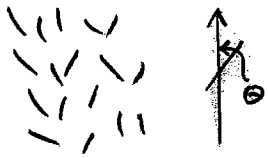
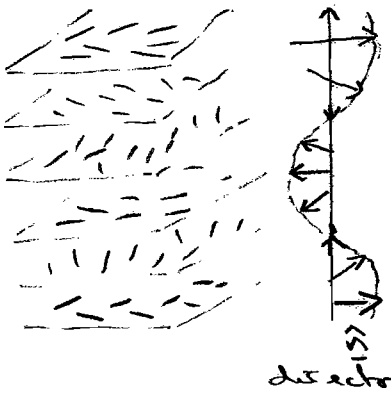
Nematic



Long range orientational order, no correlations between centres of mass. Preferred or 'average' pointing direction defined by the director $\hat{\underline{n}}$ where $\hat{\underline{n}} = -\hat{\underline{n}}$ (2)

Molecules anisotropic and phase is fluid thus molecules can slide past one another whilst maintaining 'average' parallelism. Least ordered of the thermotropic phases.

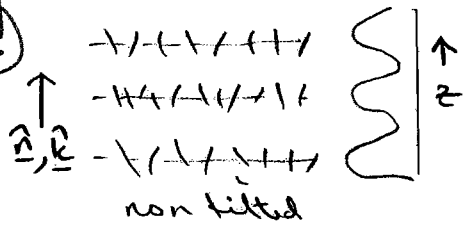
Chiral Nematic



Similar to nematic except a 'screw axis' superimposed on the director. Molecules are all chiral, low twist energy ($\sim 10^{-5}$ of total associated with $\hat{\underline{n}}$). Molecules sit in 'pseudo' layers in which each layer has the order of a non chiral nematic. Spiral axis for $\hat{\underline{n}}$ gives rise to selective reflection of polarised light. (3)

Rotatory power $\sim 10^3$ × sugar solutions.

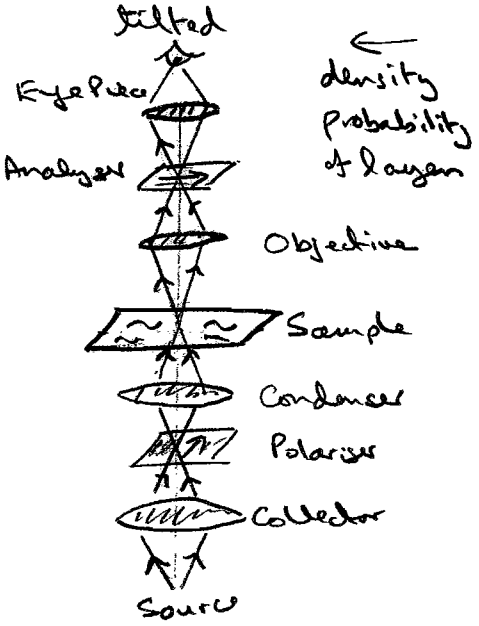
(12)



Stratified layer like structure (probability density wave). In non tilted S_A phase $\hat{\underline{n}}$ and $\hat{\underline{k}}$ (layer normal) parallel. In tilted S_C phase layer normal and $\hat{\underline{n}}$ at an angle. Layer thickness $\sim$ 1 molecular length (3)

Layers slide relative to each other ∴ fluid

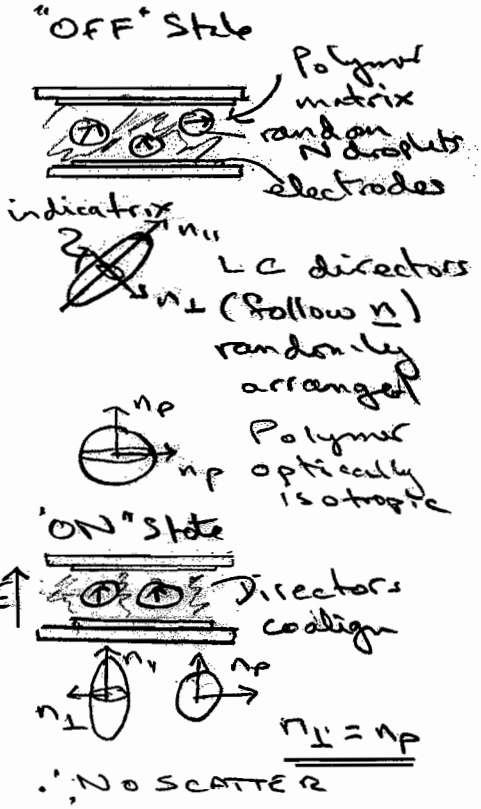
For S_A, S_C there is no structure in the 2D layer. Higher order phases, S_B etc for 2D packing structure, i.e. hexagonal, etc



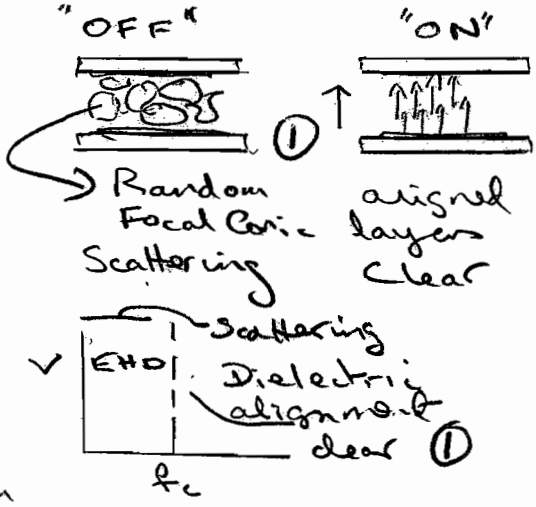
Phases identified via polarising microscopy (or DSC or X-Ray). Orientation of phase gives different optical textures characteristic of each phase (4)

I(b) continued.

(4) (i) Nematic scattering device:
Use PDLC (Polymer Dispersed LCs) to create matched ref. indices in the "ON" state, scatter light in the "off" state. Polymer matrix $n_o = n_\perp$ of the nematic in the droplet; $n_\parallel \neq n_p \neq n_\perp$. Typical droplet size ~ 2-5 μm therefore the random "OFF" state R.I. delays scatters light strongly. Haze at wide angles and higher voltages due to field loss over the polymer



(4) (ii) Smectic A scattering device
In non field effect the random focal conic texture of the S_A phase ⇒ scattering domains. Thus the local directors and layer normals are random. (1) Application of a voltage at a frequency greater than f_c (for transition from dynamic scattering to Homeotropic texture) gives a clear optical state as layers become ordered. Removal of field leads to bistability and ERASURE is achieved by applying a low frequency voltage ($f < f_c$) ⇒ ionic motion which disorders the layers & scattering reemerges in the EHD (Electro Hydro Dynamic regime. At high frequencies ($f > f_c$) for $\Delta\varepsilon > 0$ materials dielectric alignment ⇒ clear texture. (1)

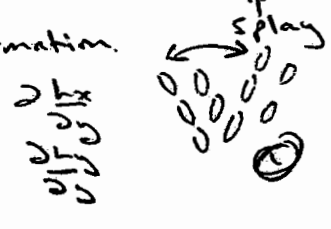


Q2

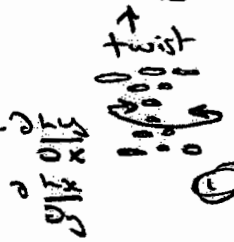
- Start with continuum theory for director field i.e. not molecular. Frank continuum theory

$$F = \frac{1}{2}\int \left[k_{11}(\mathrm{div}\,\underline{n})^2 + k_{22}(\underline{n}\cdot\mathrm{curl}\,\underline{n})^2 + k_{33}(\underline{n}\times\mathrm{curl}\,\underline{n})^2 \right] \quad (1)$$

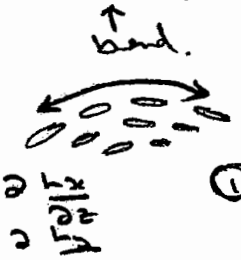
Deformation: splay, twist, bend.



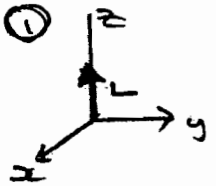
$\frac{\partial n_x}{\partial z}\underline{i} + \frac{\partial n_y}{\partial z}\underline{j}$ (1)



$-\frac{\partial n_y}{\partial x}\underline{i} + \frac{\partial n_x}{\partial x}\underline{j}$ (1)

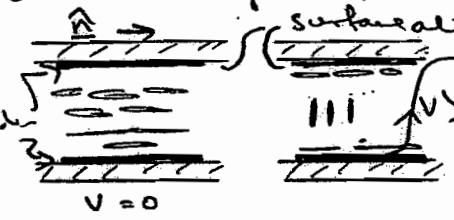


$\frac{\partial n_x}{\partial z}\underline{i} + \frac{\partial n_z}{\partial z}\underline{k}$ (1)



where $\underline{n}$ is unit vector describing local director.

A Freedericksz transition occurs when an external voltage (i.e. energy) is applied to induce a (splay / twist / bend) deformation to overcome alignment induced by surface forces.



splay F.T. (1)

$V_{th} = \pi\sqrt{\frac{k_{11}}{\varepsilon_0 \Delta\varepsilon}}$ } planar to homeotropic for $\gamma_s \to \infty$

(8)

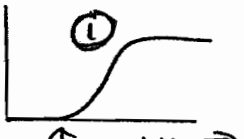
For k_{22} use twisted alignment layer (1) (c.f. TN cell below)

& k_{33} use homeotropic alignment and transverse field.

$V > V_{th} = \pi\sqrt{\frac{k_{33}}{\varepsilon_0 \Delta\varepsilon}}$ (1)

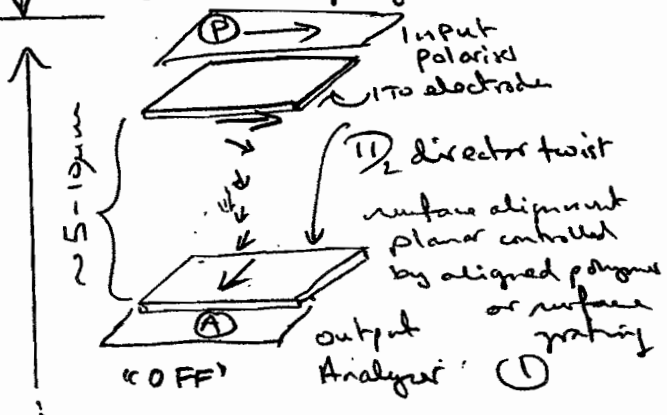
(N.B Could use $\underline{H}$ & $\Delta\chi$)

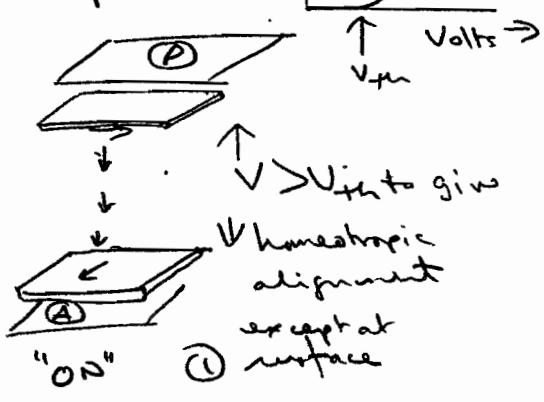
In all three cases apply increasing field and measure optical change due to each F.T.



(1)

Since birefringent materials use x polarisers



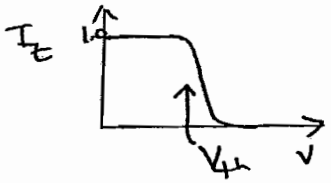


(4)

Q2 Continued

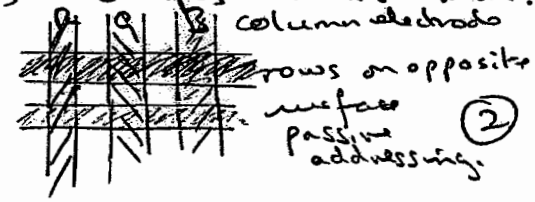
TN cell based on polarisation guiding down twisted structure induced using surface alignment layer (+ chiral additive to ensure ¼ twist & minimise optical bounce) ⇒ Transmission

(6) For $V > V_{th}$ helix unwinds to homeotropic ∴ Twist and guiding lost ∴ optical polarisation of input light (P) is maintained. ∴ P ⊥ A, as drawn, crossed → extinction. (2)

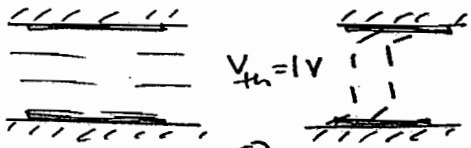


On field removal the surface pinned molecules & chiral (twist) revert back to original "off" state.

To construct colour display use R.G.B. filters at each pixel. Normally in stripes "Trinitron" mode.



(6) **Problem:** Planar sample, $\Delta\varepsilon$ +ve ∴ splay ① Freédericksz Transition



$$V_{th} = \pi \left[\frac{K_{11}}{\varepsilon_0 \Delta\varepsilon}\right]^{\frac{1}{2}} \quad (1)$$

$$\therefore K_{11} = \frac{V_{th}^2 \cdot \varepsilon_0 \cdot \Delta\varepsilon}{\pi^2} \quad (1)$$

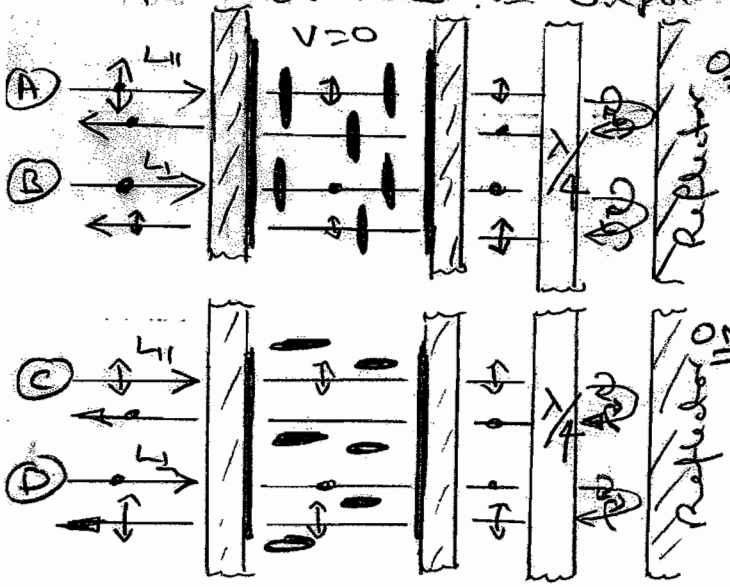
$$= \frac{1^2 \times 8.854 \times 10^{-12} \cdot 16}{\pi^2} \ [SI]$$

$$K_{11} = 14.4 \times 10^{-12} \ N. \quad (2)$$

(3) Dye Guest–Host Nematic

{NB The candidates could describe a DGH incorporating a λ/4 plate or a White Taylor Display. Either is acceptable}

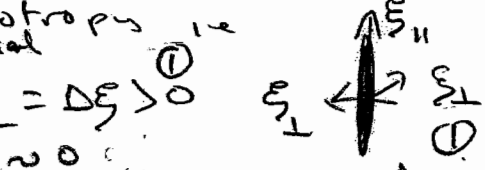
Polariser Free i.e. unpolarised light



In Dye Guest Host absorbing dye with a +ve absorption anisotropy i.e. uniaxial (1)

$\xi_\parallel - \xi_\perp = \Delta\xi > 0$

$\xi_\perp \approx 0$



is incorporated in a nematic matrix. Thus the major absorption axis follows the director $\underline{n}$.

(2) $V > V_{th}$. Quarter Wave Q.A. at 45° to dye axis

Therefore in OFF state (1) use planar alignment.

Construction incorporates λ/4 plate matched to peak absorption λ.

OFF State

For unpolarised light consider two components ∥ and ⊥ to director

$L_\parallel$ to $\underline{n}$ Route (A) $L_\parallel$ absorbed partially traversing device to λ/4 plate. $L_\parallel$ changed to circular polarisation of one handedness which is reversed on reflection (π phase change). After reflection & passage thro' λ/4 plate component left is rotated into $L_\perp$ direction which then passes back out. (2)

$L_\perp$ to $\underline{n}$ Route (B). $L_\perp$ not absorbed on initial pass – follows same process as (A) but re-enters nematic layer with polarisation rotated by 90° (i.e. in $L_\parallel$ direction) after reflection & passing via λ/4 plate. Then component is then absorbed by planar dye.

Thus in 'OFF' state all polarisation is absorbed. (2)

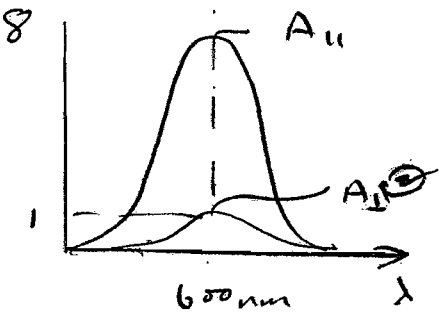
In ON case $L_\parallel$ and $L_\perp$ is always in direction of $\xi_\perp$ due to uniaxial symmetry ∴ No absorption. So for white incident light the "OFF" state is coloured (by subtraction) & ON state is white. ∴ Use either Red, Green, or Blue transmitting dyes. Wavelength specific because of λ/4 plate. (1)

(3) Cont....

$\lambda_{peak} = 600nm$, Dichroic Ratio (Definition) $= \frac{Abs_{\parallel}}{Abs_{\perp}} = \frac{1+2S}{1-S} = DR$ (2)

where S = Order Parameter.

(6) $A_{\parallel}$ for planar 'off' alignment (1)
$A_{\perp}$ for perpendicular 'on' alignment in electric field.



Calc $\Rightarrow$ $8 = \frac{1+2S}{1-S}$

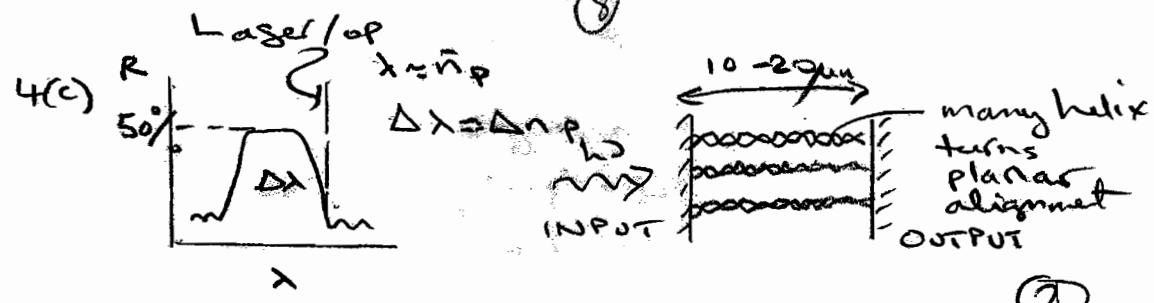
$\therefore S = 0.7$ (1)

DGH versus TN Cell.

	GH	TN
Brightness	V. good	< good
Contrast	Medium	Good
View Angle	V. good	Restricted
Construction → Complexibility	1 or 0 Polariser	2 Polarisers
Multiplexing	poor	good.

(3)

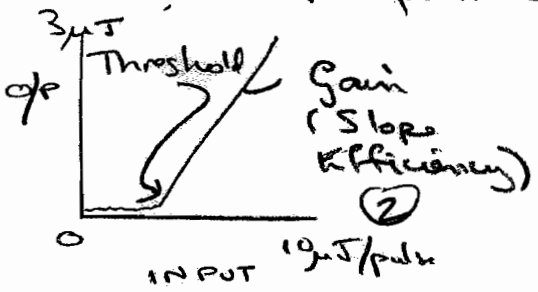
(4) Make device emissive by using a fluorescent dye i.e. absorbed energy re-emitted at lower or higher λ (1)



(2)

The N* chiral structure sets up a PB for CP light with planar surface alignment.

Gain medium: Add fluorescent laser dye to N* phase (DCM, Pyromethene etc). Pump with frequency doubled YAG laser (λ_{in} = 532nm). Chose dye that absorbs at 532nm. Up conversion to longer λ for output fluorescence. Light internally reflected until DOS → ∞ at the band edge and emission occurs (≈ 600nm). Position output fluorescence near BE for max gain



(2)

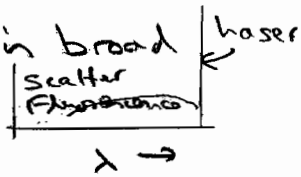
Well defined threshold and high gain (Slope Efficiency)

Beam profile (≈ TEM00) gaussian

Directional, coherent

Narrow Linewidths (≈ 0.01 nm)

Distinguished from other emission which is broad band and multi directional.

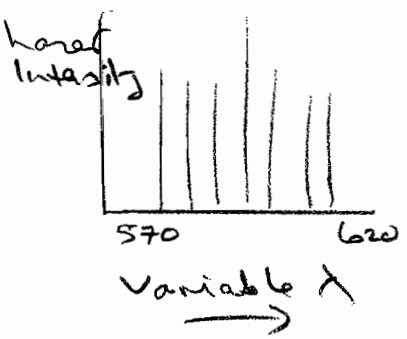


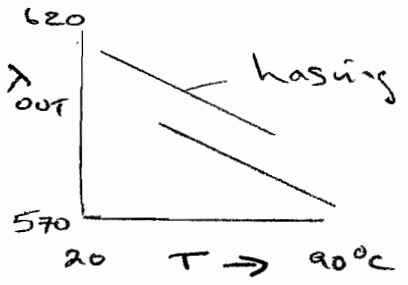
o/p pulses ≈ ns (η) Efficiency depends on ⟨S⟩

V. high η ≈ 60–70%

(4)

Tuning can be achieved by choosing an N* material in which p the helix pitch is a f(T). Slowly ramp T ∴ λ changes as helix starts to unwind. Thus the resonant conditions change and λ shifts (f(p))





(2)

Pitch jumps at surface giving different modes

(12)