Soft Matter Physics
SCHOOL OF PHYSICS AND ASTRONOMY

UNIVERSITY OF LEEDS

Help! Some potential mathematical problems from an LC device physicist

Professor Cliff Jones, FREng, FInstP, FRSC, FRSA

EPSRC ADVANCED MANUFACTURING FELLOW

History as Display Scientist

Thirty years in industry; Five years in Academia

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1985-2000

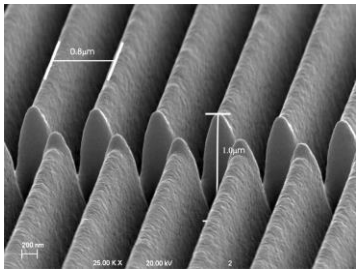
HDTV with Sharp

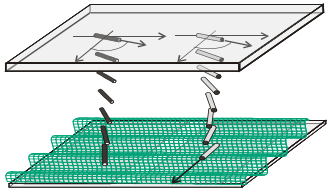
Holographic Displays with Ford

DERA

QinetiQ

2000-2013



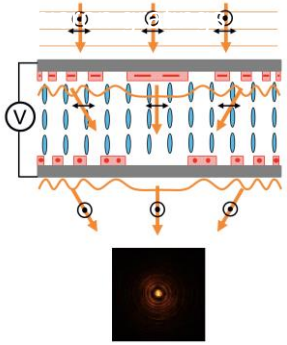


Gratings in LCD

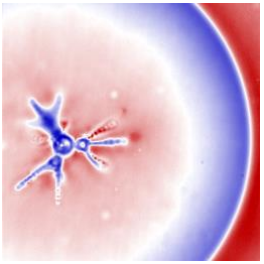
zbd.

Displaydata

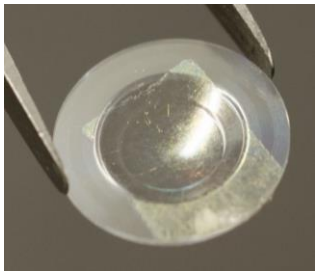
2014-2019



Embossing of birefringent optics: Polarisation independent lenses



Fractal Droplets and Droplet Sensors



Switchable Contact Lenses

MERCK

EPSRC
Engineering and Physical Sciences Research Council

DynamicVisionSystems

Leeds LCD Fabrication facilities

Application of soft materials to electronic / photonic devices

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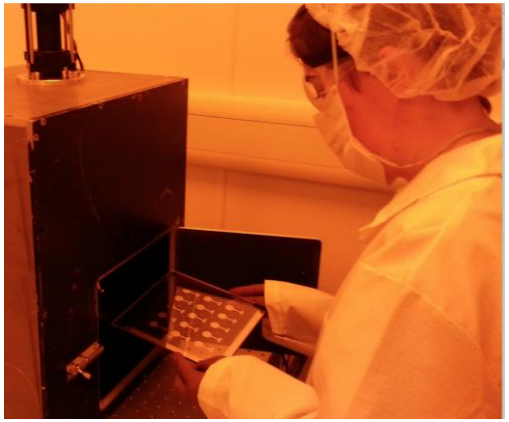

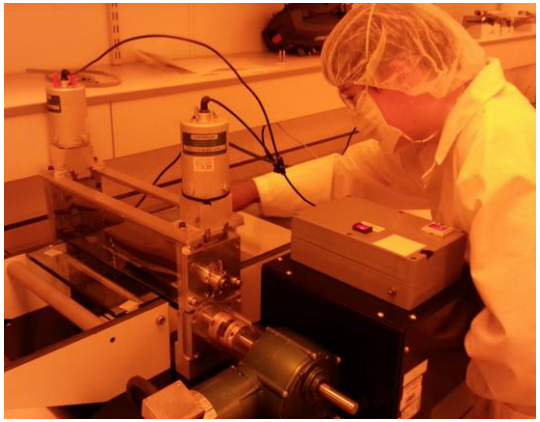

Facilities include:

- Ink-jet, screen and 3D printing
- Embossing
- Photolithography and holography
- Direct Writer Laser
- Silane vapour and vacuum deposition

Soft Matter projects include:

- Liquid Crystals
- Electro-active polymers
- Colloids and NP
- Microparticles

Overview

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1 Optimising the Zenithal Bistable Device

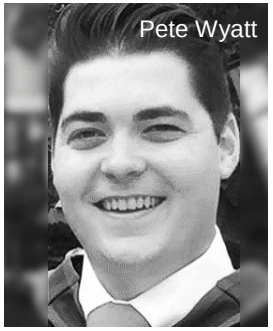
- Defect Dynamics
- Diffusion and entropy of topological defects

Displaydata

UCL

2 Confinement of smectic liquid crystals

- FLC with surface relief gratings
- Biaxial SmA_P



ZBD : Bistable grating alignment

Flexoelectric effect and topological defects

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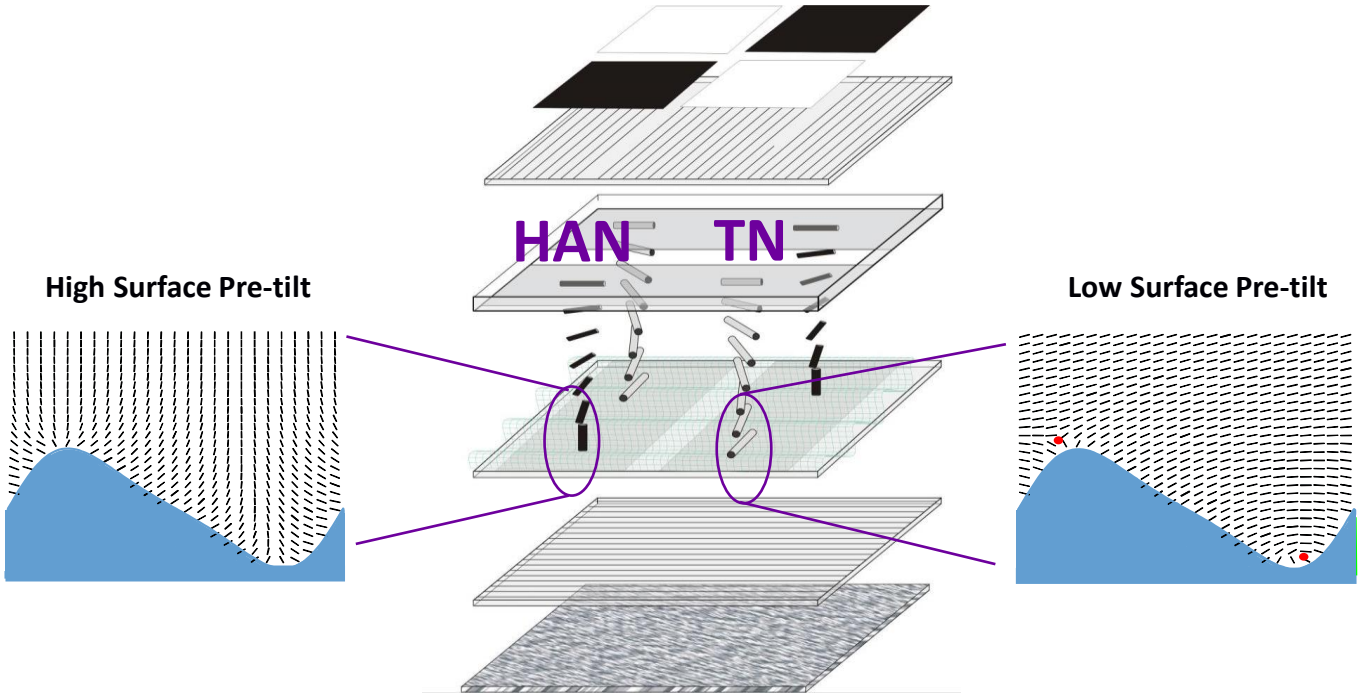
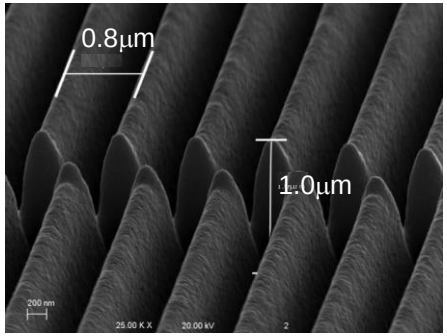
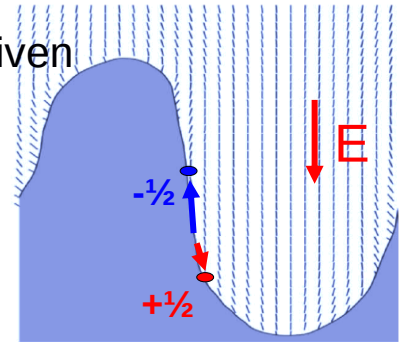


Deep Homeotropic Grating



Flexoelectric driven disclinations



Defects in D-C latching

Defect annihilate to form Continuous State

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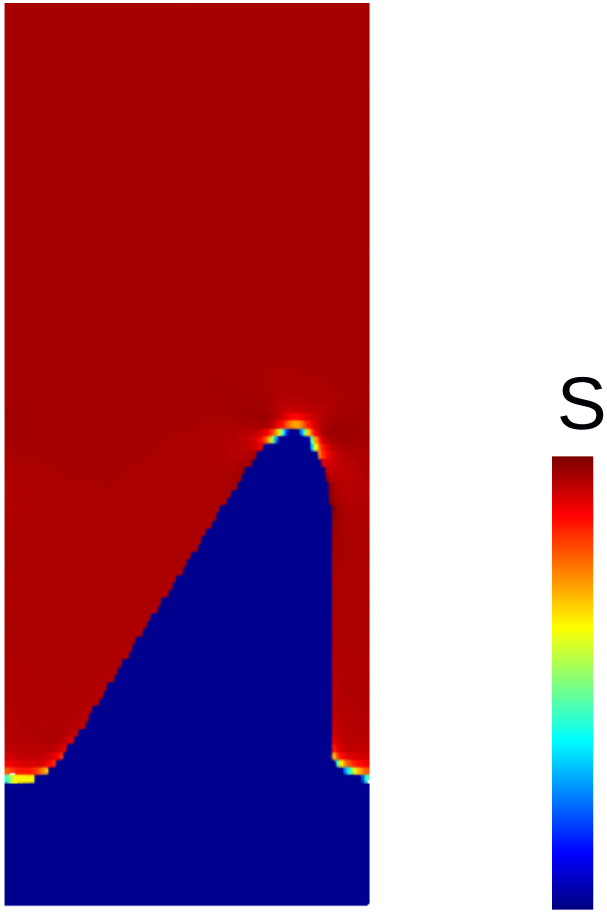

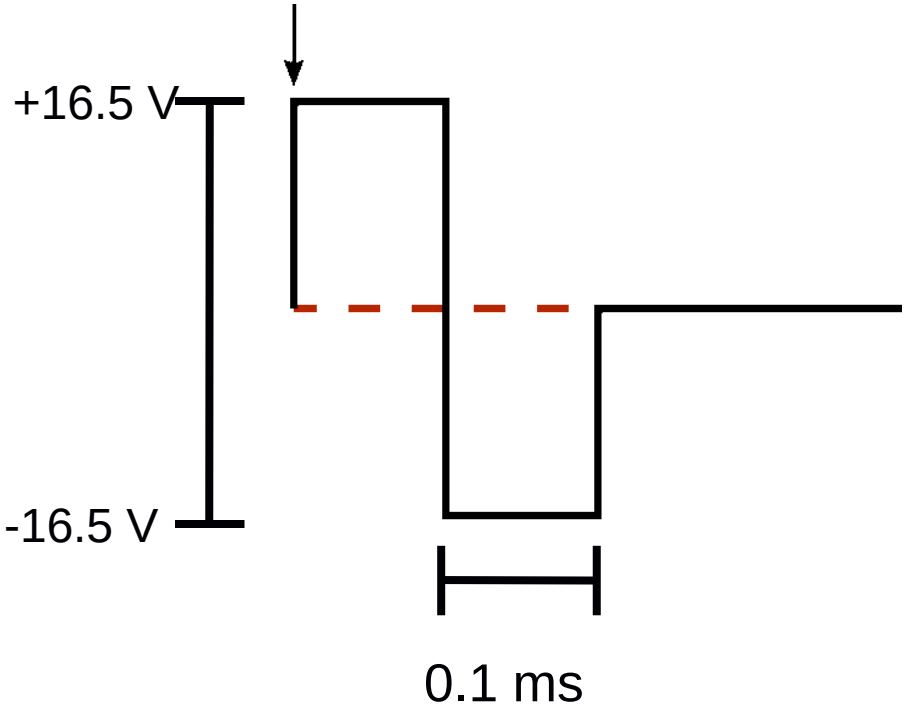

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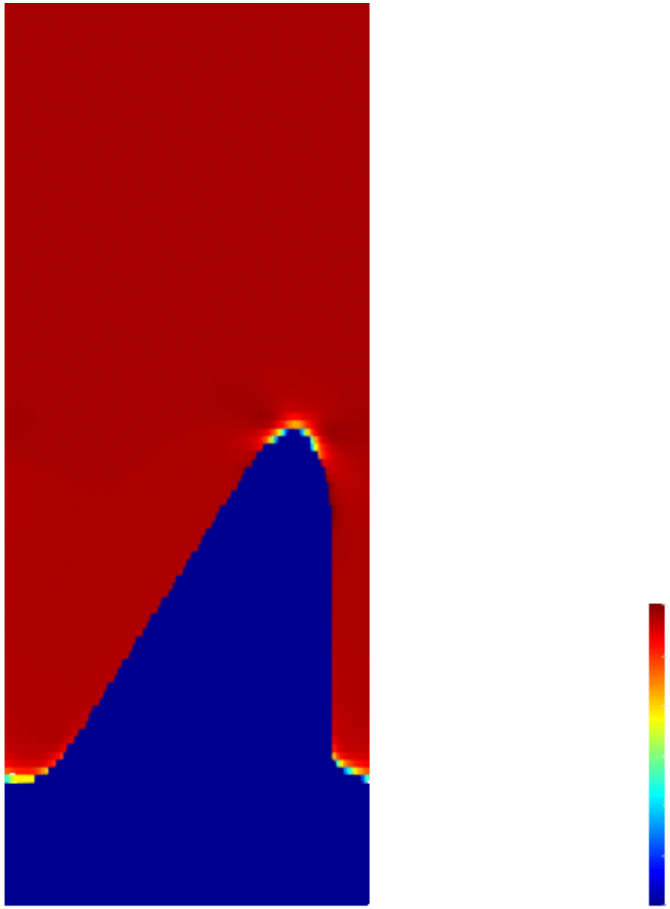

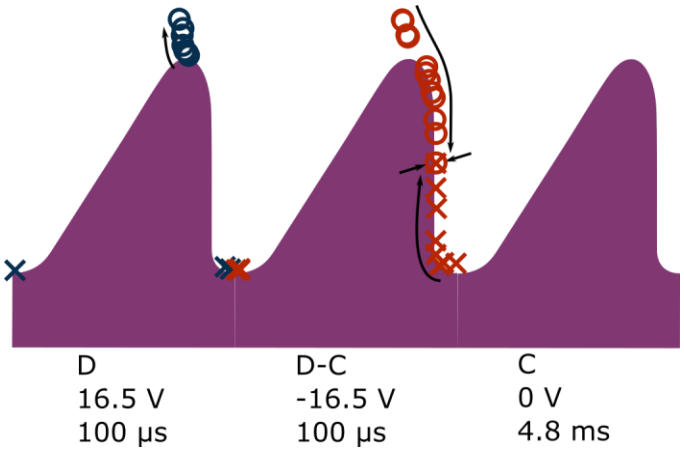

Positive pulse draws $-\frac{1}{2}$ defect off grating surface

Negative pulse pushes $+\frac{1}{2}$ defect up the sidewall

Defects in D-C latching

Defect annihilate to form Continuous State

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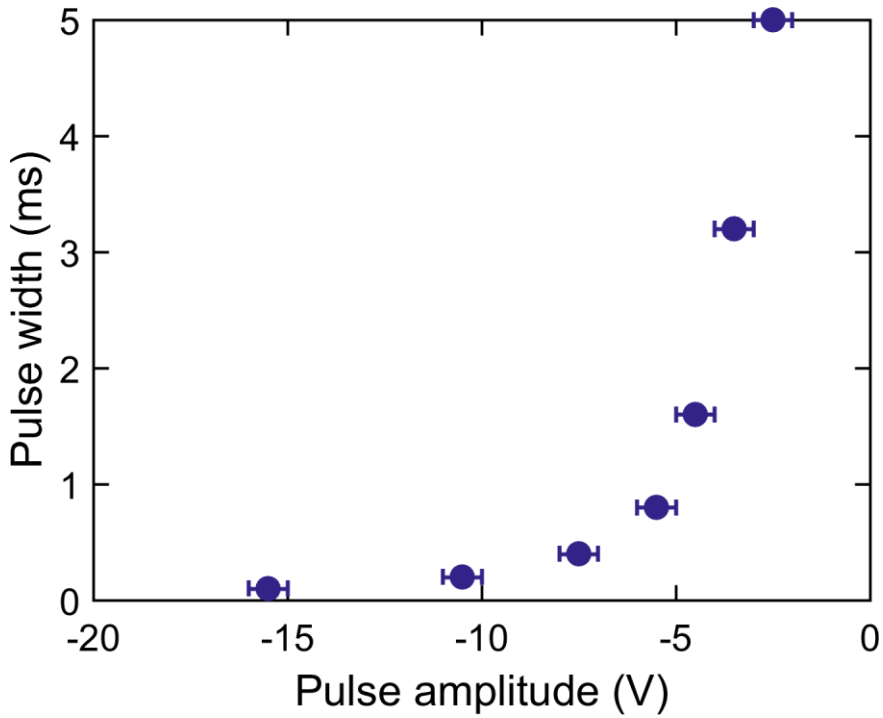
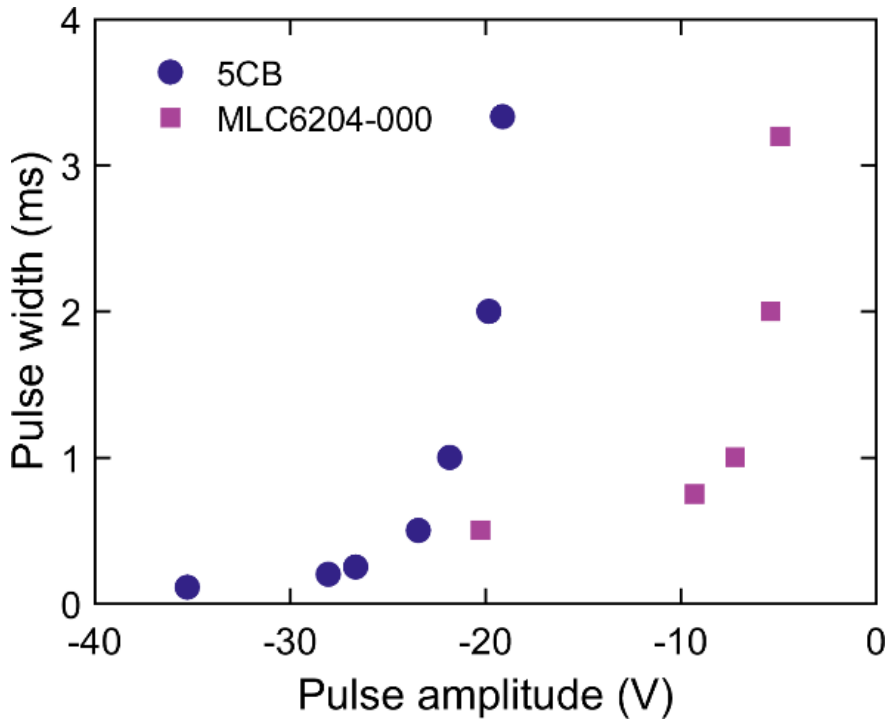
Modelling



Experimental



Defects in C-D latching

Defect nucleation and movement to points of high surface curvature

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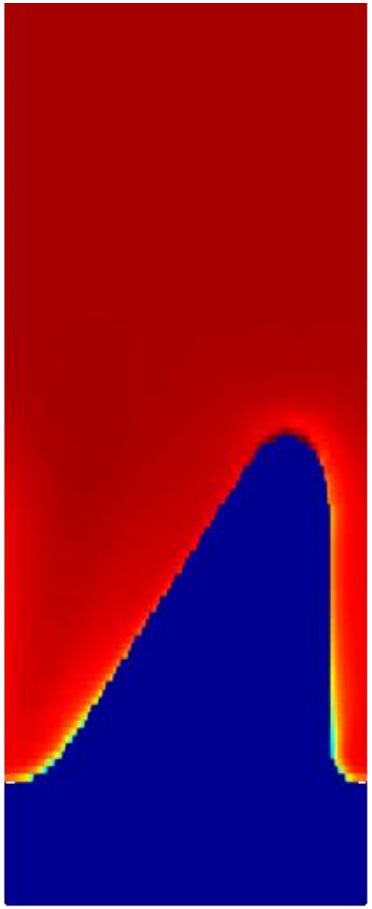

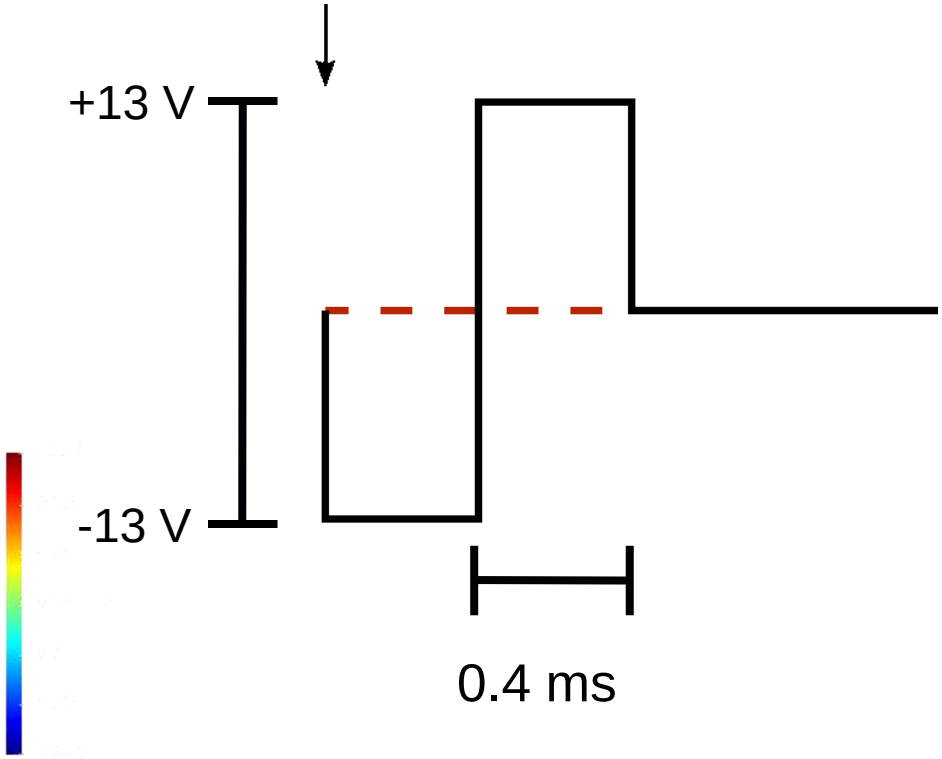

Defects in C-D latching

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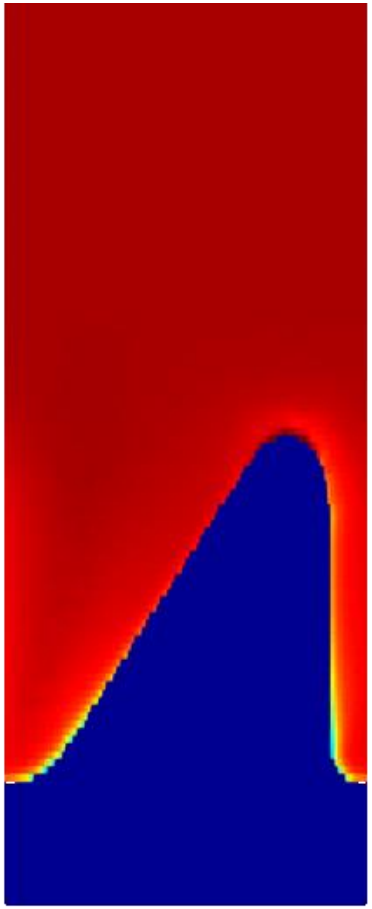

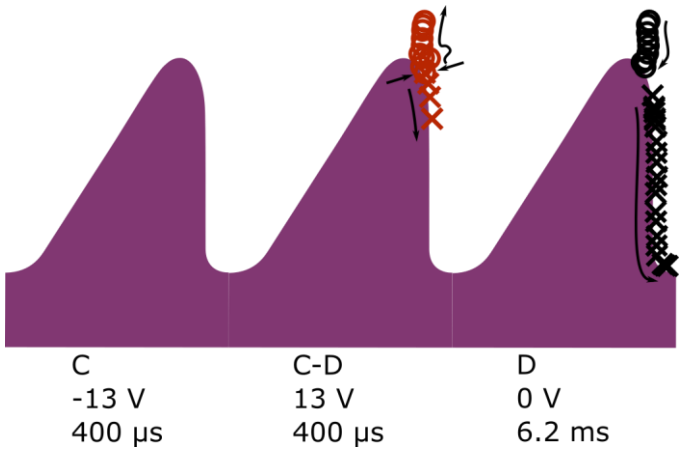

Positive pulse nucleates defects

D state adopted on relaxation

Defects in C-D latching

Defect nucleation and movement to points of high surface curvature

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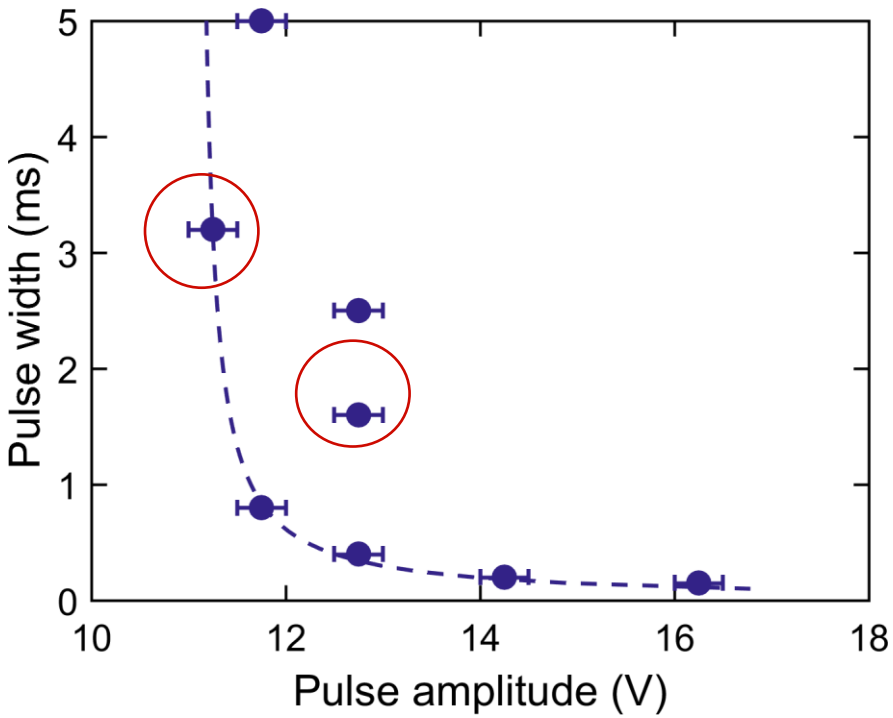
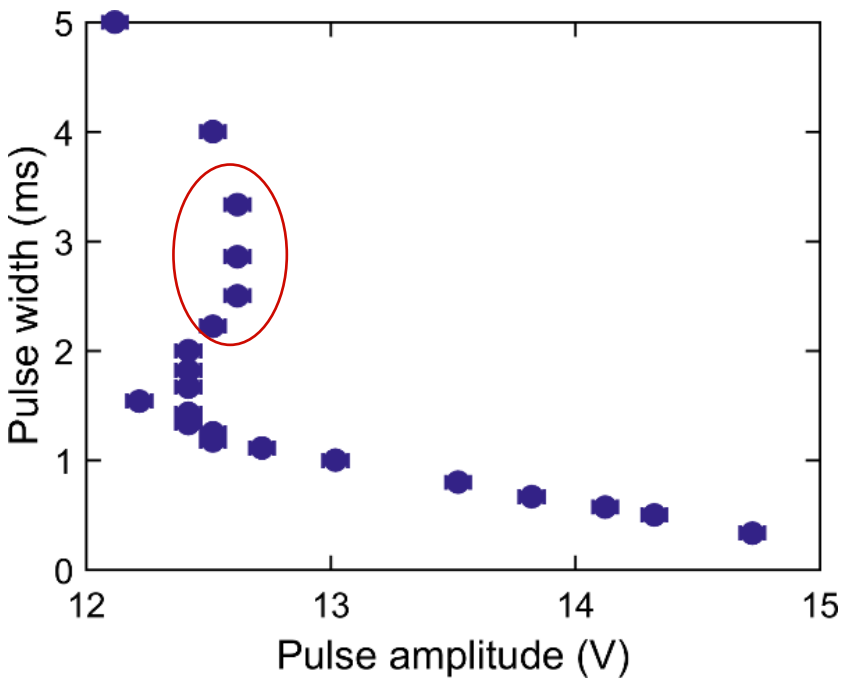
Modelling results for strong anchoring



Experimental results for 5CB



Anomalous C-D latching

1.6ms pulses and strong anchoring

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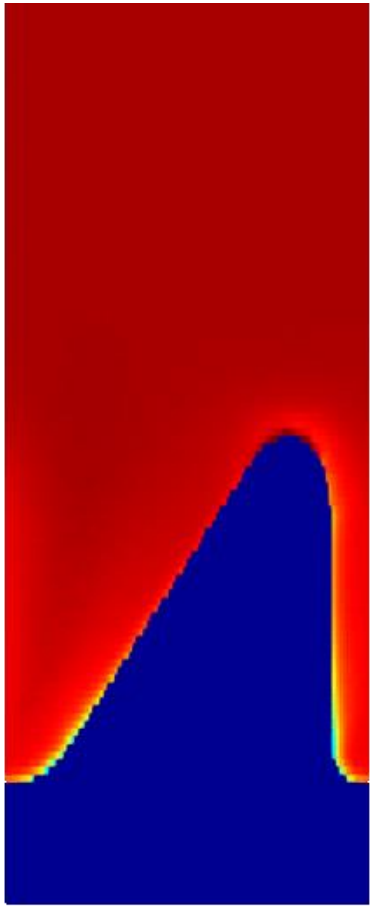
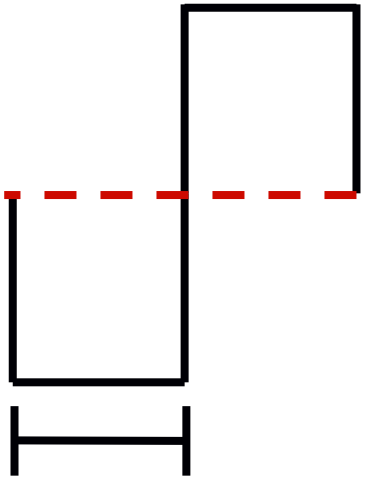
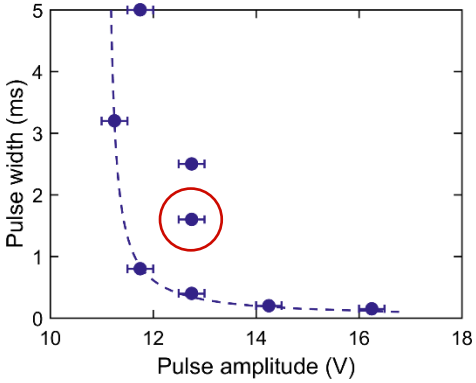
No latch

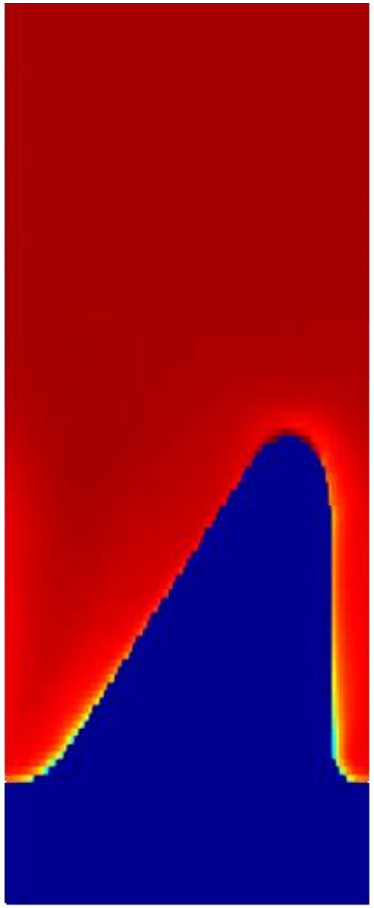
Latch

$+\frac{1}{2}$ defect suppresses latch









12.5 V

13V

Anomalous C-D latching

3.2ms pulses and strong anchoring

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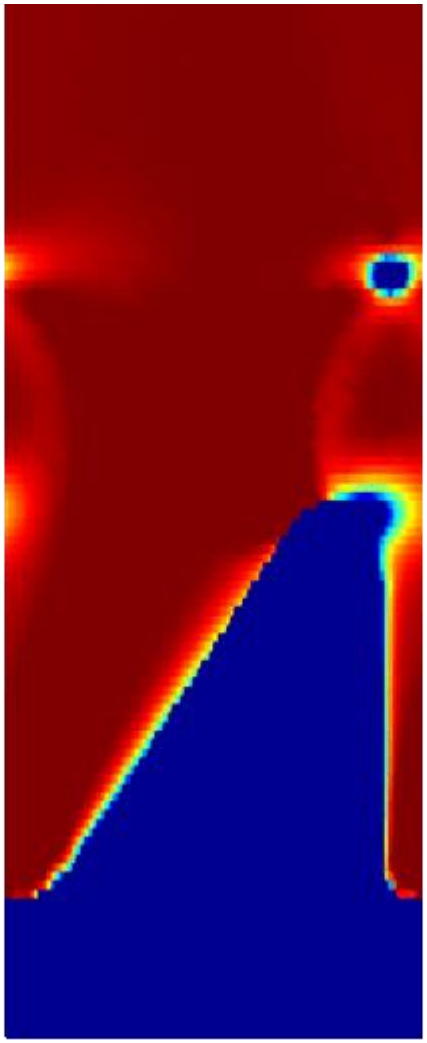
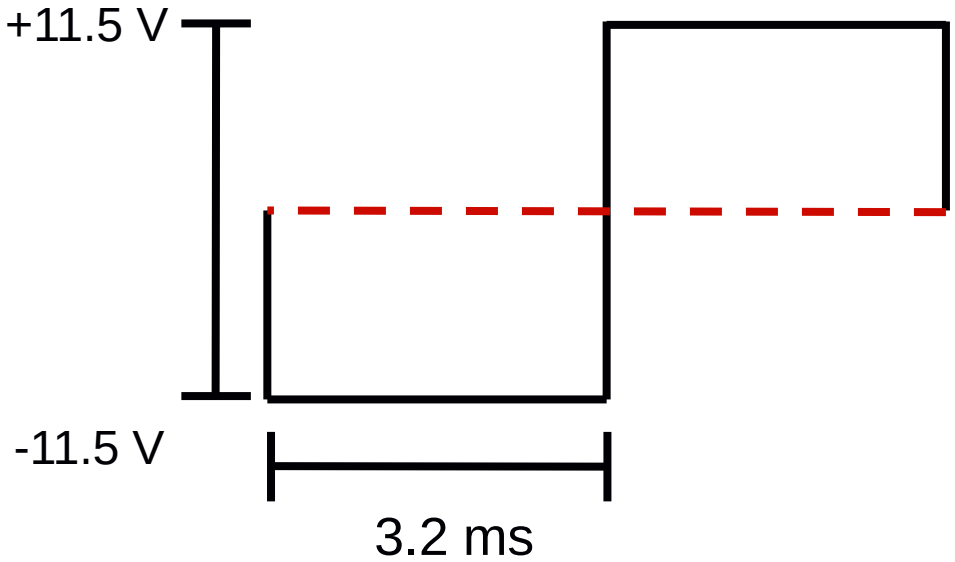
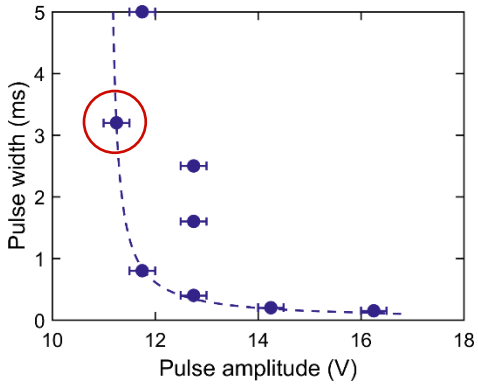
Second generation latch pair







11.5 V

Diffusion of nanoparticles within ± ½ Defects

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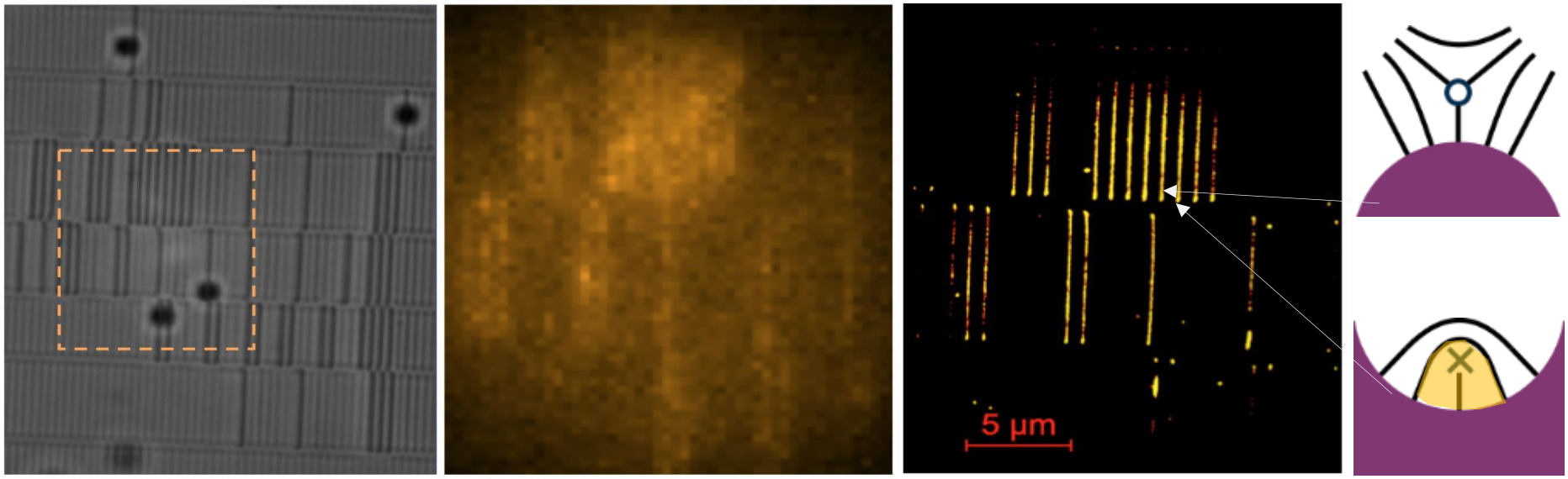

STORM showing ± ½ defects stabilising InP QD

- Containment (i.e. slow moving) of NP at – ½ defects only
- Similar finding for defect at centre of circular alignment:

  QD slow with axial alignment; not found with radial alignment
- Effect with other NP, polymers, ions, etc
- Model with entropy and diffusion required

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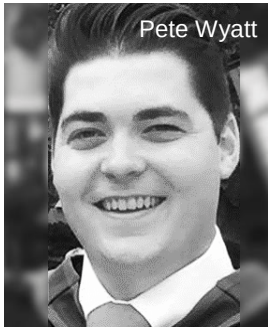
- Biaxial SmA_P



Ferroelectric SmC* Planar Layers sensitive to shock induced flow

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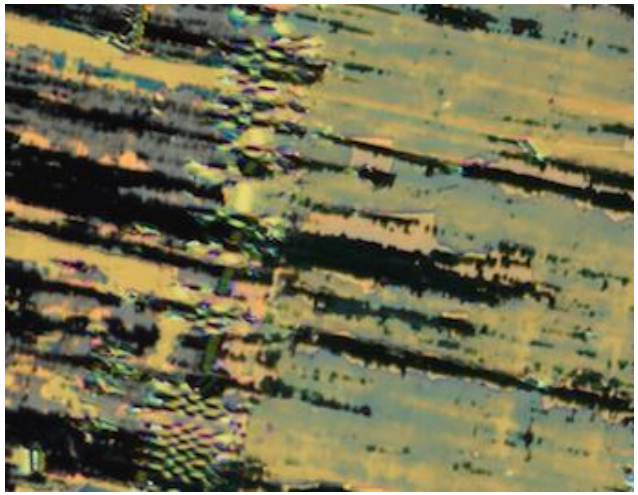
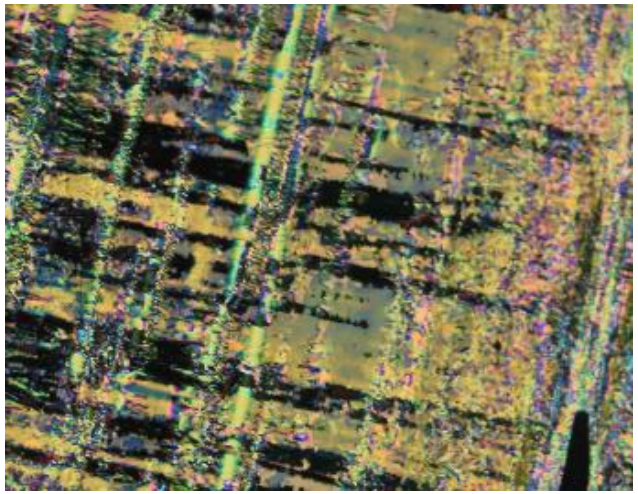
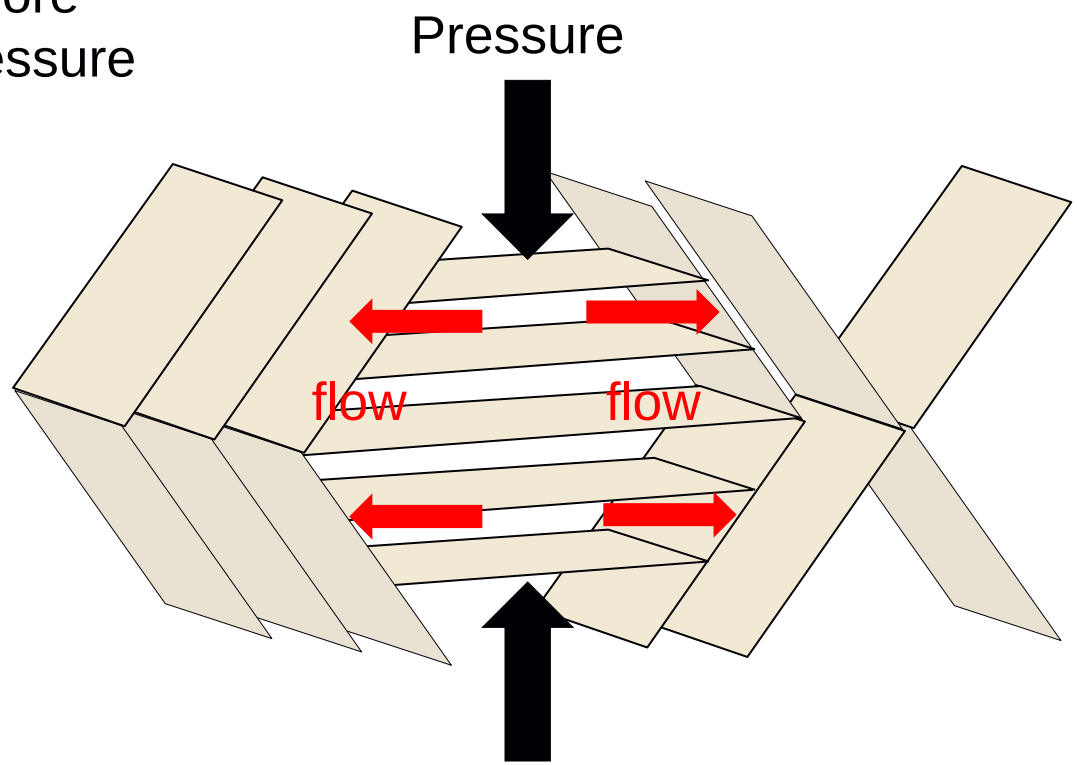


Before Pressure



After Pressure:

Severe disruption of **a**



Homeotropic Layers insensitive to shock induced flow: Self Healing

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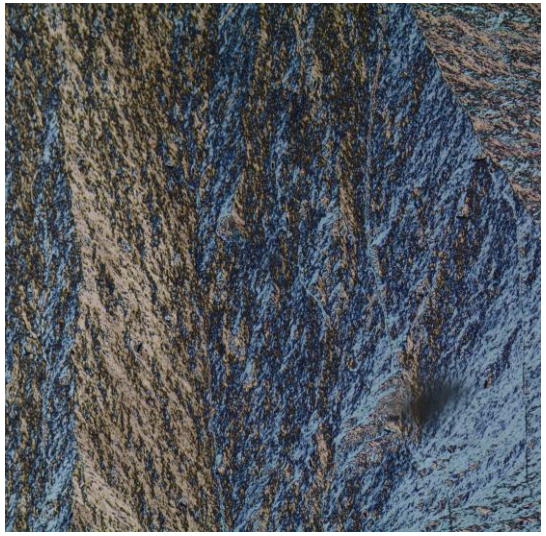
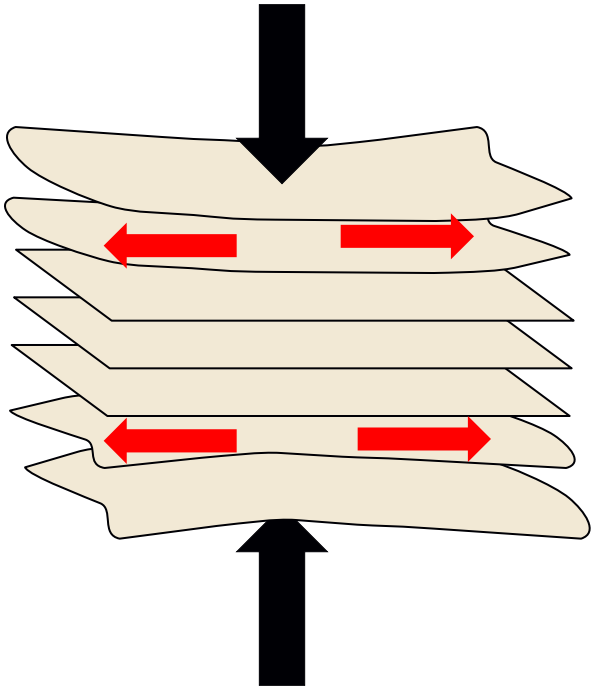
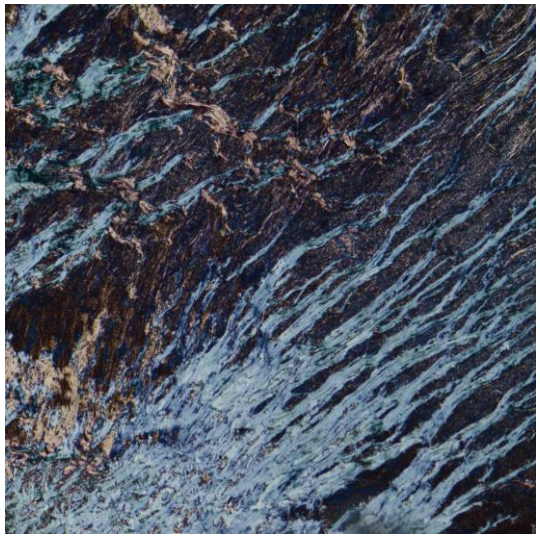


Before Pressure





After Pressure:

change of **c** not **a**

Grating alignment to define c-director of homeotropic FLC

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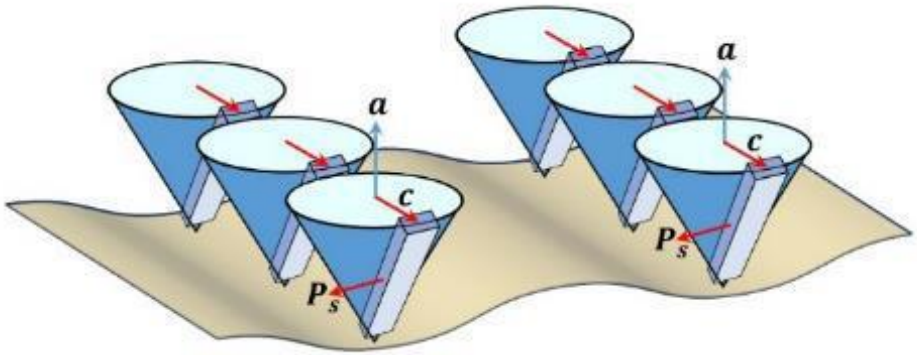
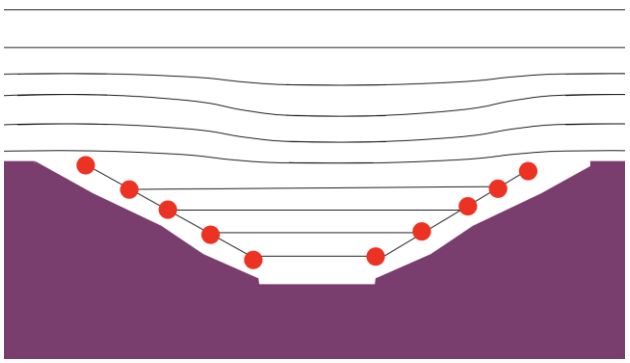


Limited layer compressibility



Dislocations at surface

Some layers at interface to bulk have oscillation of layer spacing and normal.

The Helfich-Hurault deformation
The role of A_{12} and A_{21}

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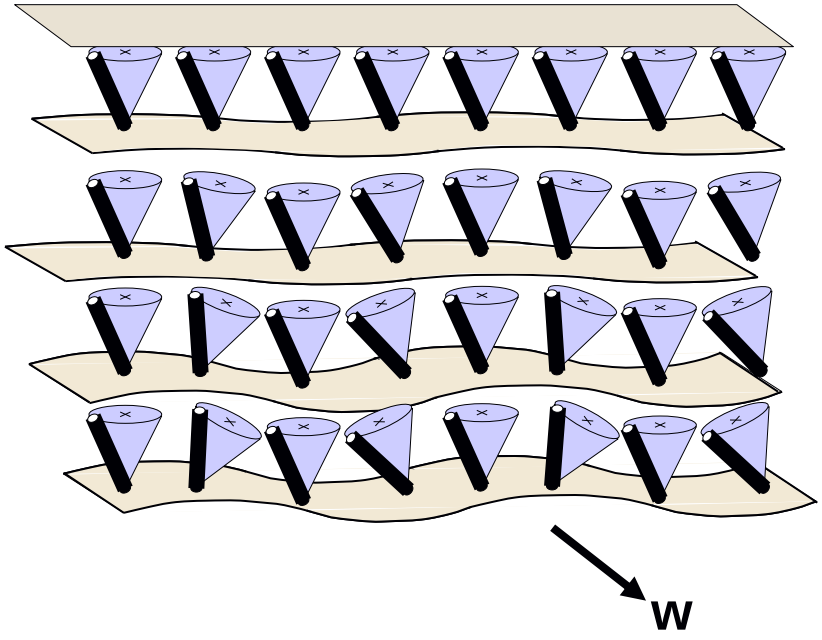

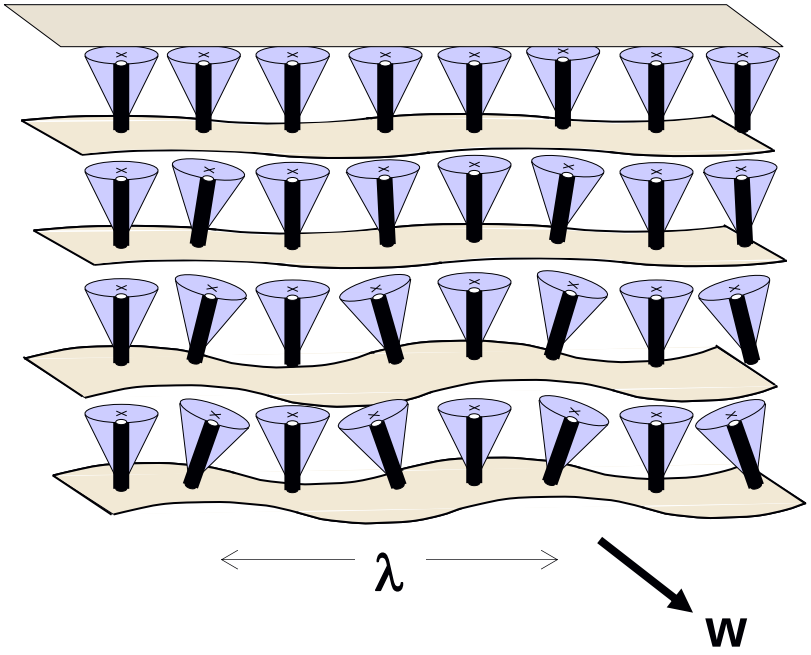

$A_{21} >> A_{12}$

c ⊥ w

$A_{12} >> A_{21}$

c || w

Optimising grating amplitude

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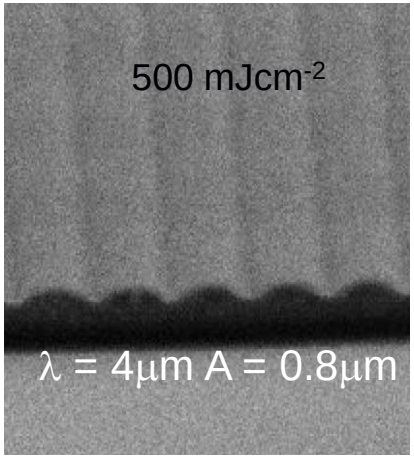

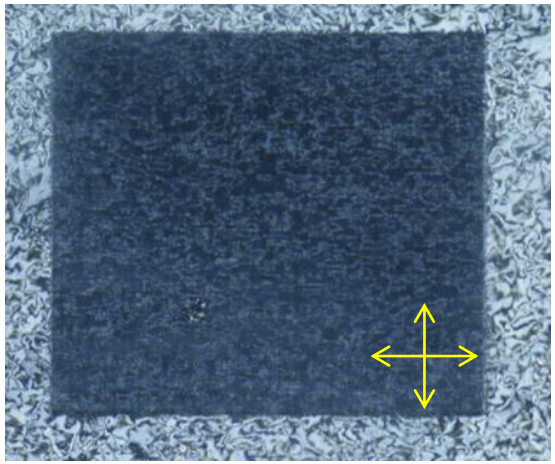

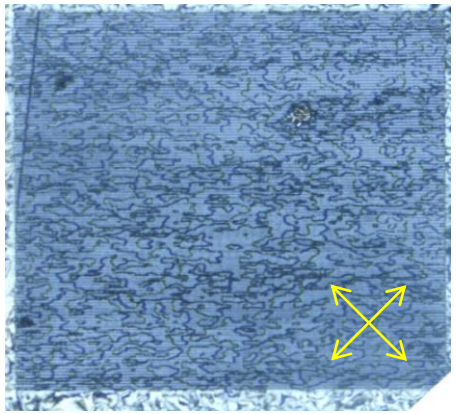

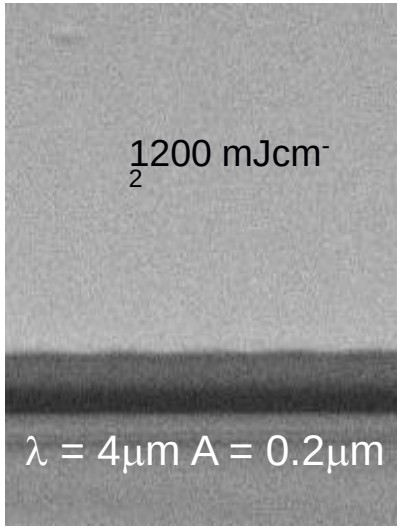

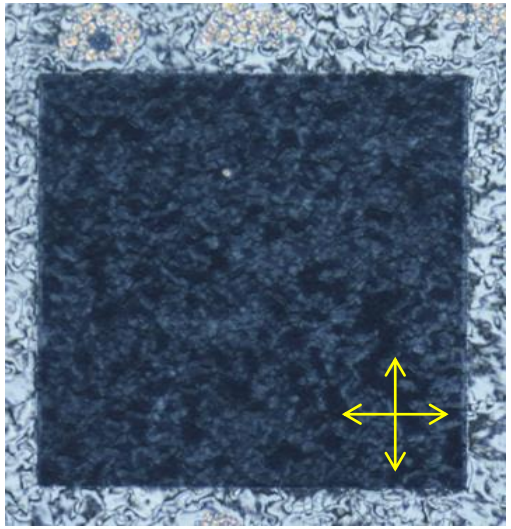

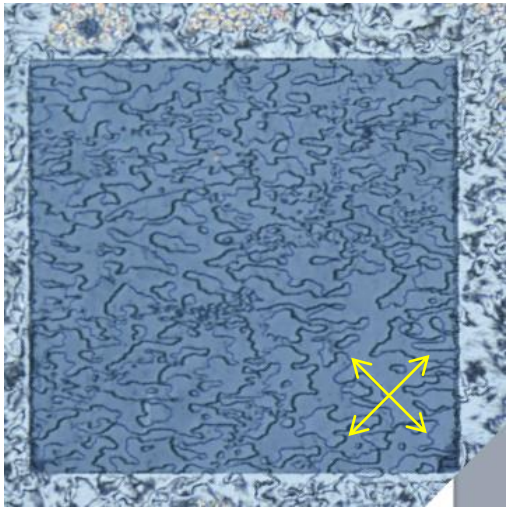

Homeotropic grating IPS FLC

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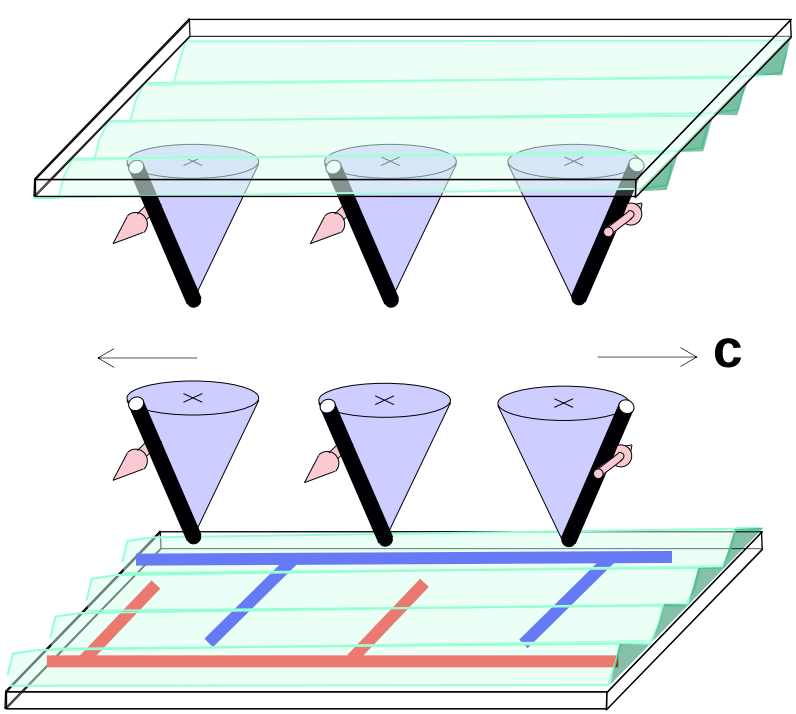

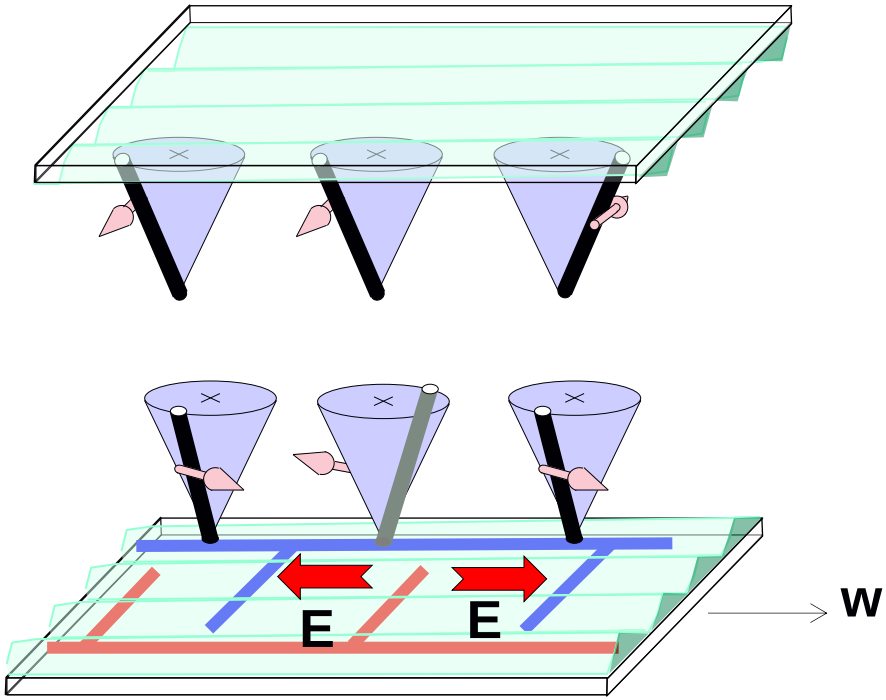

- Two domains **c** || **w**
- Black with 0V between crossed polarisers
- Gratings on both surfaces to unwind helix
- Required pitch reduction so used 20%* in R

- IPS field applied || to **w**
- **c**-director is TN (+90° and -90°)
- First Minimum TN ≈ 12μm
- V shaped switching

Homeotropic Grating FLC Results

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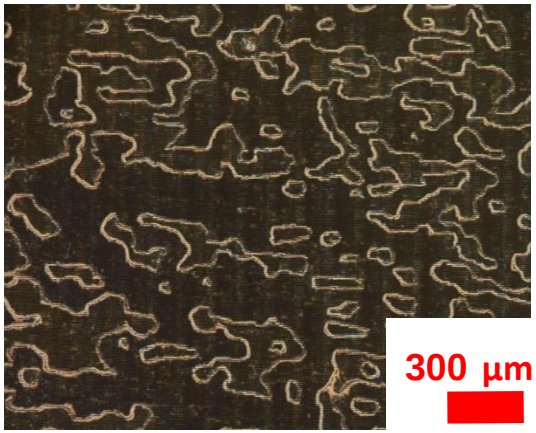

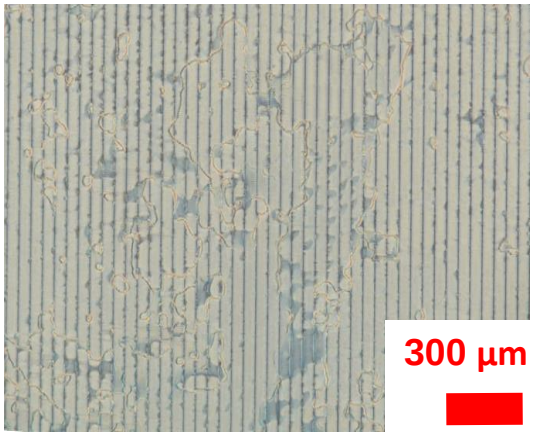

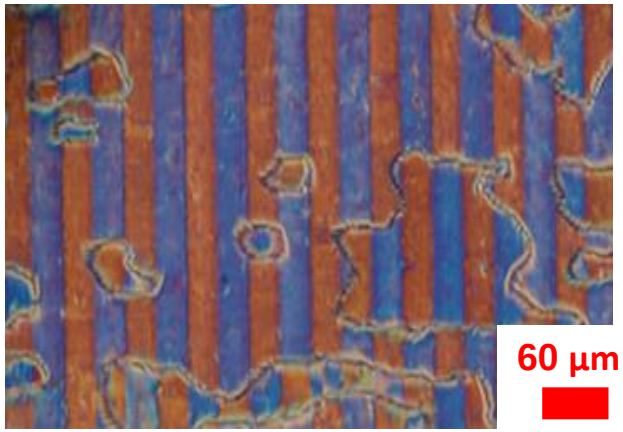

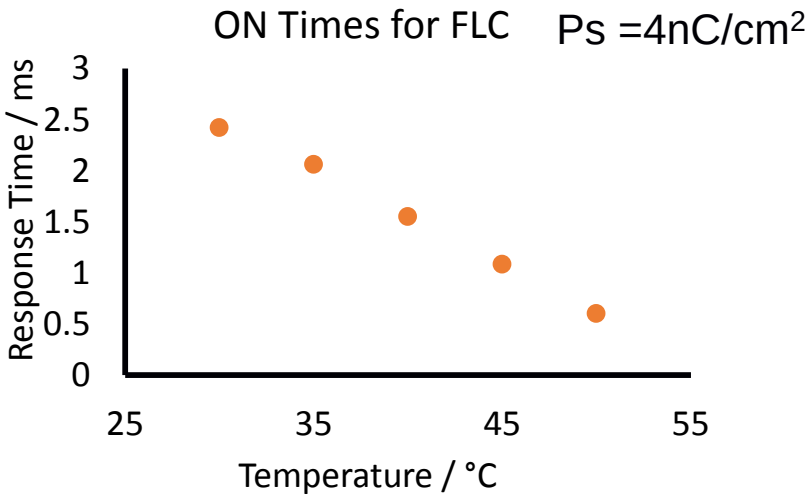

Cooling homeotropic SmC(*)

Discontinuous changes of birefringence due to layer tilt

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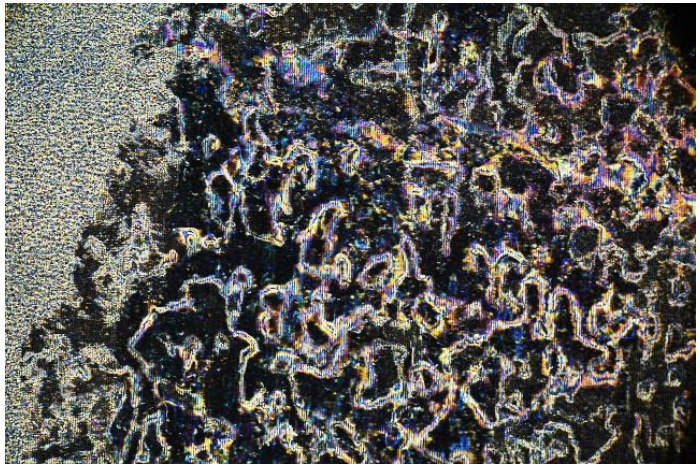

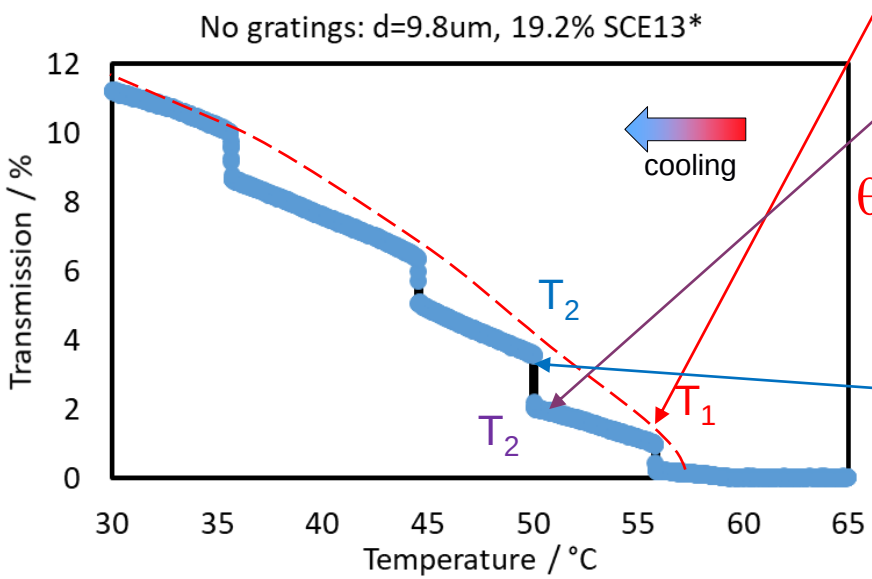

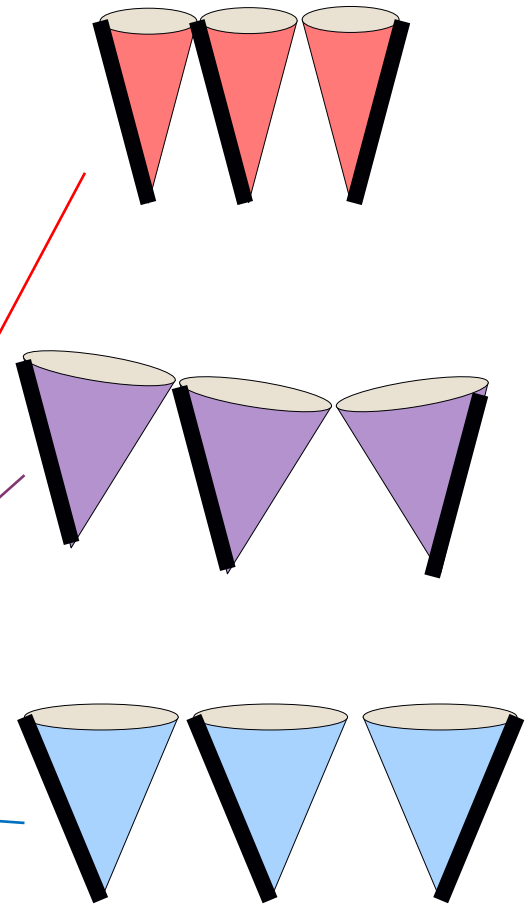

a || **s**
n at θ_{T1}

a at θ_{T2} - θ_{T1}
n at θ_{T1}

a || **s**
n at θ_{T2}

Schematics use A_{21} >> A_{12} for convenience

Conclusions

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1 Vector continuum model long established as useful for LCD engineering

2 Q-tensor now being used predictively for Bistable LCD

3 Next generation theories for LCD engineers?

- Thermodynamic models to include diffusion and entropy for NP
- Compressible smectic theories