Tekoči kristali – zakaj se zdijo zanimivi meni?

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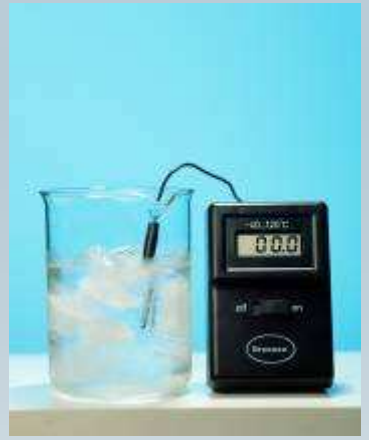
O čem

- tekoči kristali za novince
  - kaj tekoči kristali sploh so
  - kako jih prepoznamo
  - zakaj so zanimivi
- tekoči kristali za vajence
  - njih optične lastnosti
  - kako jih urejamo
- tekoči kristali za strokovnjake

Kaj imenujemo “tekoči kristali”?

običajne snovi

kristal → tekočina

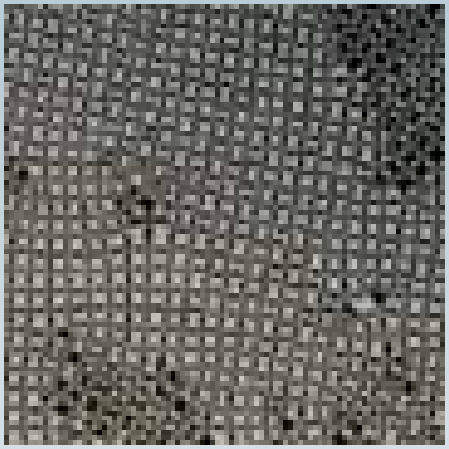


tekoči kristali

kristal → tekoči kristal → tekočina

Kaj imenujemo “tekoči kristali”?

Vsaj ena od faz mora biti tekoče kristalna.



Zakaj se tako imenujejo?

lastnosti tekočine
tečejo

lastnosti kristalov
anizotropne lastnosti
mikroskopska urejenost

Različne tekoče kristalne faze

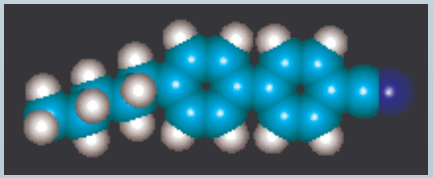
Nematiki
Kiralni nematiki

Smektiki
Nagnjeni smektiki

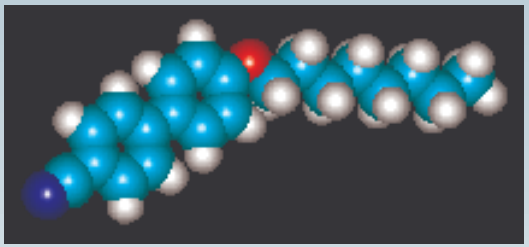
Kolumnarne faze

Molekularne lastnosti...

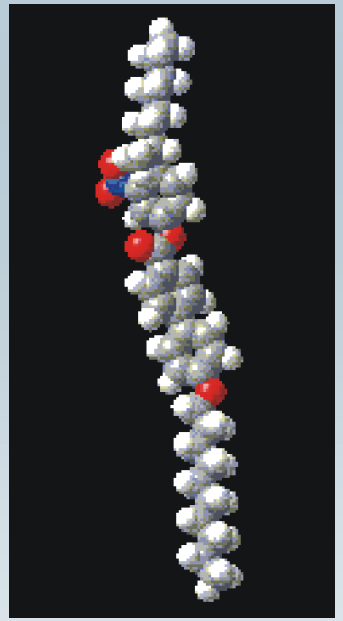
Podolgovate molekule



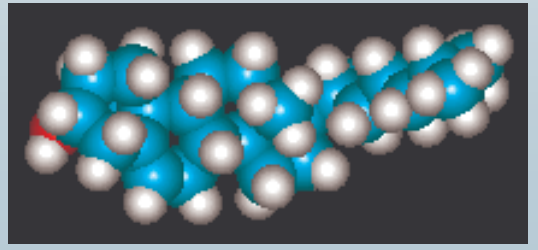
5CB



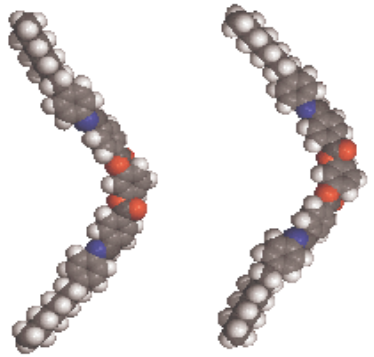
OOCBP



DOBAMC

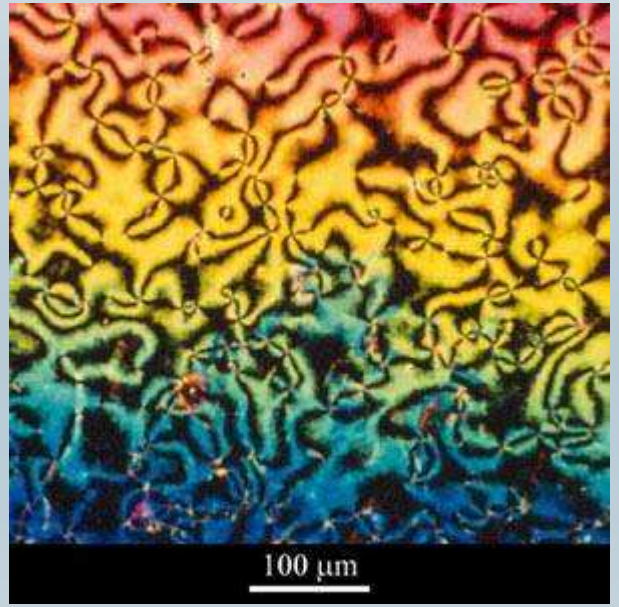


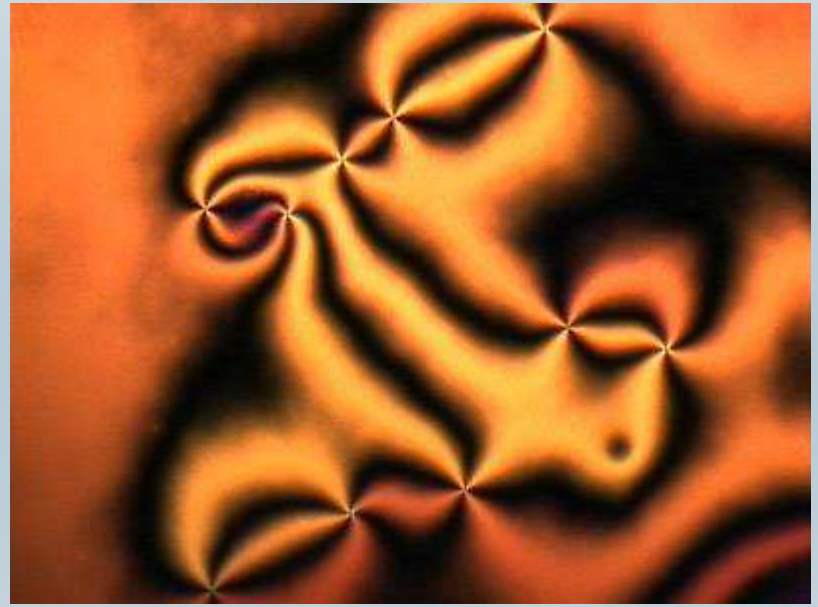
holesterik



banane

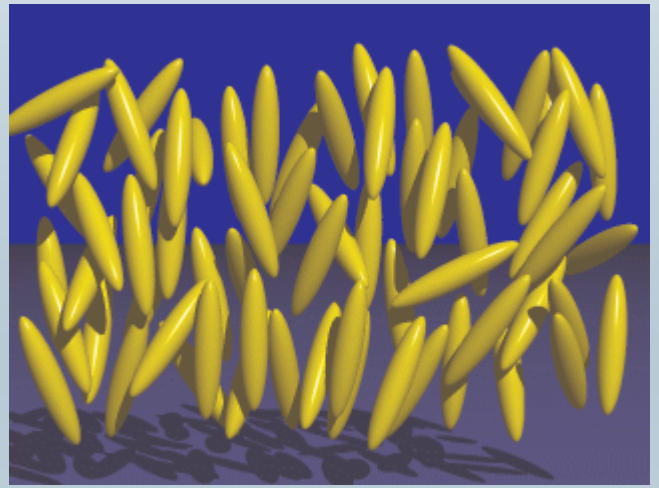
Nematiki

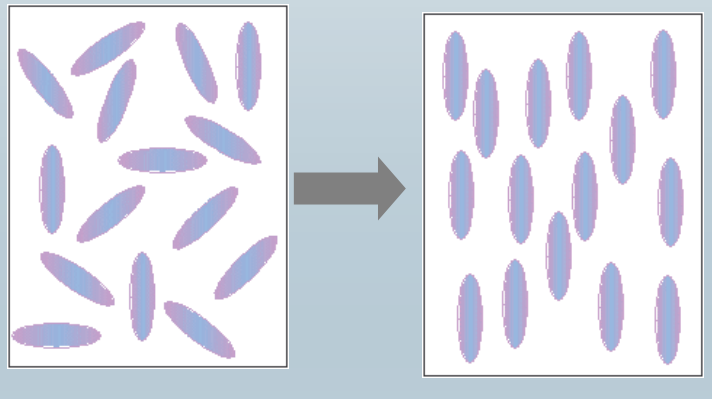




Med tekočino in kristalom:
Motna, koloidom podobna tekočina
Dvolomna

Kako opisati urejenost?

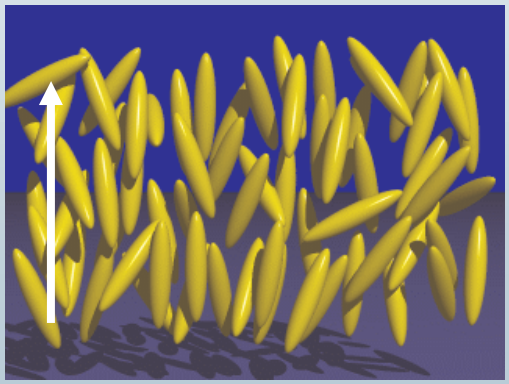




izotropna faza nematik

- **ureditveni parameter – mera za red**
- **0 za neurejeno fazo**
- **čim večji je parameter tem večji mora biti red**
- **1 za idealno urejen (ni vedno res)**
- **upoštevati mora simetrijo**

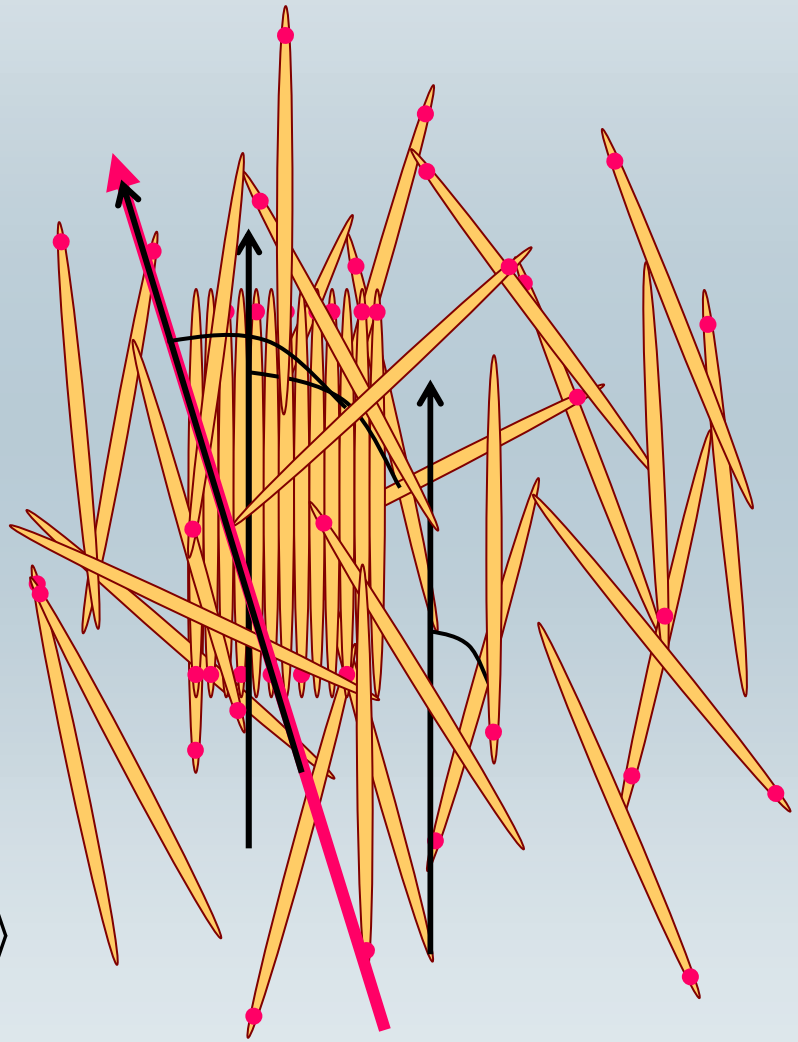
Nematski ureditveni parmeter



Uredtiveni parameter opisuje, kako dobro so urejene molekule.

- $\eta = \langle \cos\theta \rangle = ?$
- $\eta = \langle \cos^2\theta \rangle = ?$
- **čim večja je vrednost, tem večji je red**
- **je 1/3 za enurejen sistem**
- **renormalizacija:** $\eta = \left\langle \frac{3\cos^2\theta - 1}{2} \right\rangle$

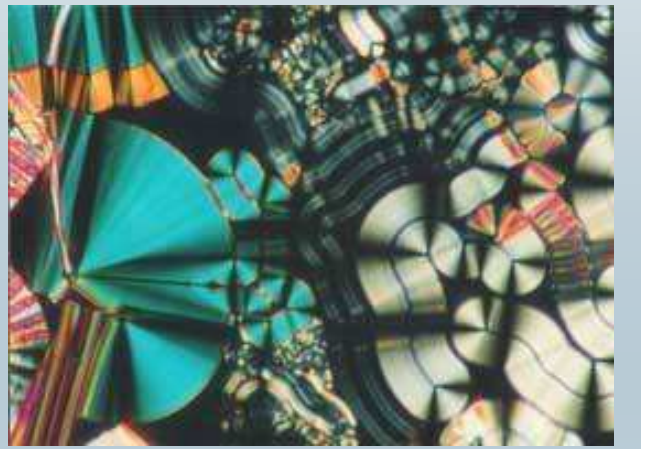
Določanje ureditvenega parametra na modelu zobotrebcev



$$\eta = \left\langle 2\cos^2\theta - 1 \right\rangle$$

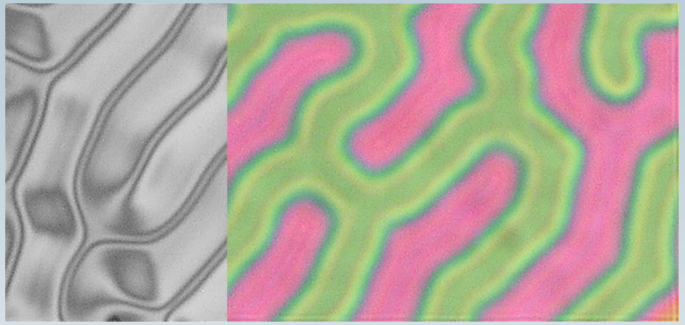
Dvolomnost

Barva tekočega kristala je odvisna od:



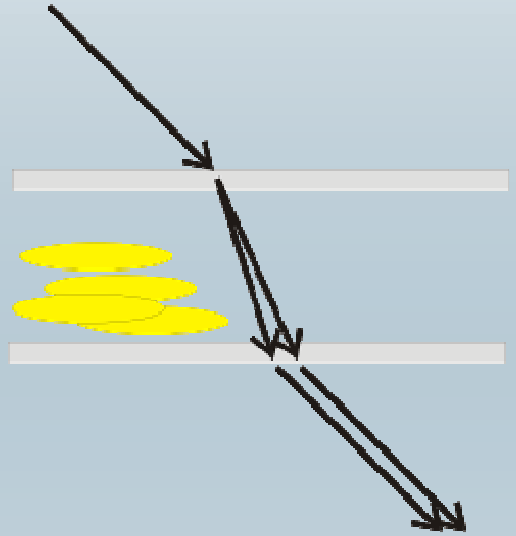
- **debeline vzorca**
- **dvolomnosti vzorca**
- **orientacije polarizatorjev**

Dvolomnost tekočega kristala je odvisna od:



- **reda, ureditvenega parametra**
- **smeri molekul**

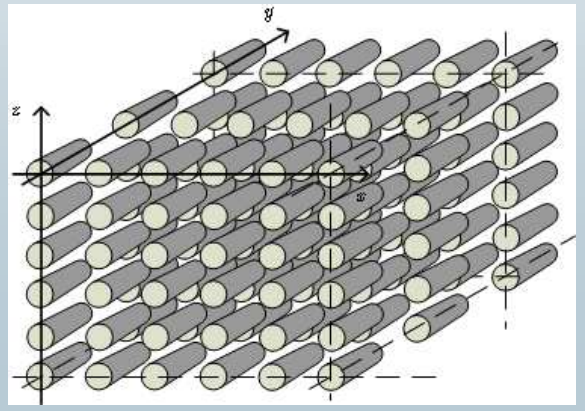
Dvolomnost

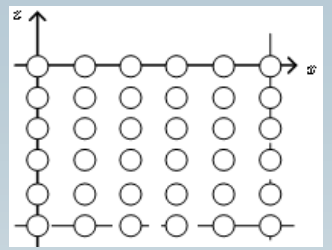


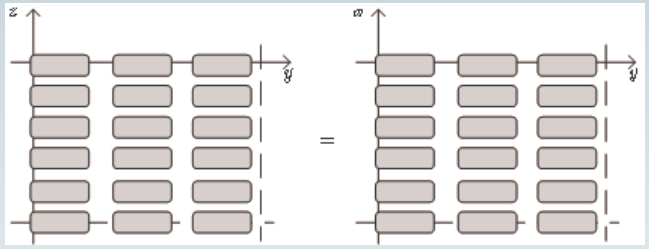
Svetloba s polarizacijo pravokotno na dolge osi molekul ima manjšo hitrost kot svetloba s polarizacijo vzporedno z dolgimi osmi molekul.

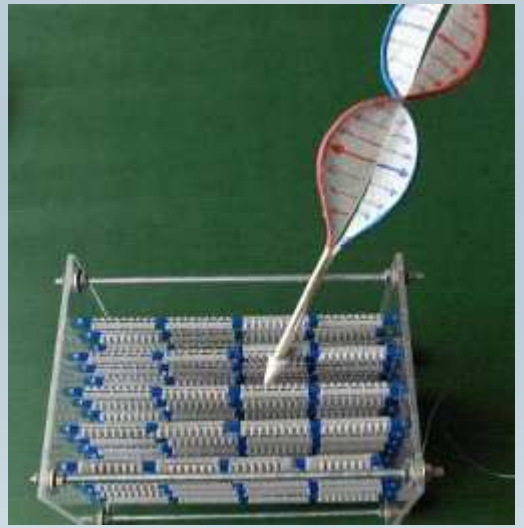
Tekoči kristali imajo običajno zelo veliko razliko med lomnima količnikoma za obe polarizaciji (0.1- 0.3).

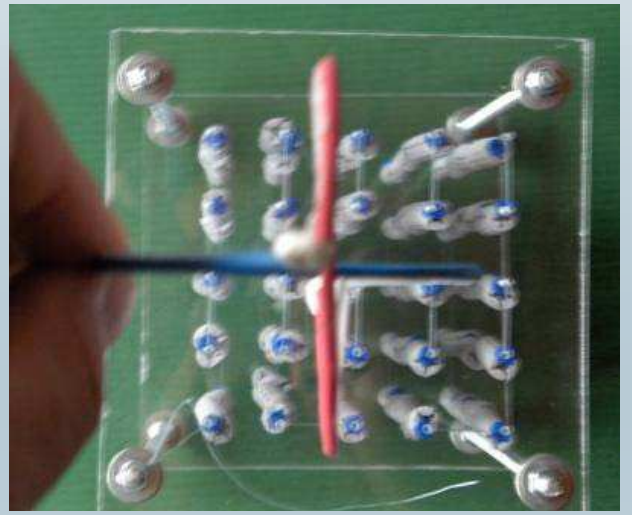
Vzroki za dvolomnost

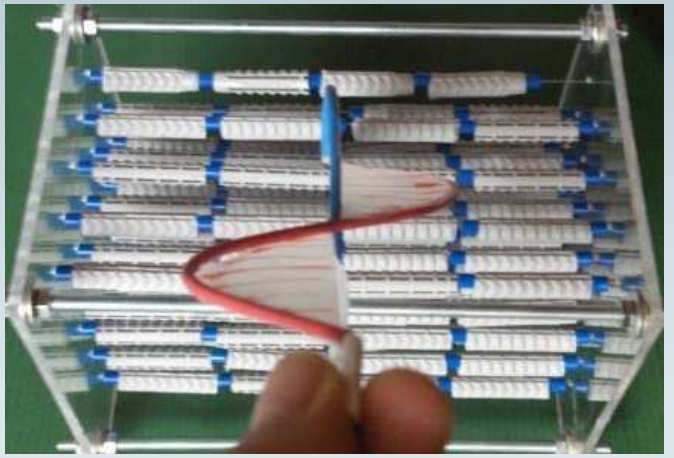












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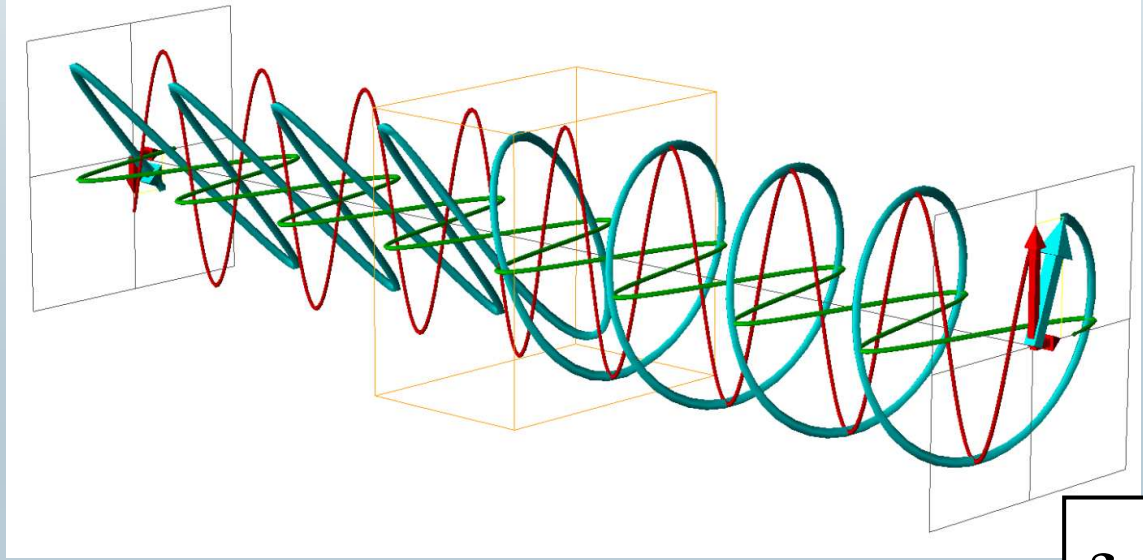
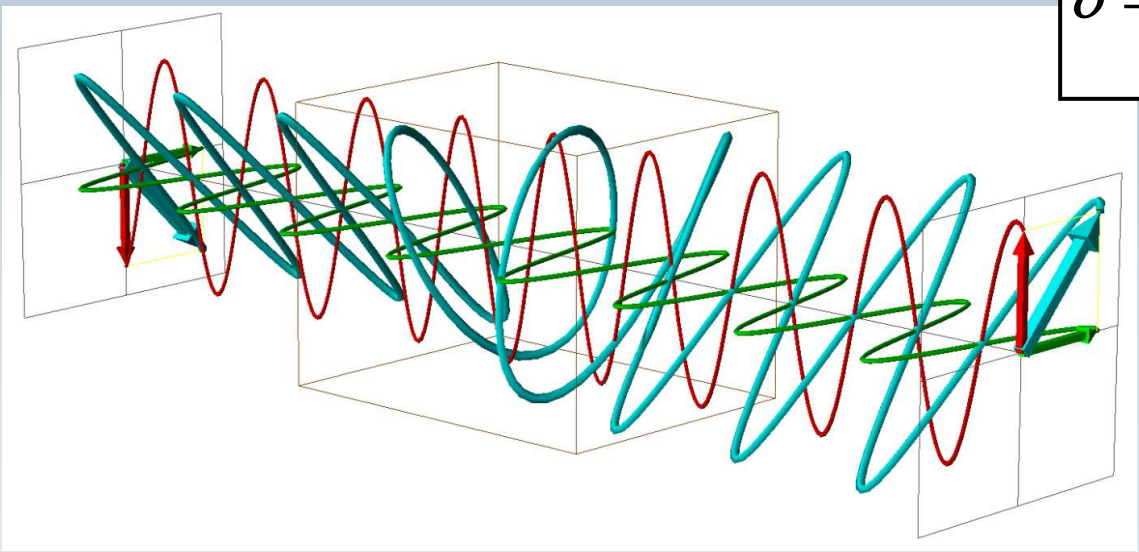
Kaj se dogaja pri prehodu ?

$\lambda/4$ plošča

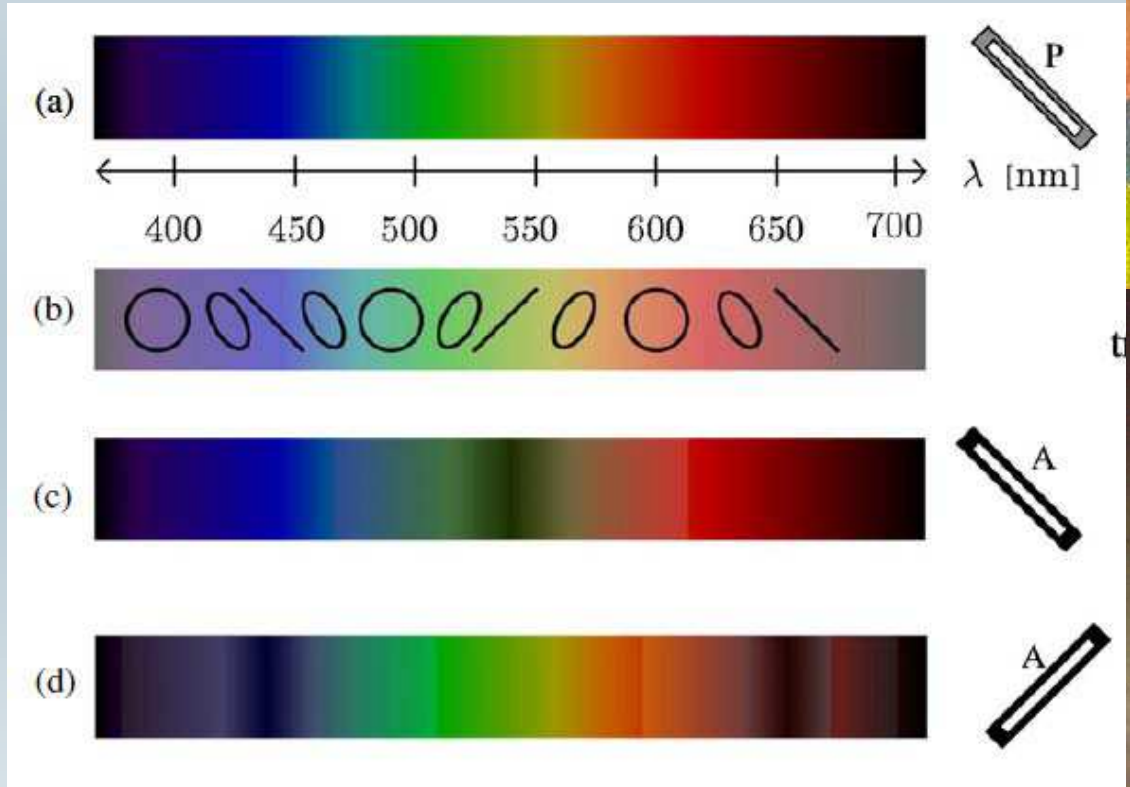


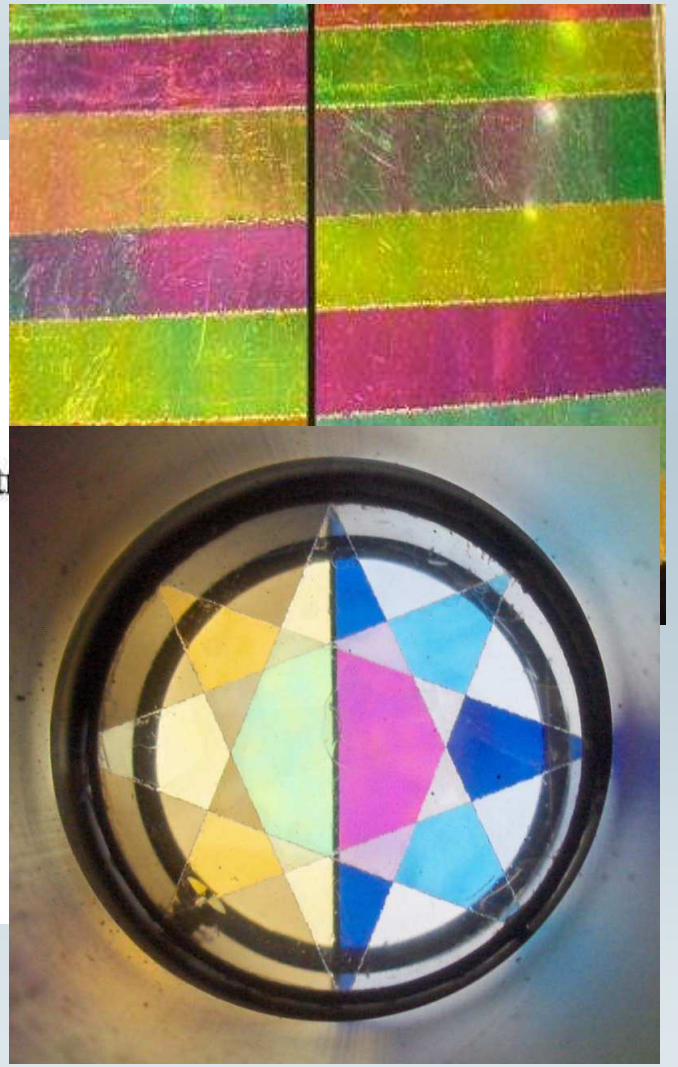
$$\delta = \frac{2\pi}{\lambda_0}\left(n_r - n_i\right)d$$

$\lambda/2$ plošča

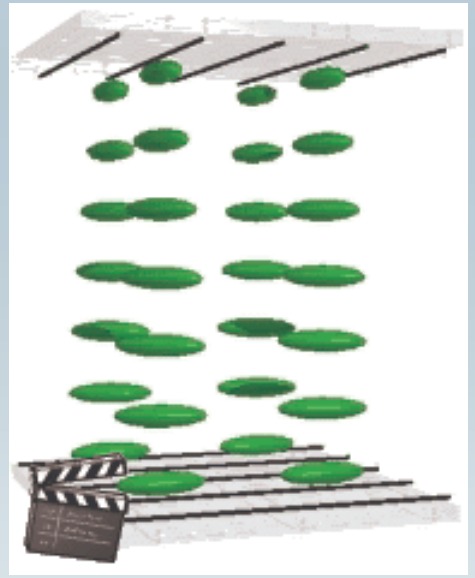


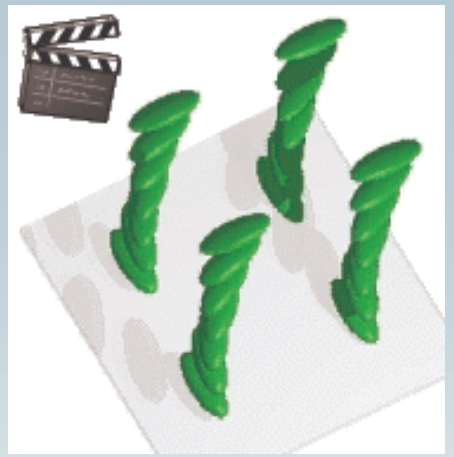
Kako je pri prehodu bele svetlobe?



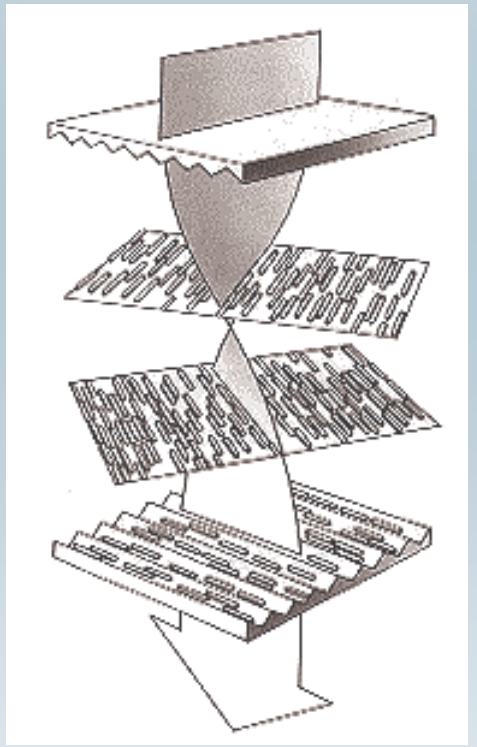


Kako delujejo prikazalniki?





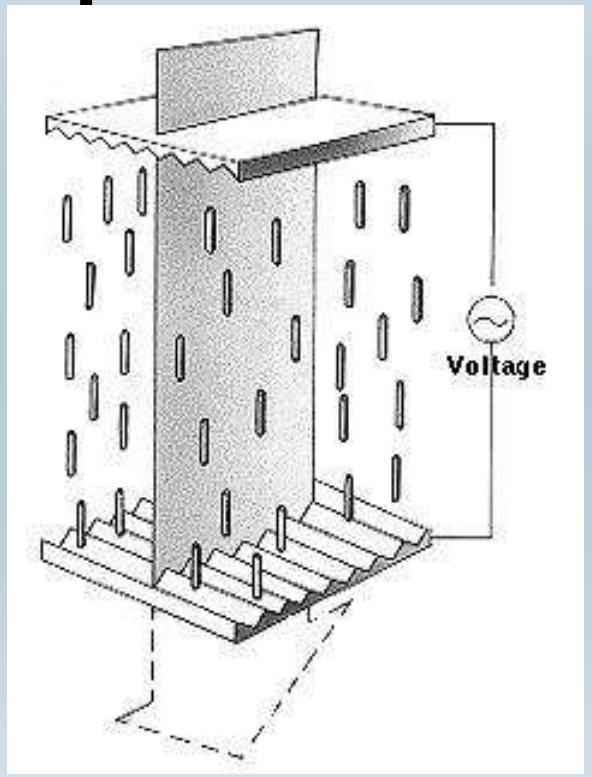
polarizator



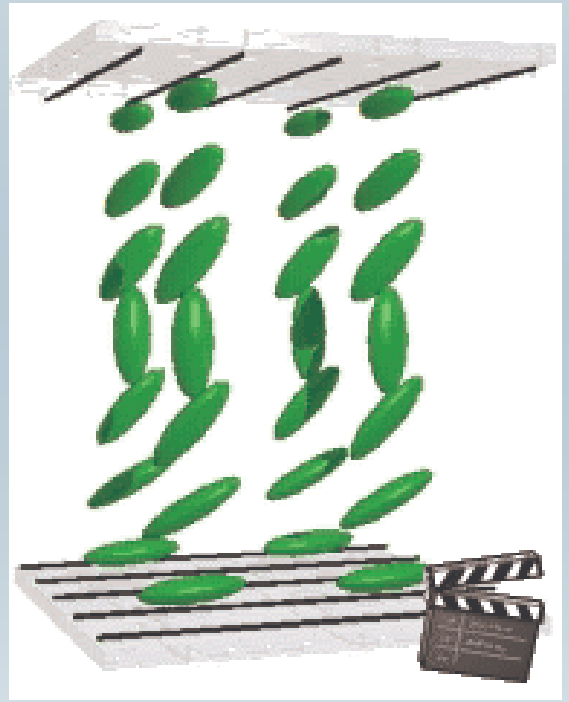
analizator

Prikazalnik

polarizator

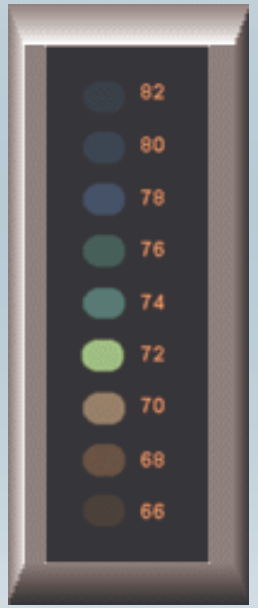


analizator

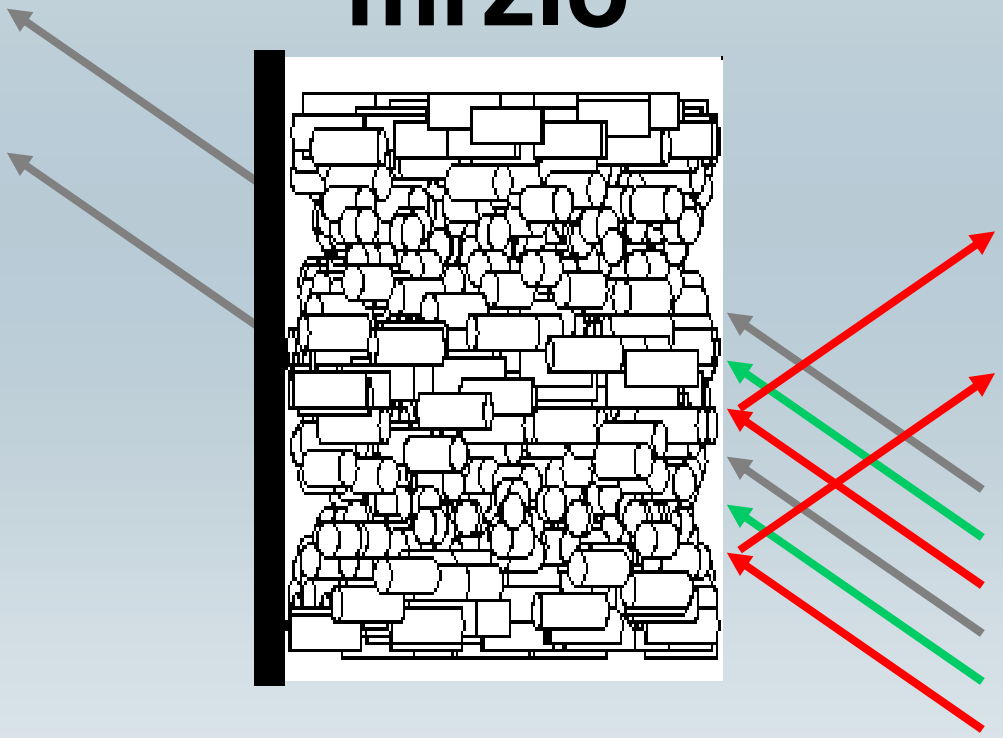


električno polje zasuče dolge osi molekul v smeri polja

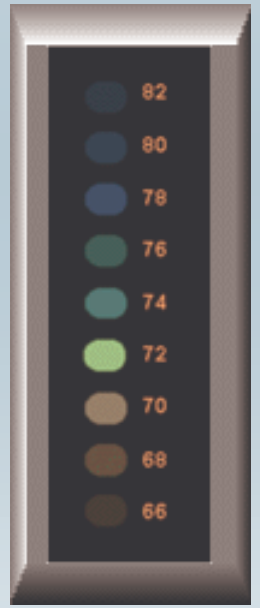
Termometri



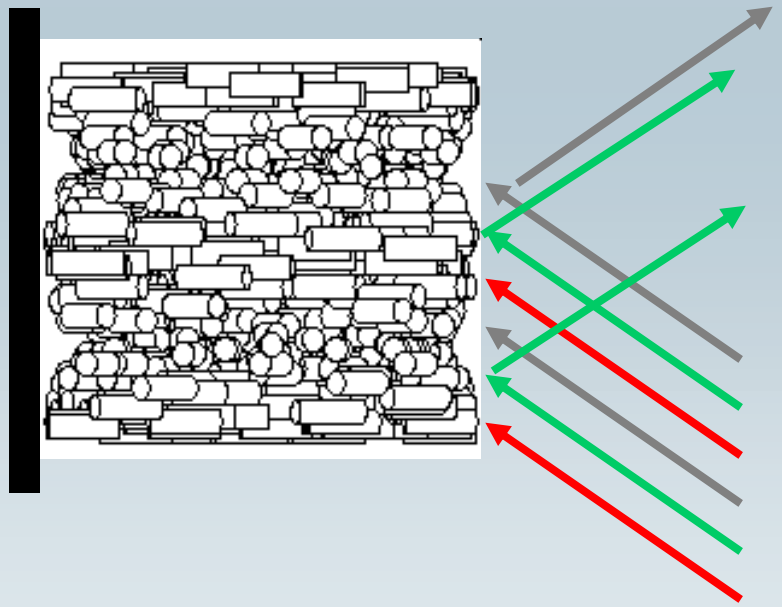
mrzlo



Termometer

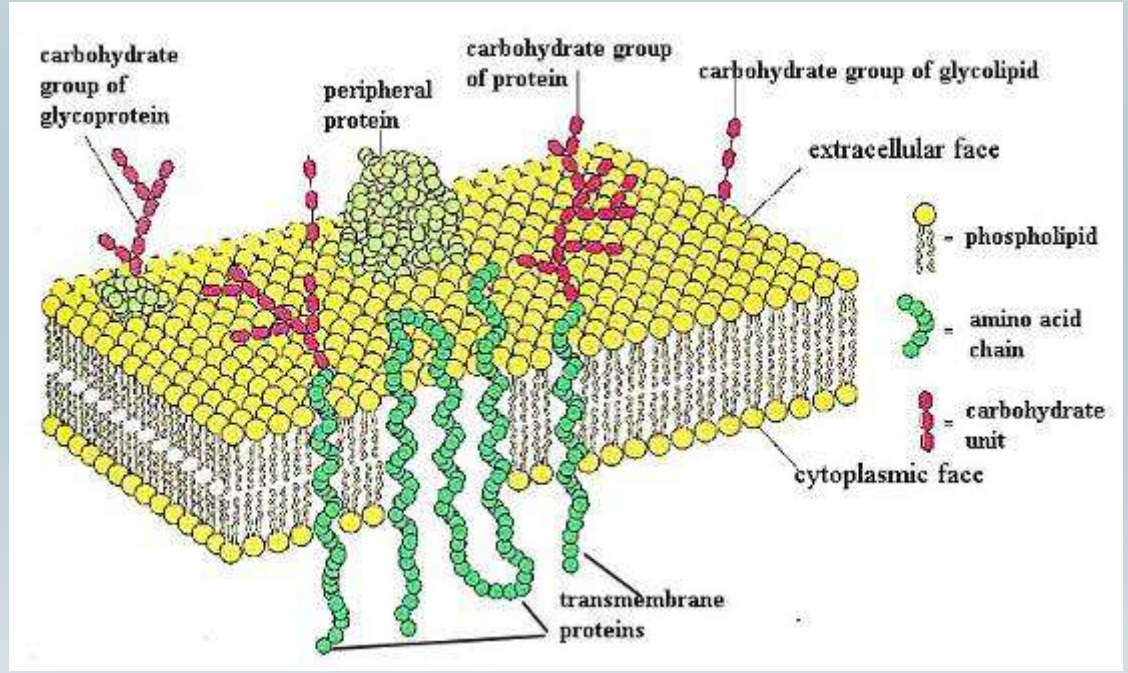


vroče



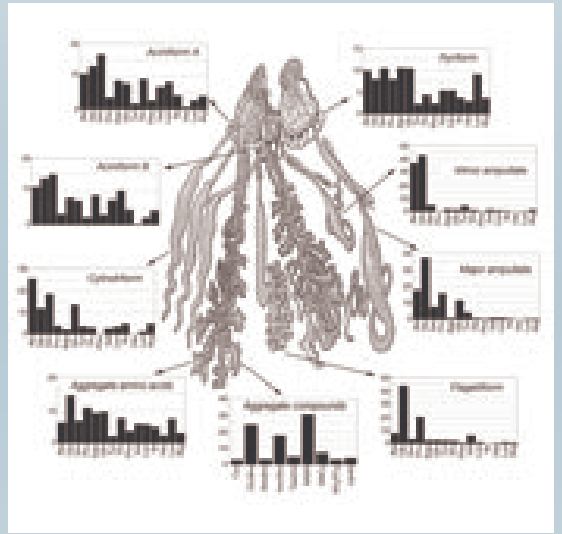
Tekoči kristali v naravi

Membrane v živih bitjih

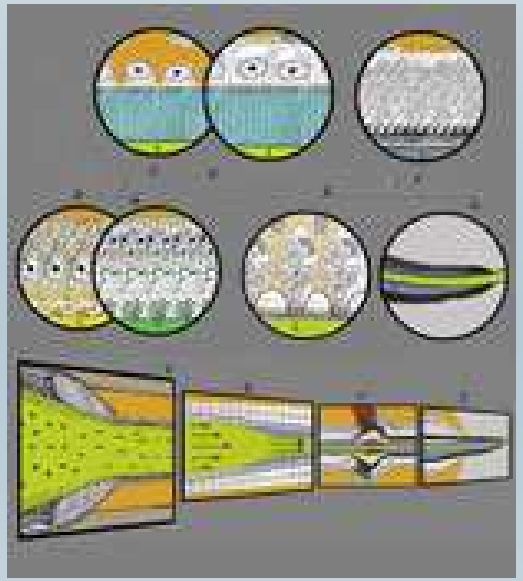


Tekoči kristali v naravi

Svila

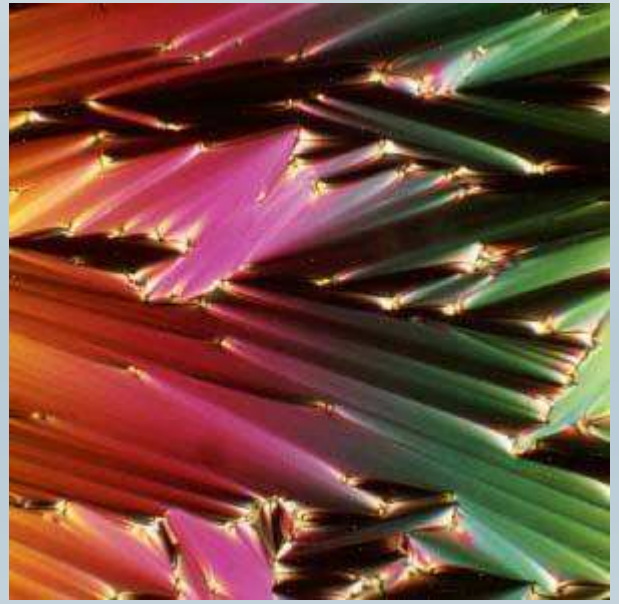


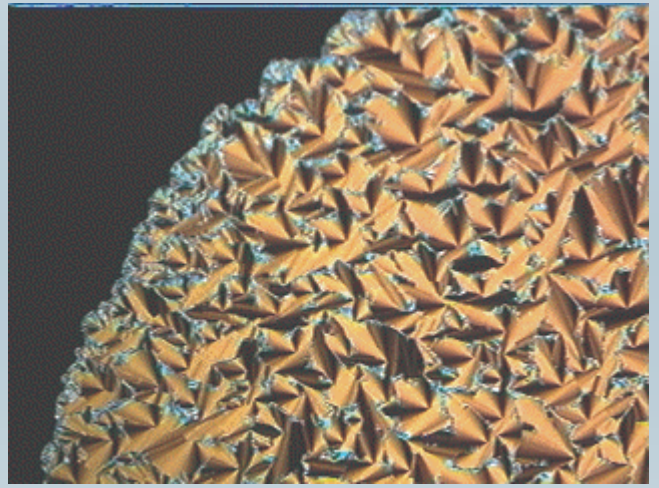
V različnih žlezah se tvorijo snovi, ki na zraku polimerizirajo v vlakna pajkove mreže.



Med tokom skozi šobe, se podolgovate molekule uredijo.

Smektiki

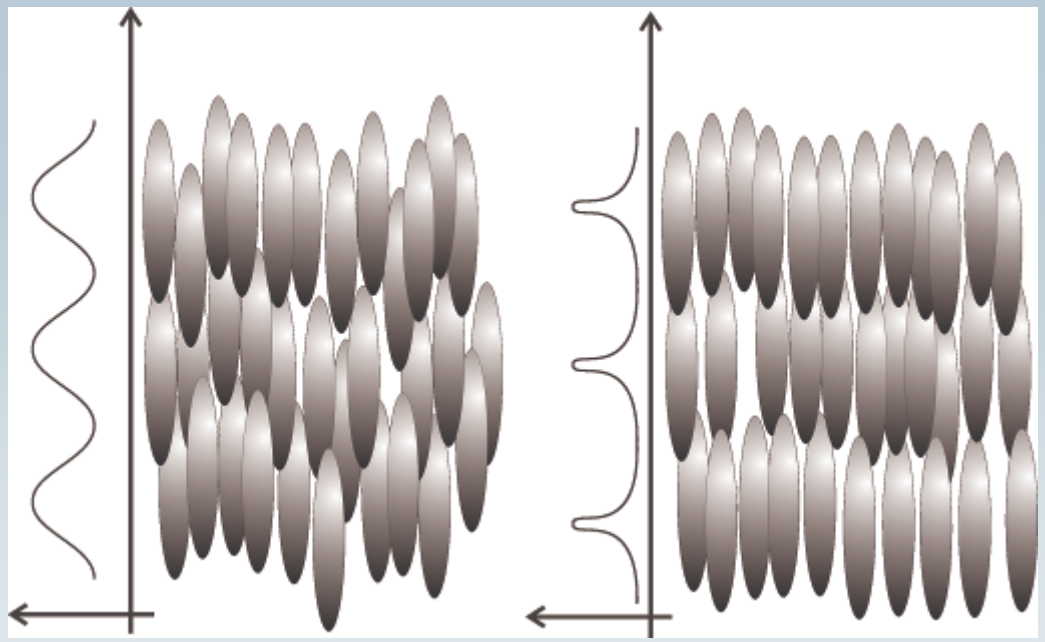


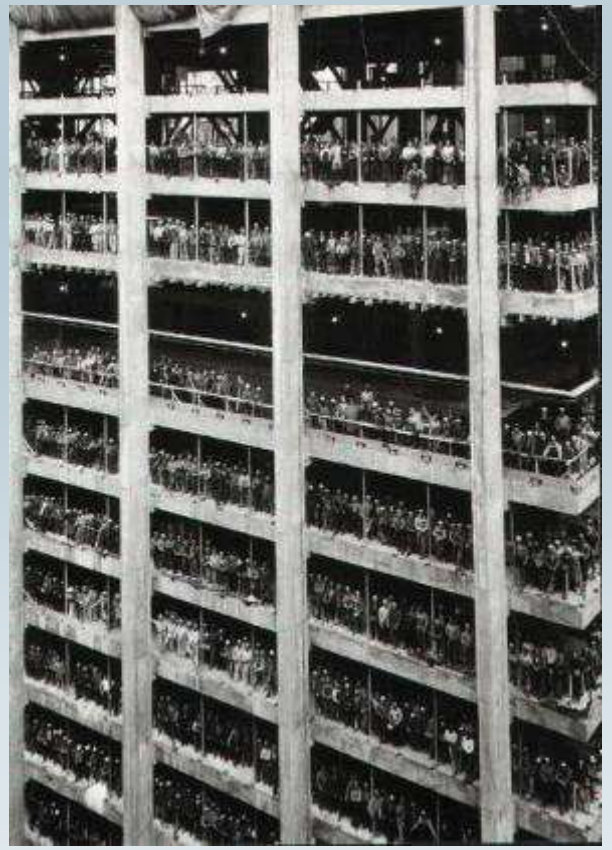


Kako opisati smektični red?

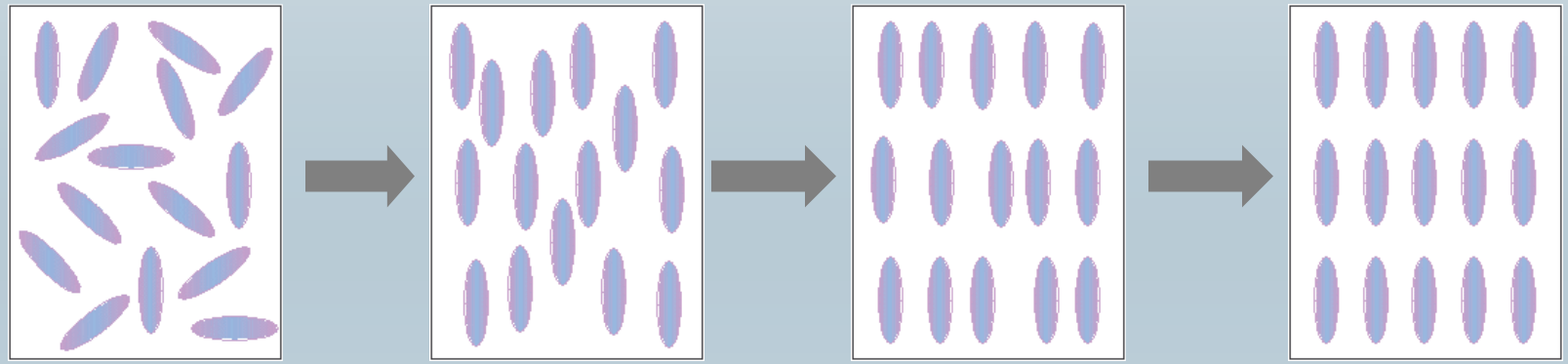
- **smektični red**
  - **koliko so molekule urejene v plasteh**

$$\psi = \langle \cos(qz) \rangle$$





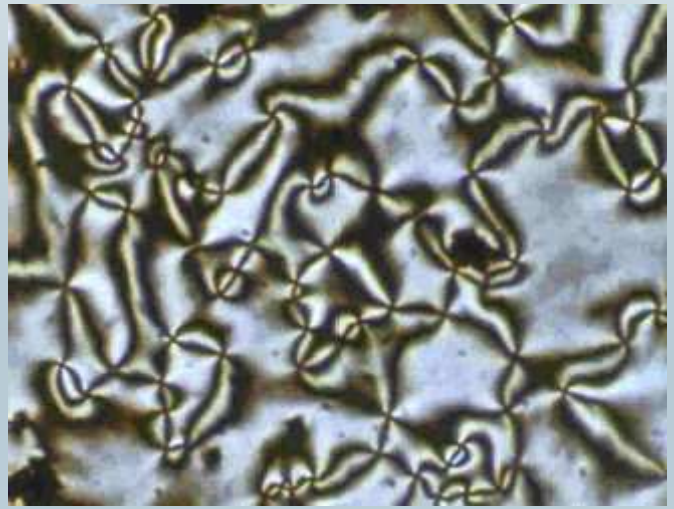
Kaj se dogaja pri hlajenju?

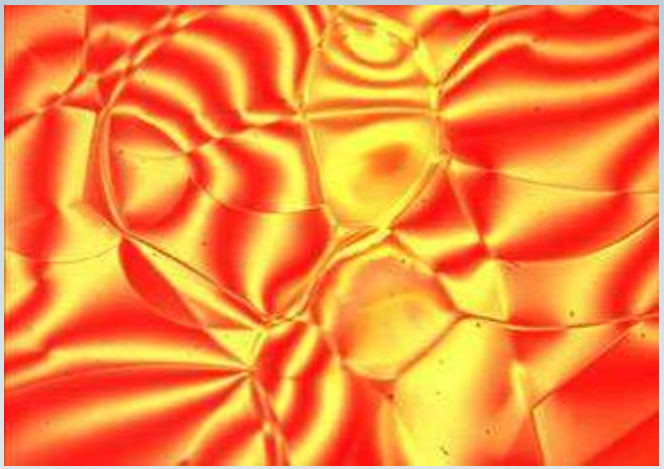


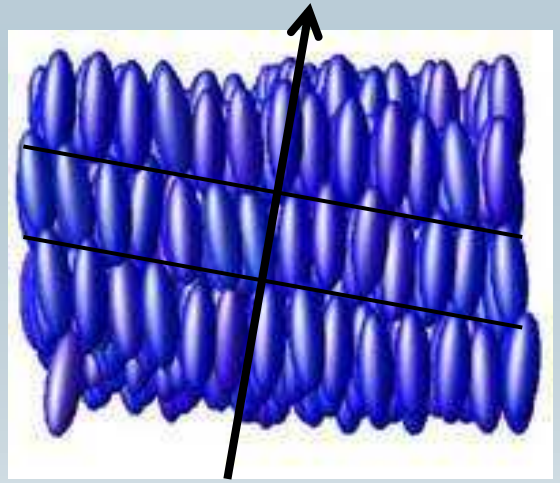
izotropna faza **nematska** **smektična** **kristal**

hlajenje→

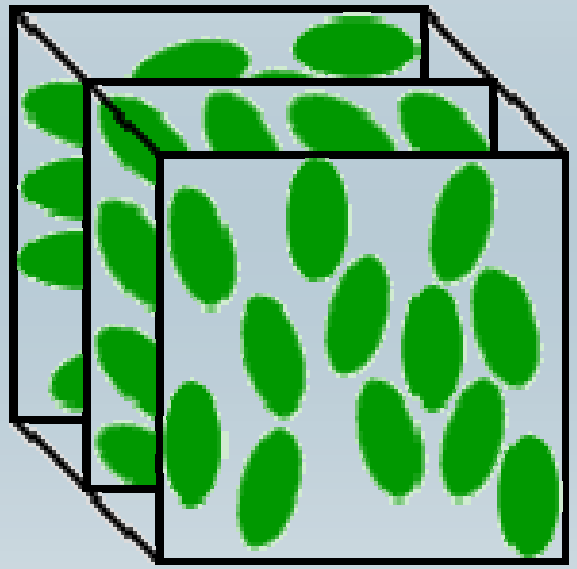
Nagnjeni smektiki



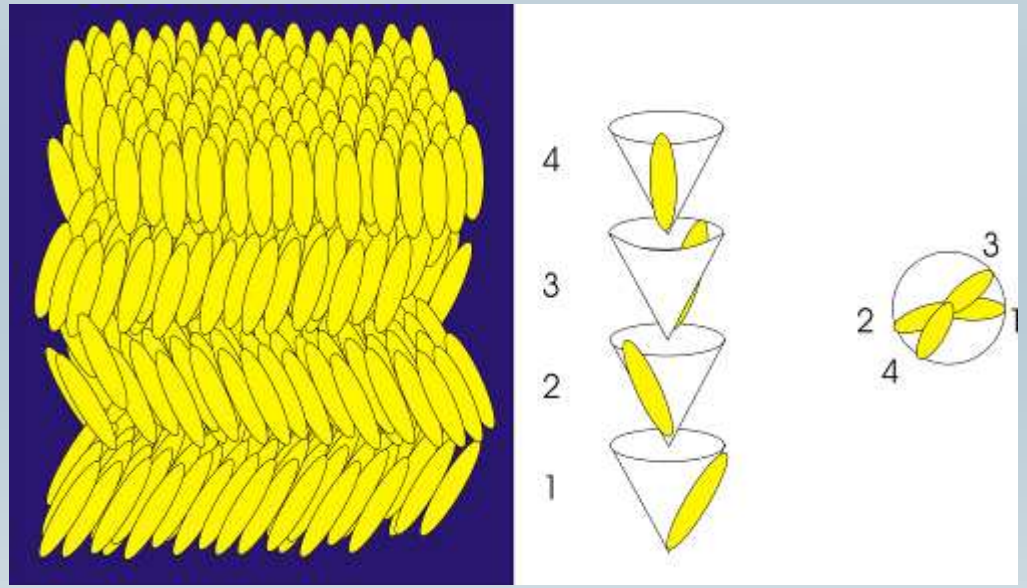




Bolj kompleksne strukture



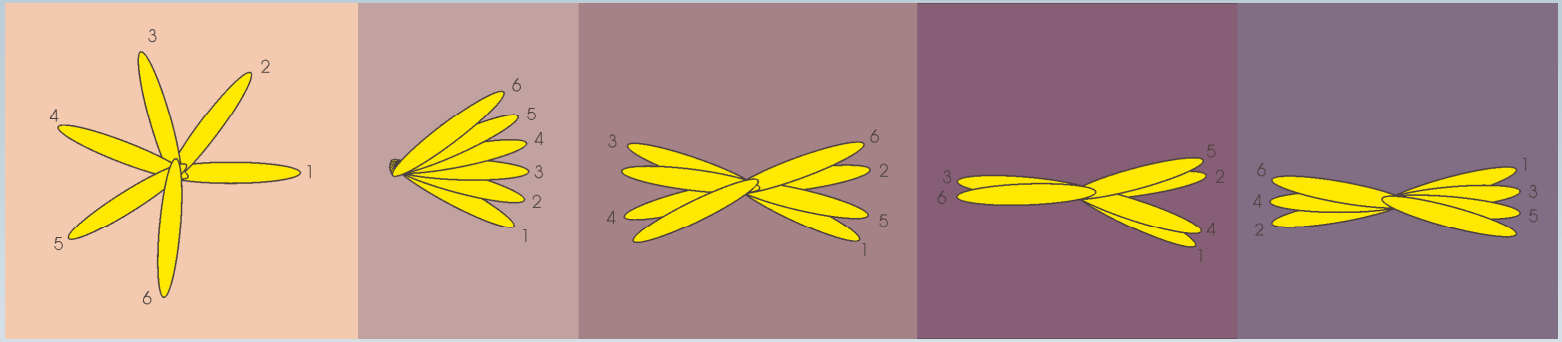
kiralni nematik ali holesterik



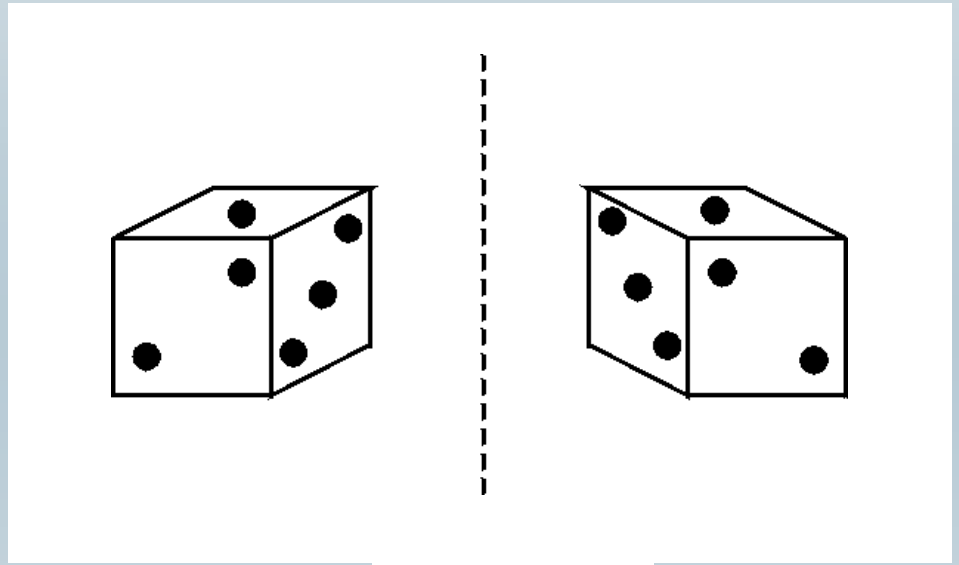
kiralni polarni smektik

Bolj kompleksne strukture

$$SmC^*_{\alpha} \rightarrow SmC^* \rightarrow SmC^*_{FI2} \rightarrow SmC^*_{FI1} \rightarrow SmC^*_{A}$$

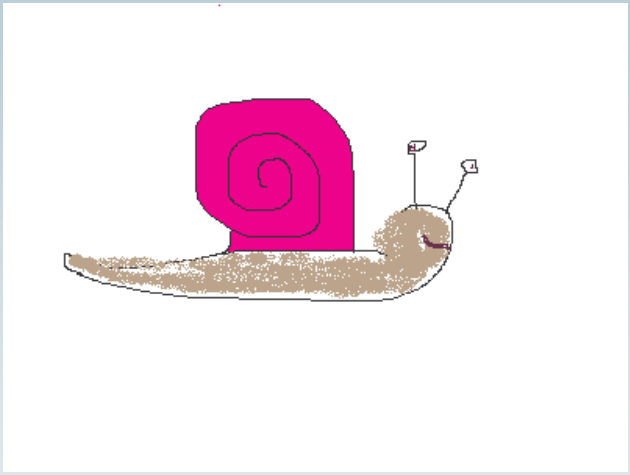


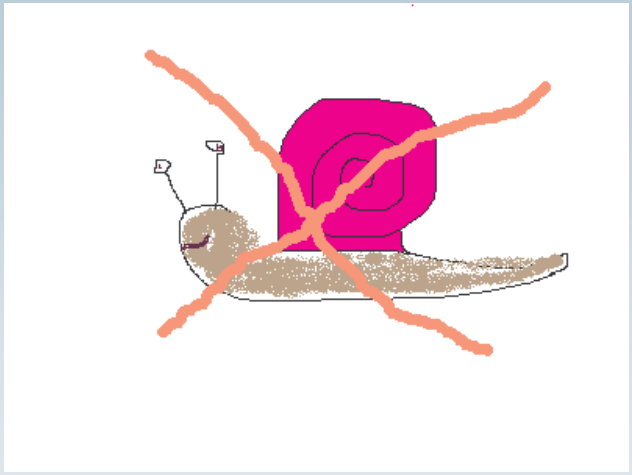
Kaj je to kiralnost?



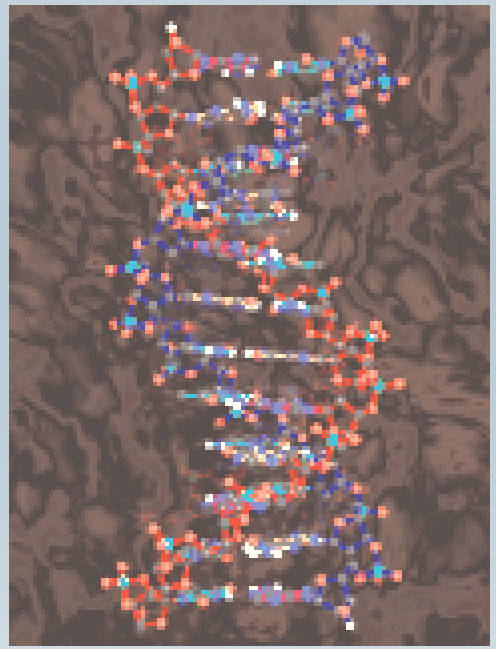
Predmet, ki se razlikuje od svoje zrcalne slike, je kiralen.

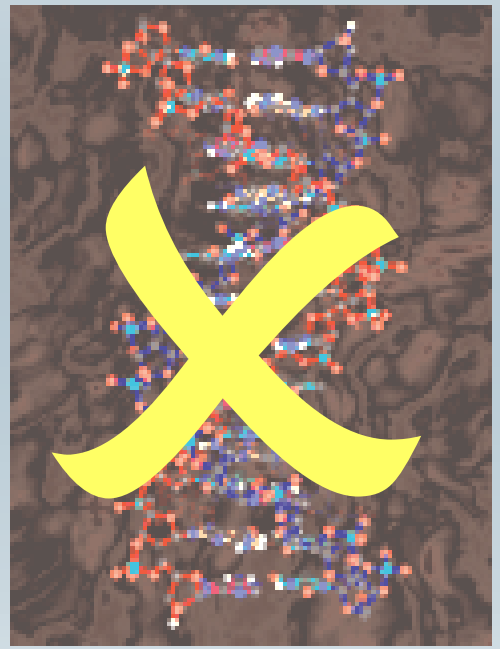
Kiralnost v naravi





Kiralnost v naravi



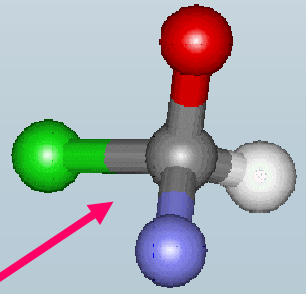


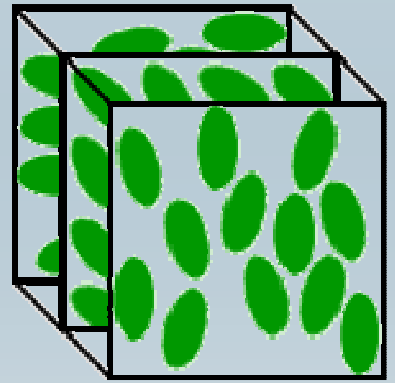
amino-kisline – desno sučne

sladkorji – levo sučni

Nivoji kiralnosti

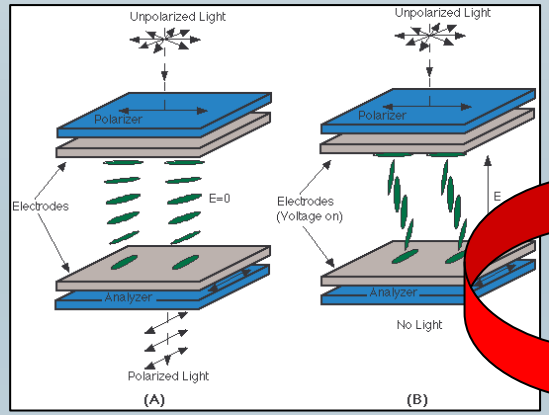
– osnovna kiralnost
– molekularna kiralnost
– strukturna kiralnost
– kiralnost objektov





Kuball, LCToday 1999

Prenos kiralnosti



med objekti

predmeti

strukture

med strukturami

dopanti

molekule

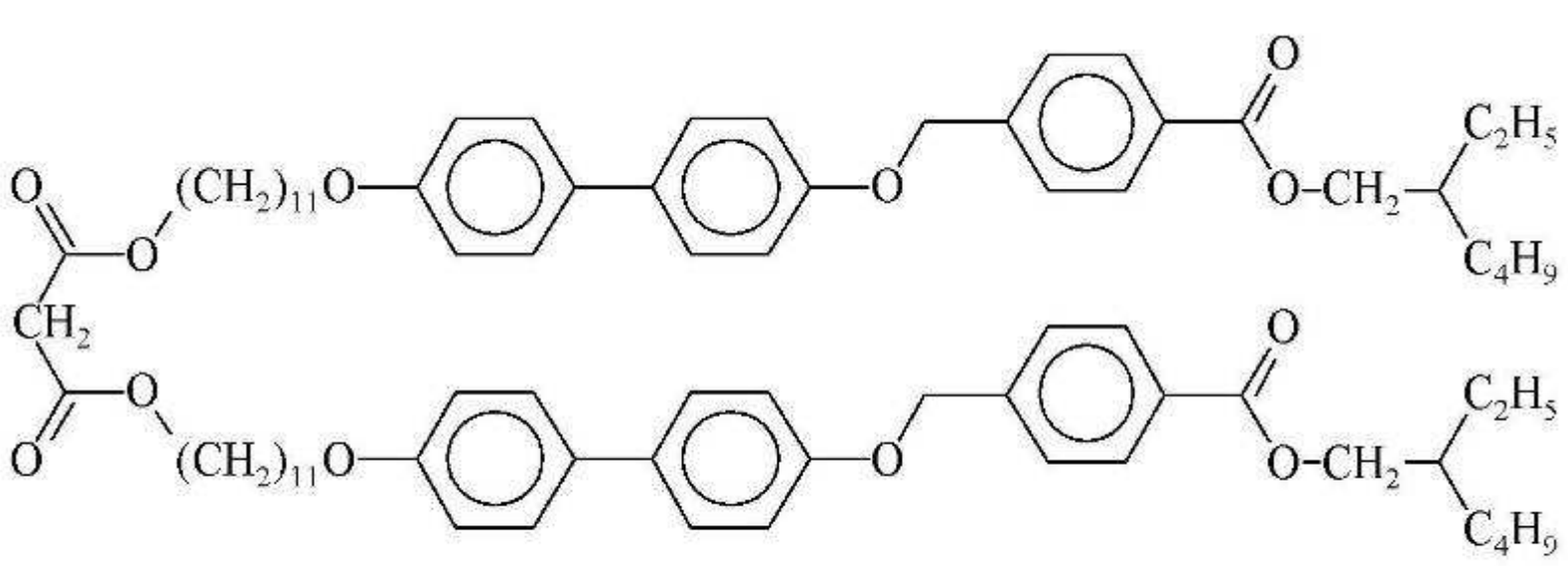
med molekulami

Labirinti v tankih filmih smektičnega tekočega kristala*

Nataša Vaupotič[1,2], Mojca Čepic[1,3], Damian Pociecha[4], Ewa Gorecka[4], Jozef Mieczkowski[4]

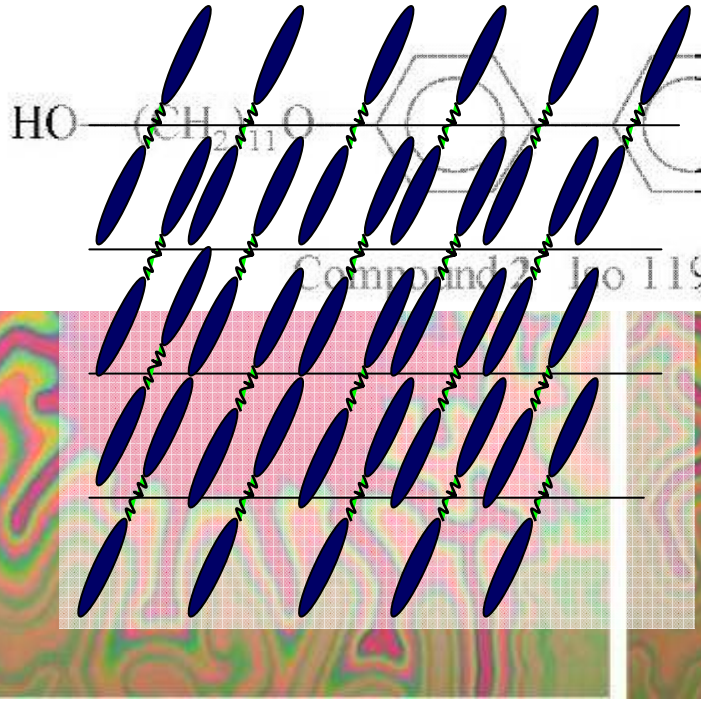
[1] Inštitut Jožef Stefan, Ljubljana
[2] Oddelek za fiziko, Fakulteta za naravoslovje in matematiko (FNM), Univerza v Mariboru
[3]Oddelek za fiziko in tehniko, PeF, Univerza v Ljubljani
[4]Oddelek za kemijo, Univerza v Varšavi, Poljska

*Phys. Rev. Lett. 95, 207901 (2005)



Compound 1 Iso 122.9 S

obe spojini tvorita interkalirano SmC strukturo

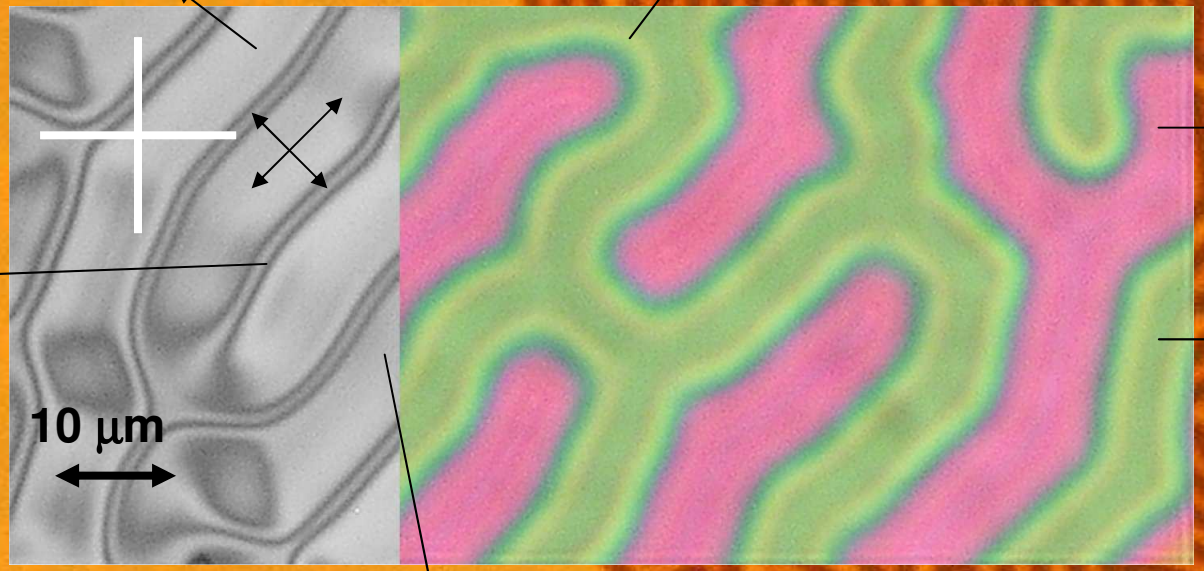


Compound 2 Iso 119.8 SmA 118.8 SmC

EKSPERIMENT

med prekrižanima polarizatorjema

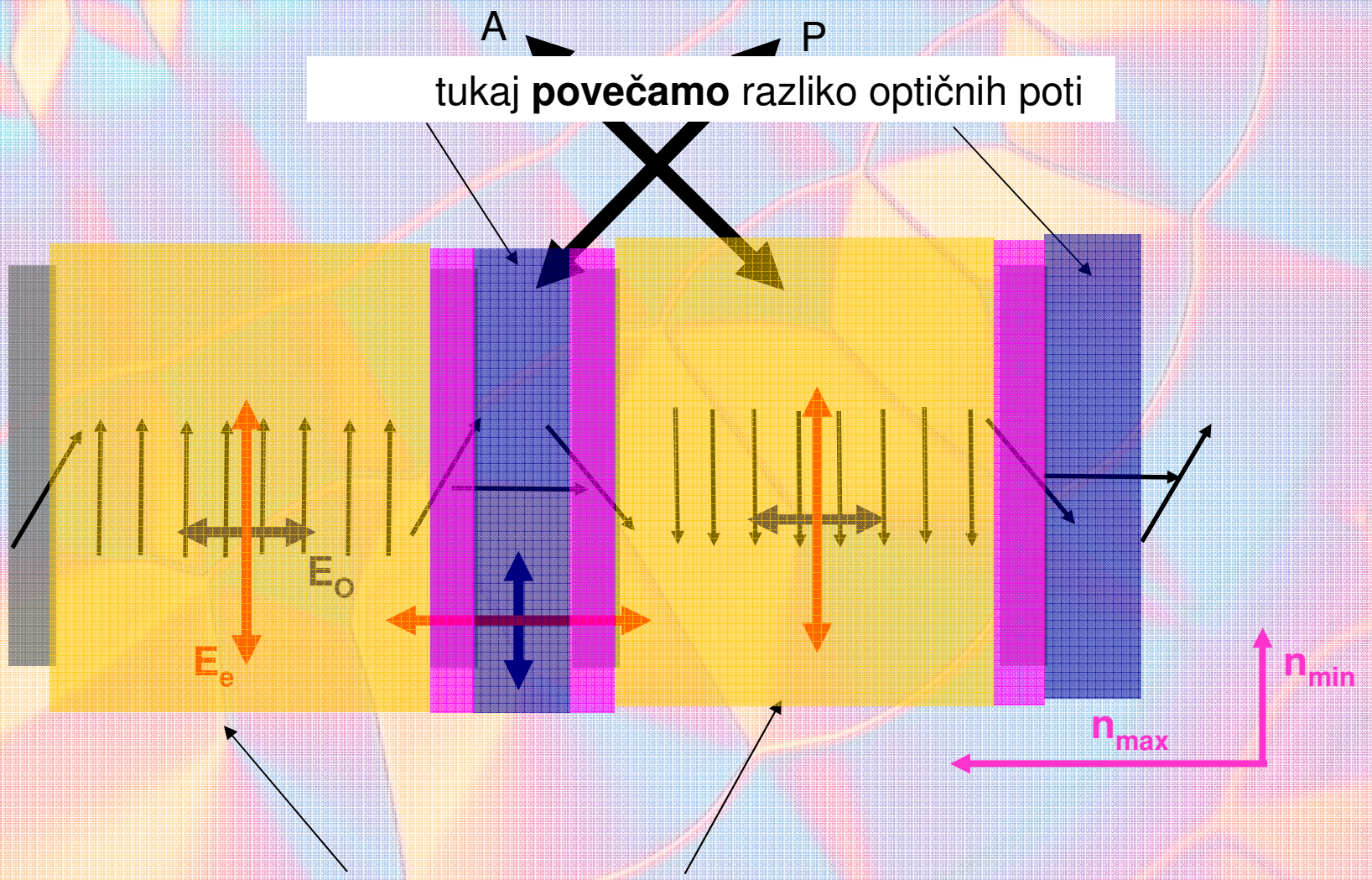
odboj



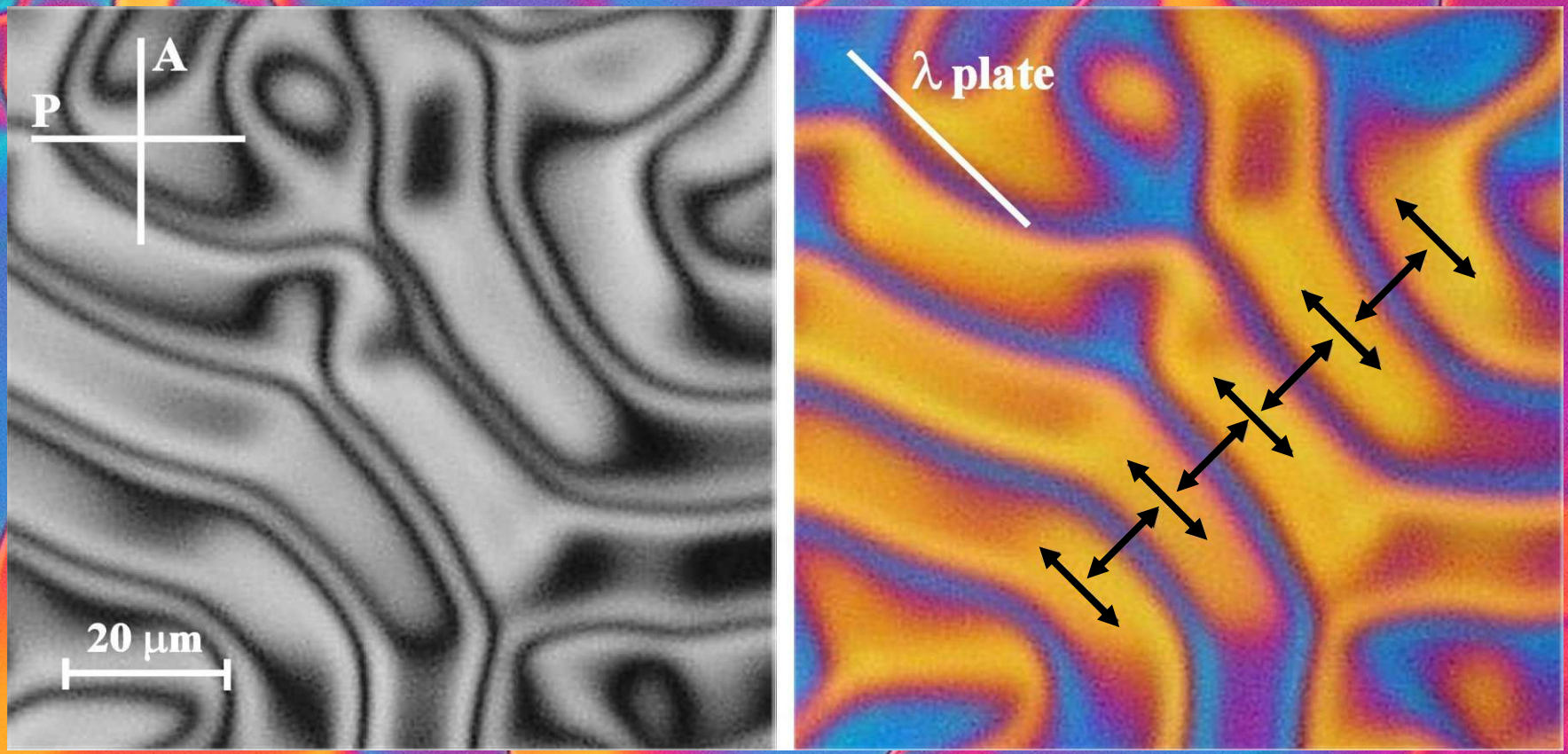
π - stena

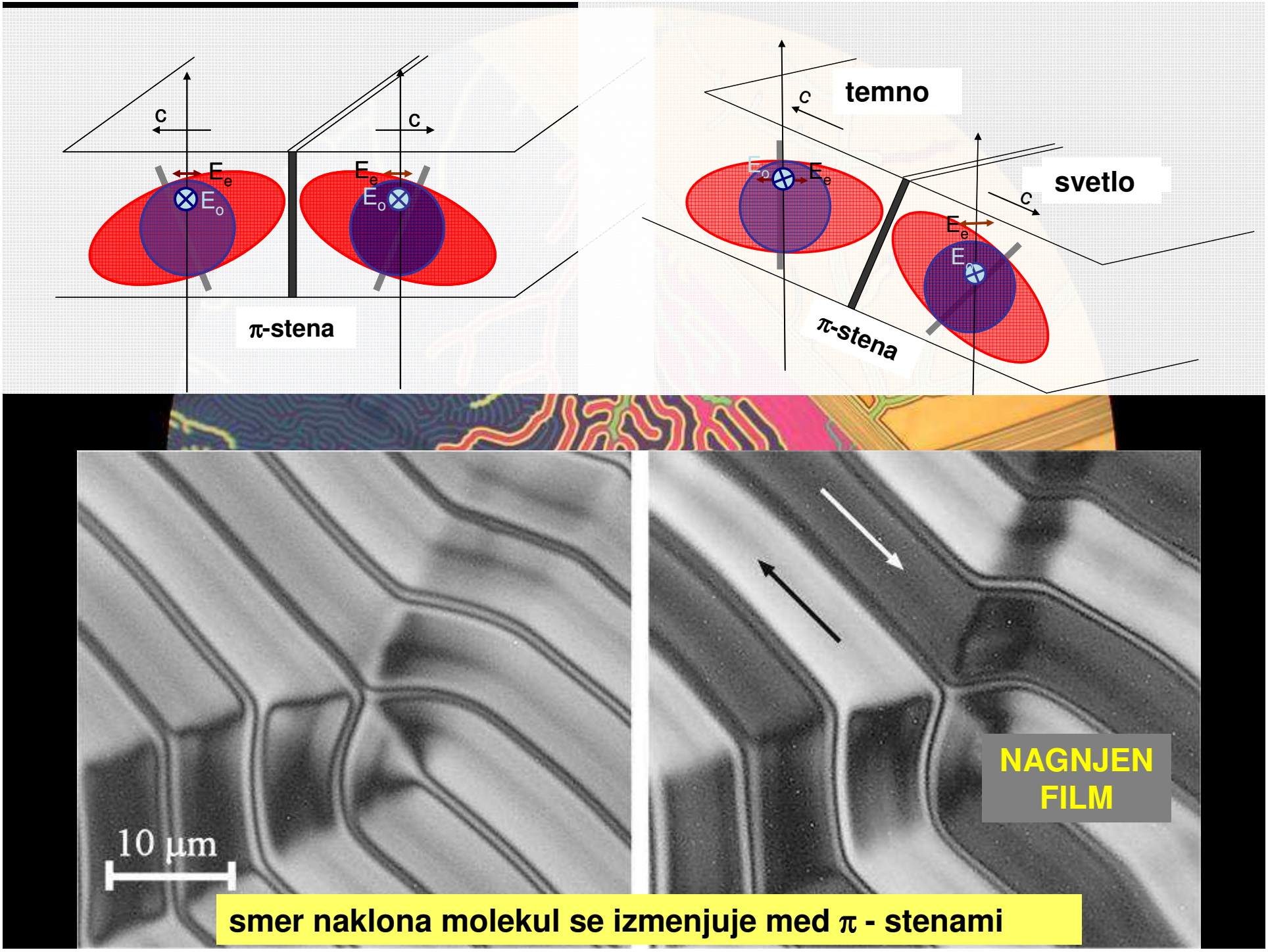
homogena ureditev molekul
→ spreminjanje debeline filma

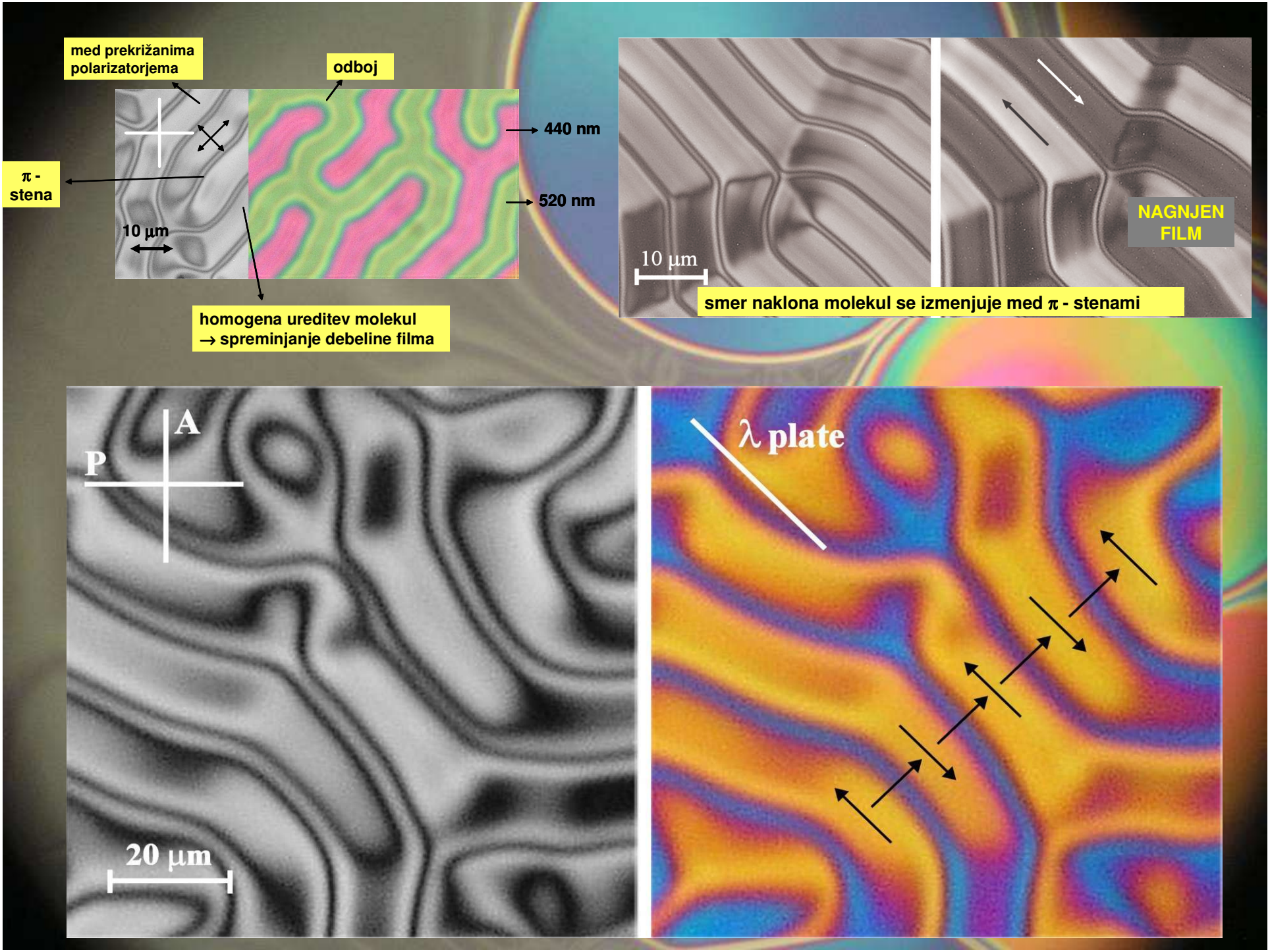
PLOŠČICA LAMBDA



PLOŠČICA LAMBDA

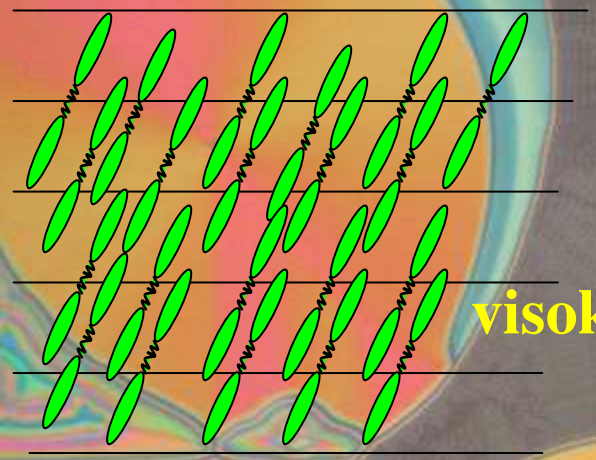



c
c
E_e
E_o
E_e
E_o
π-stena
c
temno
E_o
E_e
svetlo
c
E_e
E_o
π-stena
10 μm
NAGNJEN FILM
smer naklona molekul se izmenjuje med π - stenami


med prekrižanima polarizatorjema
odboj
440 nm
520 nm
π - stena
10 μm
homogena ureditev molekul
→ spreminjanje debeline filma
10 μm
NAGNJEN FILM
smer naklona molekul se izmenjuje med π - stenami
A
P
20 μm
λ plate

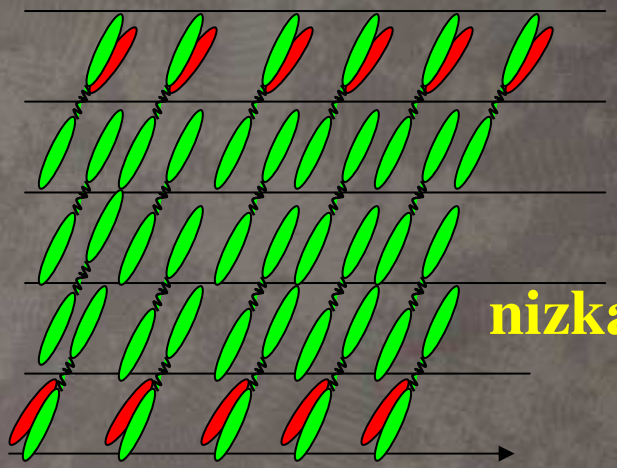
TEORETIČNA RAZMIŠLJANJA

labirintna nagubanost debeline filma



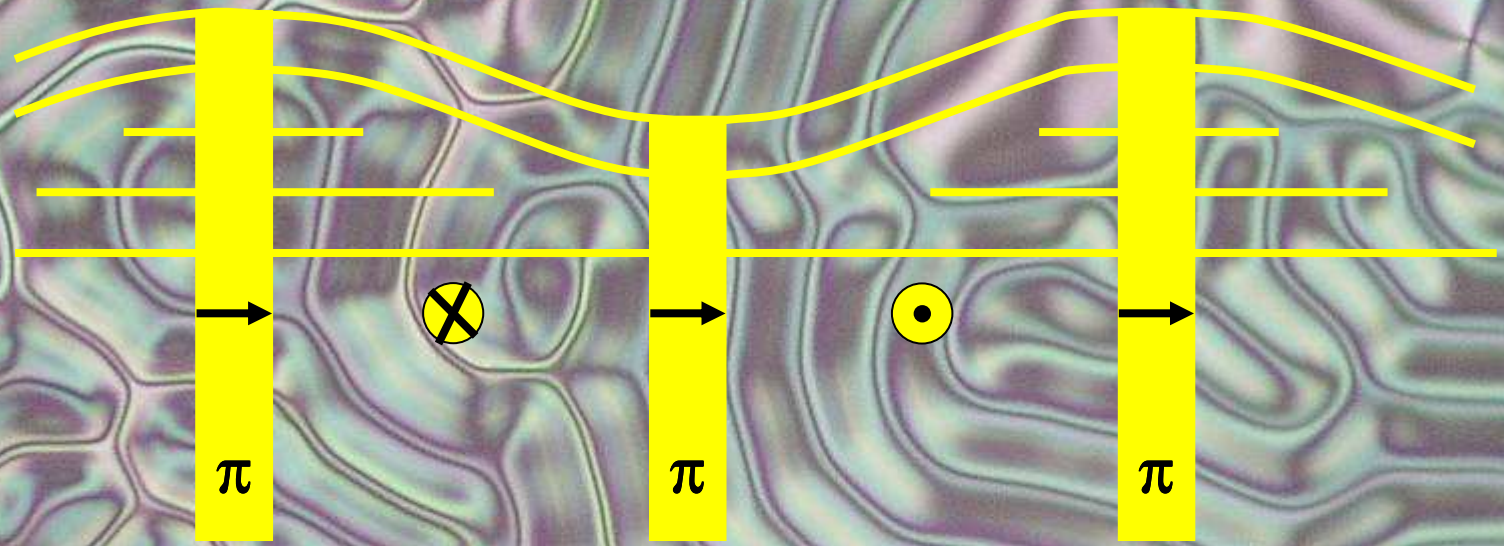
visoka *T*

površina se poveča



nizka *T*

Kako lahko sistem zmanjša debelino vrnje plasti?



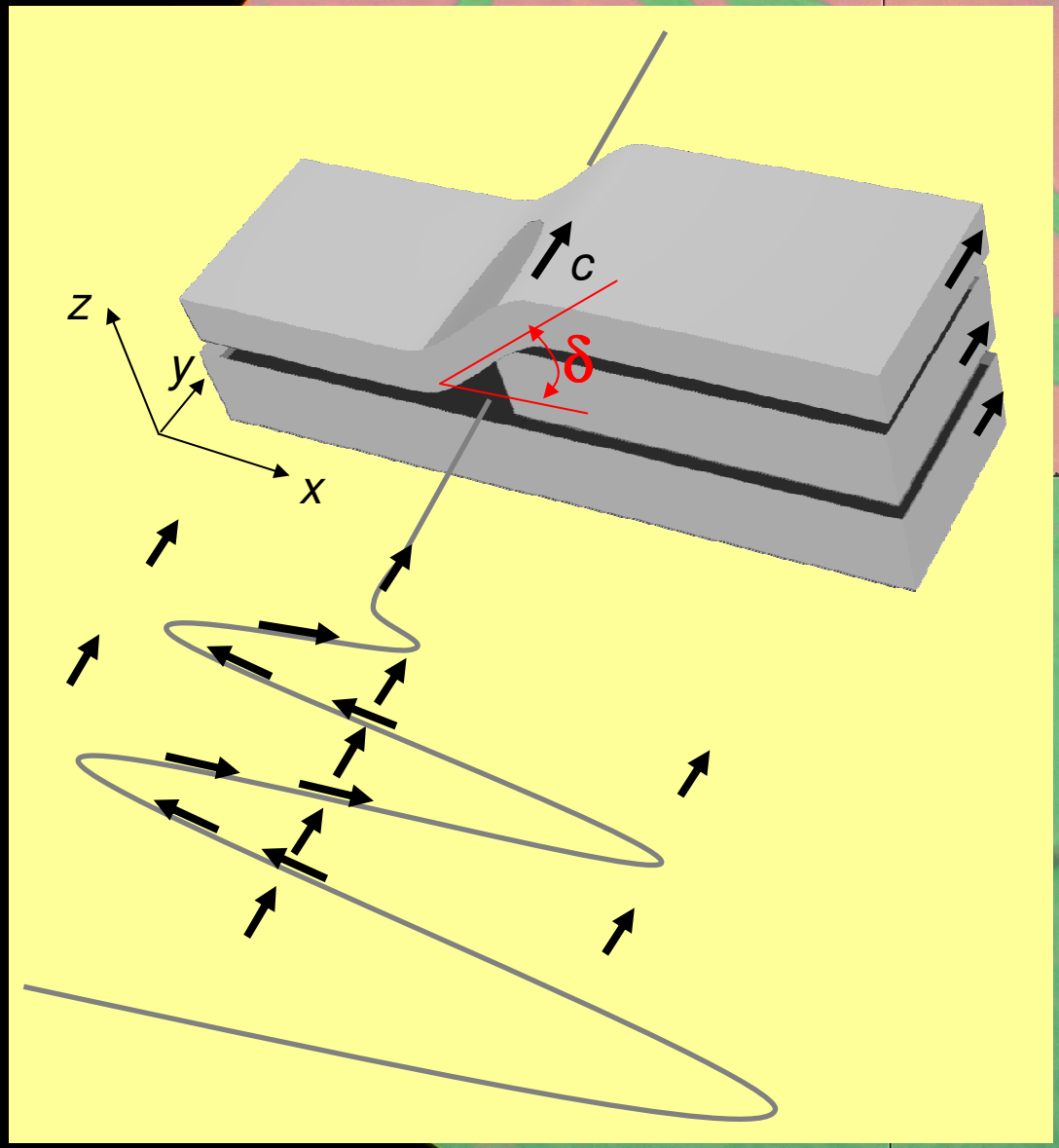
Ali so lahko defekti blizu površine ?

$\frac{\gamma}{\sqrt{KB}}$

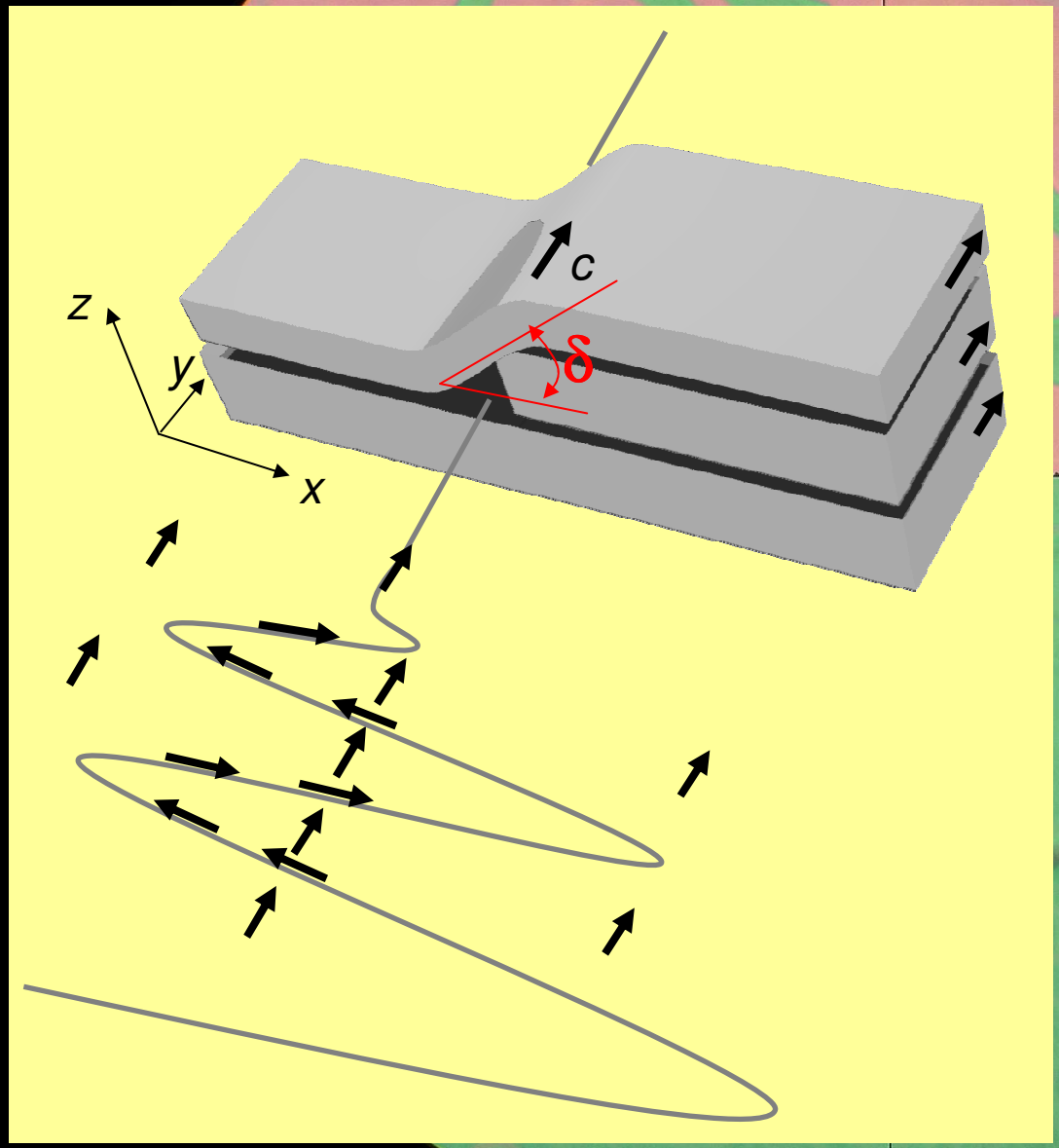
$\frac{\gamma}{\sqrt{KB}} > 1$ površina defekte odbija

$\frac{\gamma}{\sqrt{KB}} < 1$ površina defekte privlači

Vzrok za takšno prostorsko odvisnost c-direktorja?



Vzrok za takšno prostorsko odvisnost c-direktorja?



$$F_S = \frac{1}{2} W_S(T) \left(1 - \frac{\delta^2}{\delta_0^2}\right)^2 d_S$$

$$F_{edge} = \sqrt{KB}\, d_0^2 / (2r_c) + E_c$$

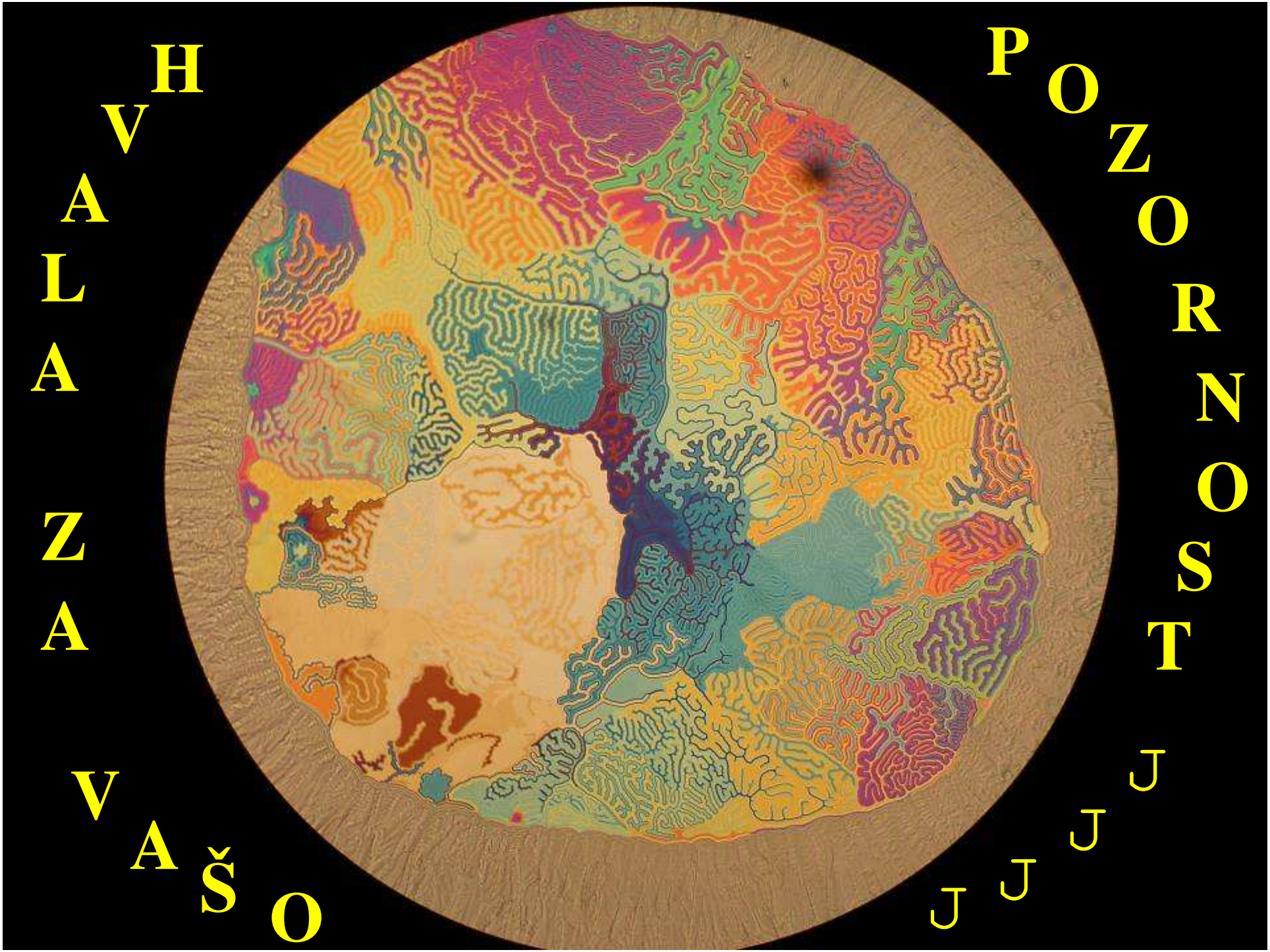
$$F_\pi = \frac{K\pi^2}{2d_S^2} d_S d$$

$$F = F_\pi + F_{edge} N + F_S$$

$$d_S \propto d^{0.5}$$

$$W_S(T) < 2\sqrt{KB}\,\delta_0$$

potreben pogoj ta tvorbo labirintne strukture


HVALA ZA VAŠO POZORNOST
J J J J