Help! Some potential mathematical problems from an LC device physicist

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History as Display Scientist
Thirty years in industry; Five years in Academia

1985-2000
- HDTV with Sharp
- Holographic Displays with Ford

2000-2013
- Gratings in LCD

2014-2019
- Embossing of birefringent optics: Polarisation independent lenses
- Fractal Droplets and Droplet Sensors
- Switchable Contact Lenses
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

1. Optimising the Zenithal Bistable Device
   - Defect Dynamics
   - Diffusion and entropy of topological defects

2. Confinement of smectic liquid crystals
   - FLC with surface relief gratings
   - Biaxial SmA\textsubscript{P}
ZBD: Bistable grating alignment
Flexoelectric effect and topological defects

Deep Homeotropic Grating
Flexoelectric driven disclinations

High Surface Pre-tilt
Low Surface Pre-tilt
Defects in D-C latching
Defect annihilate to form Continuous State
Defects in D-C latching
Defect annihilate to form Continuous State

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
Defects annihilate to form Continuous State

Modelling

Experimental

- Pulse width (ms) vs. Pulse amplitude (V)
- 5CB
- MLC6204-000
Defects in C-D latching
Defect nucleation and movement to points of high surface curvature
Defects in C-D latching
Defect nucleation and movement to points of high surface curvature

Positive pulse nucleates defects

D state adopted on relaxation
Defects in C-D latching
Defect nucleation and movement to points of high surface curvature

Modelling results for strong anchoring

Experimental results for 5CB
Anomalous C-D latching
1.6ms pulses and strong anchoring

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

12.5 V

13 V

Pulse width (ms) vs. Pulse amplitude (V) graph
Second generation latch pair

Anomalous C-D latching
3.2 ms pulses and strong anchoring

+11.5 V

-11.5 V

3.2 ms

11.5 V

Pulse width (ms)

Pulse amplitude (V)
Diffusion of nanoparticles within $\pm \frac{1}{2}$ Defects

STORM showing $\pm \frac{1}{2}$ defects stabilising InP QD

- Containment (i.e. slow moving) of NP at $-\frac{1}{2}$ 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
1. Optimising the Zenithal Bistable Device
   • Defect Dynamics
   • Diffusion and entropy of topological defects

2. Confinement of smectic liquid crystals
   • FLC with surface relief gratings
   • Biaxial SmAP
Ferroelectric SmC* Planar Layers sensitive to shock induced flow
Homeotropic Layers insensitive to shock induced flow: Self Healing

Before Pressure

After Pressure: change of $c$ not $a$
Grating alignment to define c-director of homeotropic FLC

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 $A_{21}$

$A_{21} \gg A_{12}$
$c \perp w$

$A_{12} \gg A_{21}$
$c \parallel w$
Optimising grating amplitude

$\lambda = 4 \mu m$ $A = 0.8 \mu m$

500 mJcm$^2$

$\lambda = 4 \mu m$ $A = 0.2 \mu m$

1200 mJcm$^2$
Homeotropic grating IPS FLC

- Two domains \( \mathbf{c} \parallel \mathbf{w} \)
- Black with 0V between crossed polarisers
- Gratings on both surfaces to unwind helix
- Required pitch reduction so used 20%* in \( \mathbf{R} \)
- IPS field applied \( \parallel \) to \( \mathbf{w} \)
- \( \mathbf{c} \)-director is TN (+90° and -90°)
- First Minimum TN \( \approx 12\mu\text{m} \)
- V shaped switching
Homeotropic Grating FLC Results

ON Times for FLC  \( P_s = 4nC/cm^2 \)

<table>
<thead>
<tr>
<th>Temperature / °C</th>
<th>Response Time / ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td>35</td>
<td>2.5</td>
</tr>
<tr>
<td>45</td>
<td>2</td>
</tr>
<tr>
<td>55</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Images show different regions of FLC with labels: 300 µm and 60 µm.
Cooling homeotropic SmC(*)
Discontinuous changes of birefringence due to layer tilt

\[ a \parallel s \]
\[ n \text{ at } \theta_{T_1} \]
\[ a \text{ at } \theta_{T_2} - \theta_{T_1} \]
\[ n \text{ at } \theta_{T_1} \]

\[ a \parallel s \]
\[ n \text{ at } \theta_{T_2} \]

Schematics use $A_{21} \gg A_{12}$ for convenience.

No gratings: $d=9.8\mu m$, 19.2% SCE13*
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