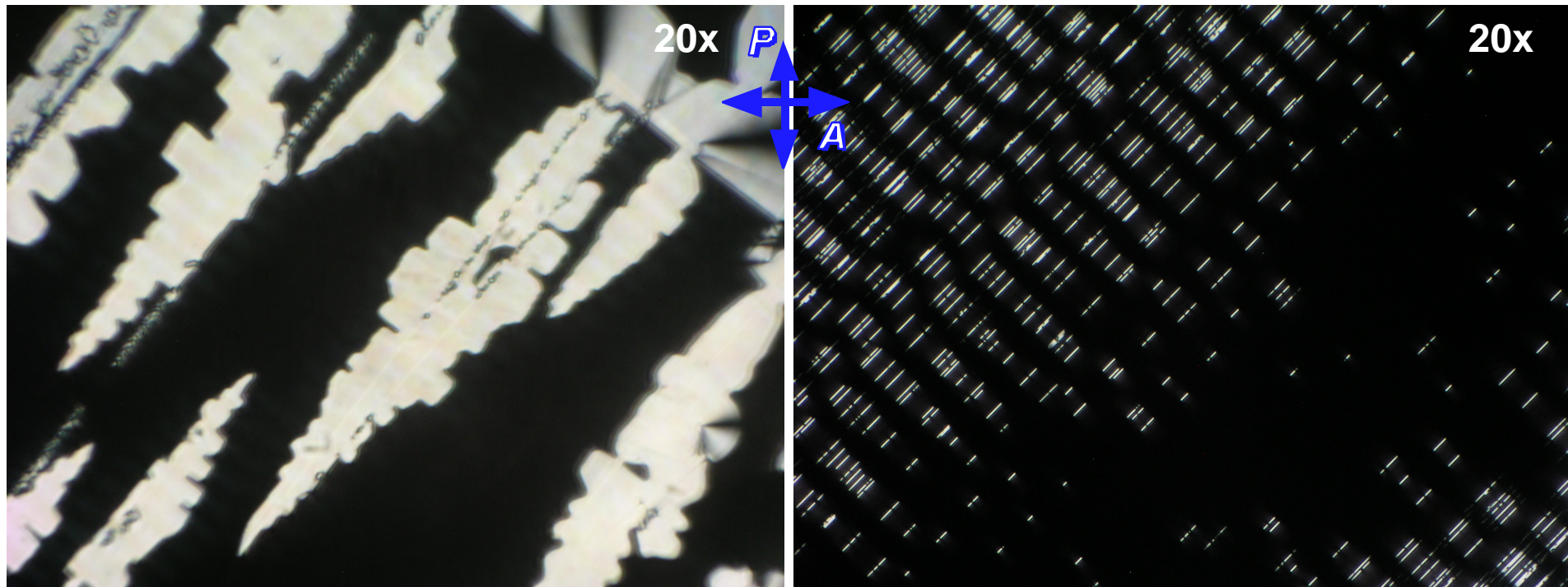
Gray value profile align the green line in the left picture

Contrast: 4

I-SmA Transition of an Overlaid 11CB Cells

Medium thick cell

Thin cell

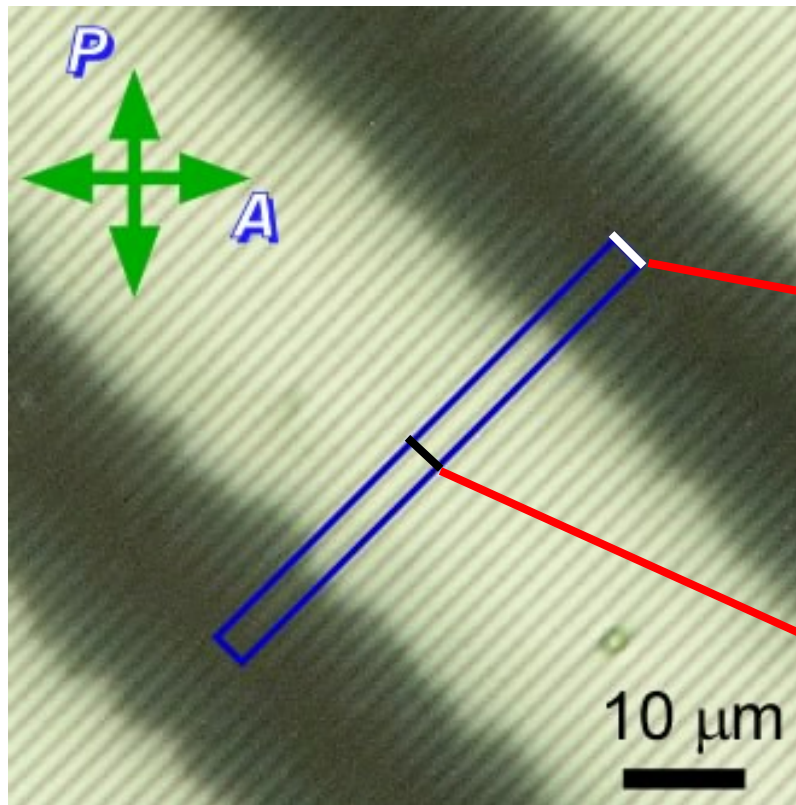


Continuous growth

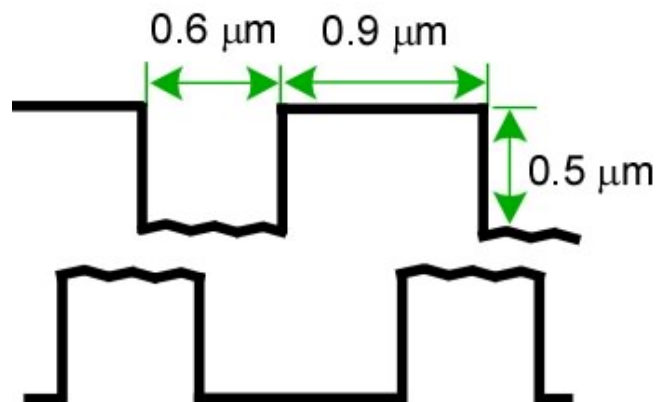
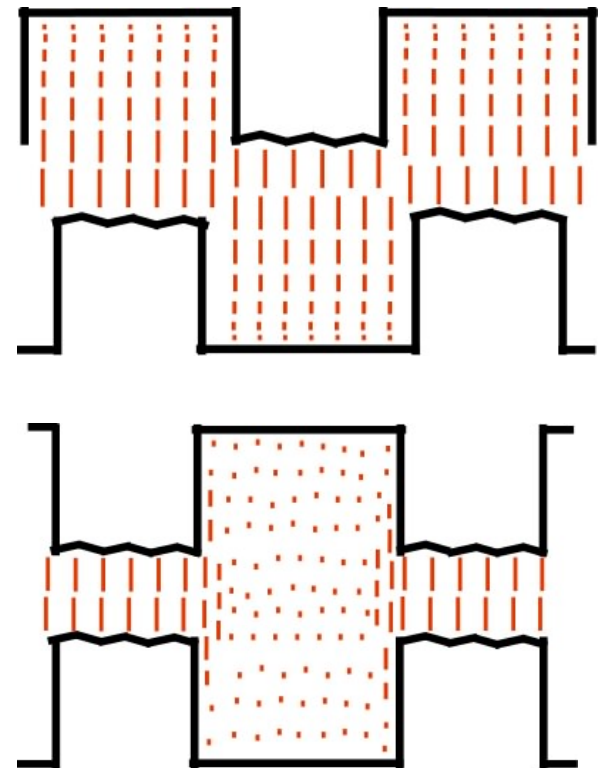
Scattered and interrupted growth

For the thin cell the smectic growth is hindered by the alternation of ridges and channels, indicating heterogeneous organization of molecules.

Organization of LCs in the Overlaid Thin Cells



Cross section views of director fields



At the ridges, homeotropic organization is promoted due to large Aq ($=2$) and rougher surface.

Summary

- Topographic line patterns align rod-like nematic and smectic liquid crystals.
- Details of surface properties such as roughness and wetting become more important as the cell becomes thinner.
- Alternation of the alignment of the thin overlaid cells is caused by reduced polar anchoring energy at a rougher part and large Aq value of the channel.

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Overlaid Thin 11CB Cells

Identifying positions of the dark and bright bands

