

Modeliranje širjenja svetlobe vzdolž ograjenih tekočekristalnih defektnih linij

Avtor Miha Čančula

Mentor prof. dr. Slobodan Žumer

Somentor doc. dr. Miha Ravnik

3. september 2013

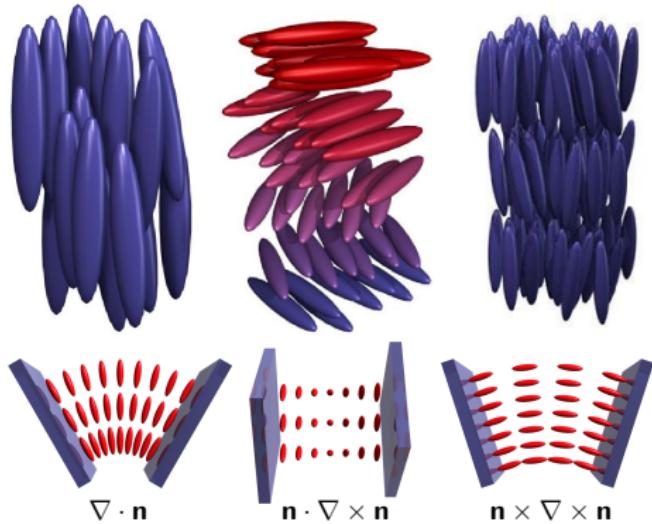
Tekoči kristali

- Lastnosti tekočin in kristalov
- Orientacijski red
 - Direktor \mathbf{n}
 - Stopnja reda S
 - Simetrija $\mathbf{n} \leftrightarrow -\mathbf{n}$
- Delni pozicijski red



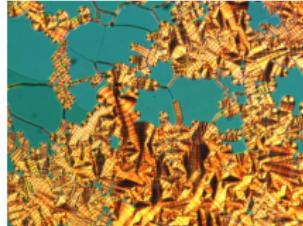
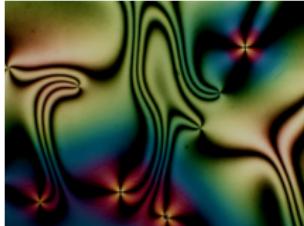
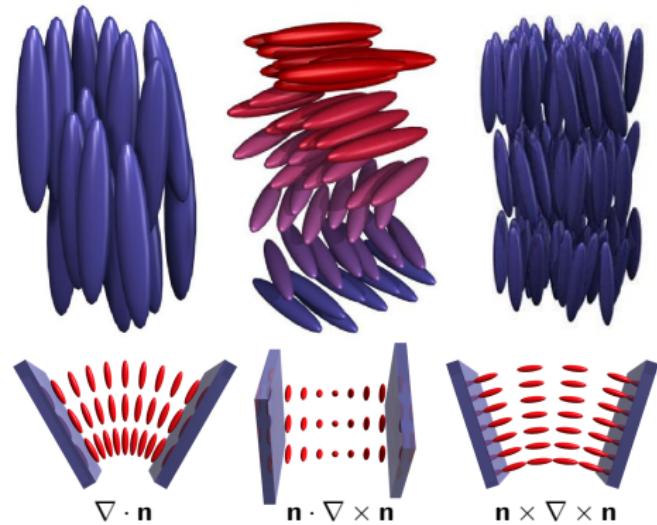
Tekoči kristali

- Lastnosti tekočin in kristalov
- Orientacijski red
 - Direktor \mathbf{n}
 - Stopnja reda S
 - Simetrija $\mathbf{n} \leftrightarrow -\mathbf{n}$
- Delni pozicijski red
- Dvolomnost
- Nadzor z zunanjimi polji
- Elastične deformacije direktorja



Tekoči kristali

- Lastnosti tekočin in kristalov
- Orientacijski red
 - Direktor \mathbf{n}
 - Stopnja reda S
 - Simetrija $\mathbf{n} \leftrightarrow -\mathbf{n}$
- Delni pozicijski red
- Dvolomnost
- Nadzor z zunanjimi polji
- Elastične deformacije direktorja



Elektromagnetno valovanje

Maxwellove enačbe

$$\nabla \cdot \mathbf{D} = \rho_f \quad \nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \quad \nabla \times \mathbf{H} = \mathbf{J}_f + \frac{\partial \mathbf{D}}{\partial t}$$

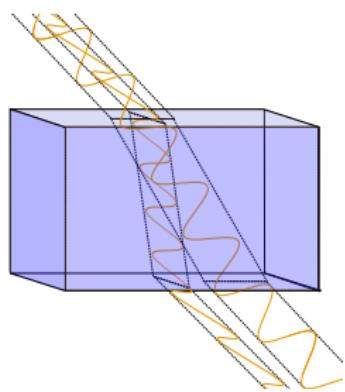
Konstitutivni zvezi

$$\mathbf{D} = \epsilon \epsilon_0 \mathbf{E} \quad \mathbf{B} = \mu \mu_0 \mathbf{H}$$

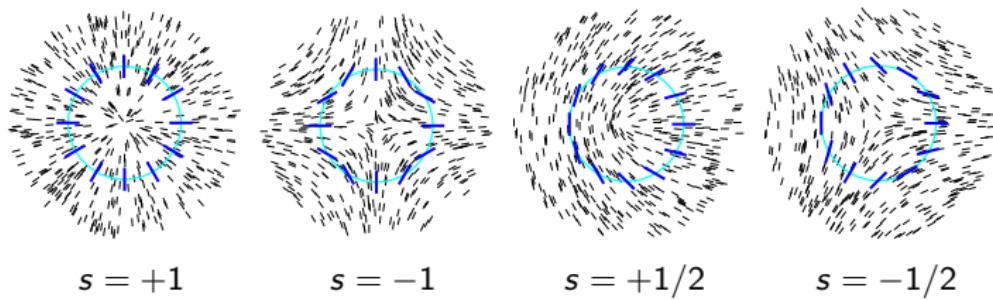
- ϵ in μ sta anizotropna tenzorja
- V vzorcu ni prostih nabojev ali tokov
- Izredna os in dvolomnost Δn
v TK krajevno odvisna

Dvolomnost

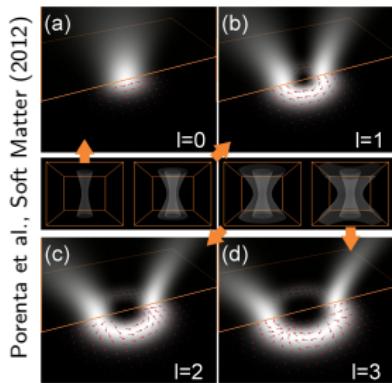
- Lomni količnik odvisen od polarizacije svetlobe
- Ena izredna os z n_e pravokotne smeri n_o



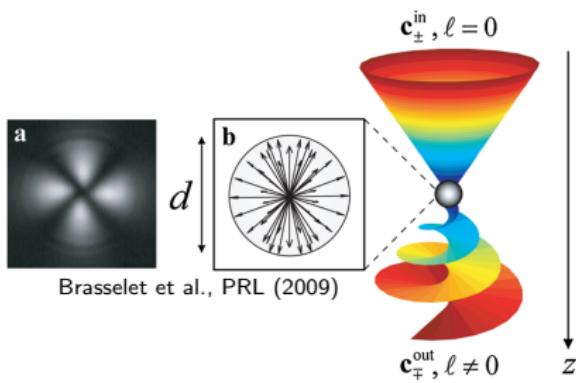
Topološki defekti



- Točka z nedefinirano smerjo direktorja ali električnega polja
- Ovojno število – celo za vektorska polja, polcelo za direktor



Poreta et al., Soft Matter (2012)



Brasselet et al., PRL (2009)

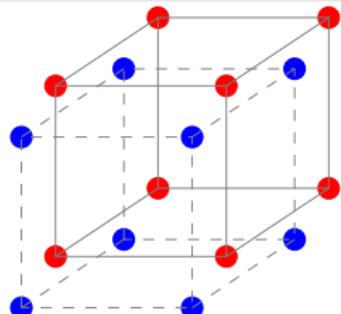
Metoda končnih diferenc v časovni domeni – FDTD

- Časovni razvoj vseh 6 komponent \mathbf{E} in \mathbf{B}
- Dinamični Maxwellovi enačbi na diskretni mreži

$$\frac{\partial \mathbf{B}}{\partial t} = -(\nabla \times \mathbf{E}) \quad \frac{\partial \mathbf{E}}{\partial t} = \epsilon^{-1} (\nabla \times \mathbf{B})$$

Diskretizacija na mreži

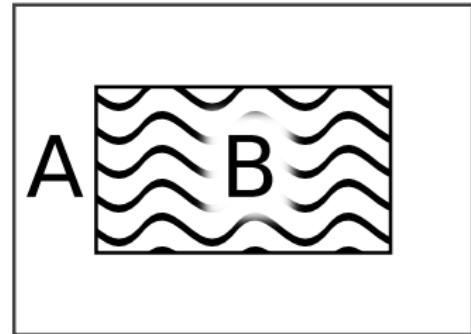
- Komponente polj znane na različnih krajih ob različnih časih
- Izvor in absorpcija valovanja na robu



Simulacijska celica

Izvor valovanja

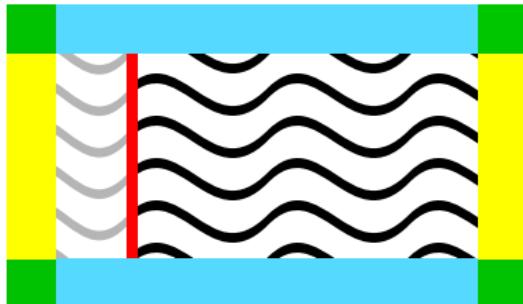
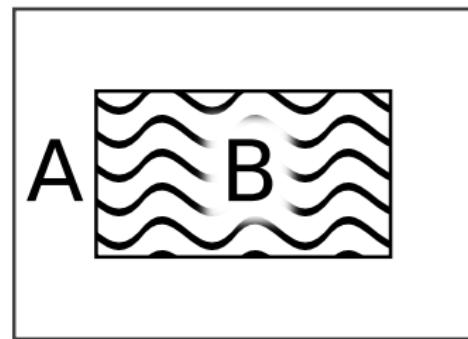
- Delitev na dve območji
- Linearne enačbe →
vpadno + sipano valovanje
- Zunaj samo sipano valovanje
- Izvor modeliran na meji



Simulacijska celica

Izvor valovanja

- Delitev na dve območji
- Linearne enačbe → vpadno + sipano valovanje
- Zunaj samo sipano valovanje
- Izvor modeliran na meji

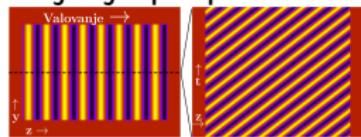


Absorpcija na robu

- Električna prevodnost in magnetne izgube
- Nefizikalnen material – dodatne prostostne stopnje

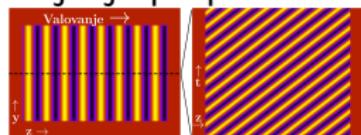
Primeri uporabe metode

- Širjenje po praznem prostoru

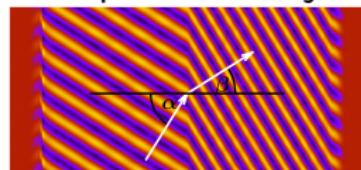


Primeri uporabe metode

- Širjenje po praznem prostoru

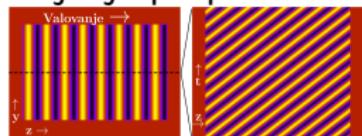


- Lom pri Brewsterjevem kotu

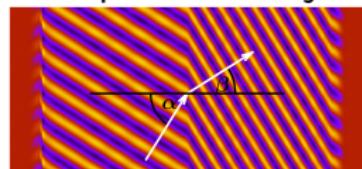


Primeri uporabe metode

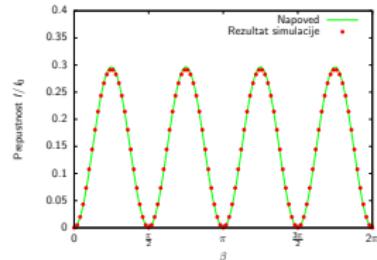
- Širjenje po praznem prostoru



- Lom pri Brewsterjevem kotu

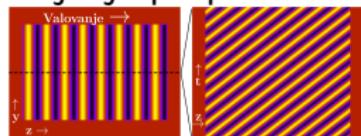


- Dvolomni kristal med prekrižanima polarizatorjema

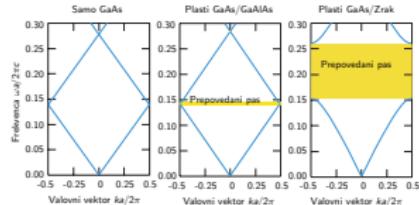


Primeri uporabe metode

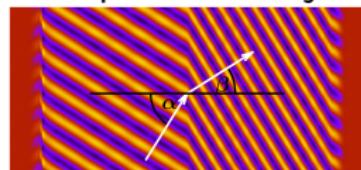
- Širjenje po praznem prostoru



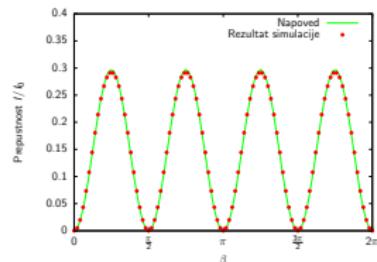
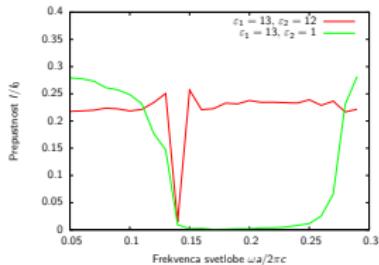
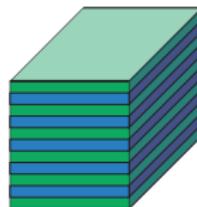
- Fotonski prepovedani pas



- Lom pri Brewsterjevem kotu

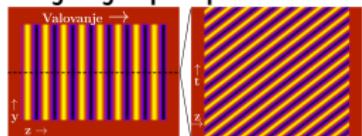


- Dvolomni kristal med prekrižanima polarizatorjema

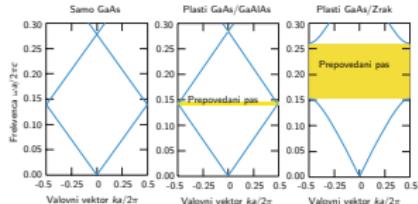


Primeri uporabe metode

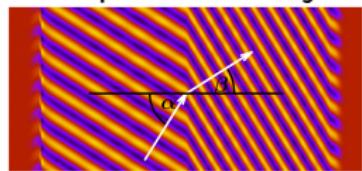
- Širjenje po praznem prostoru



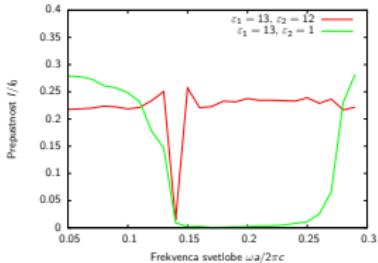
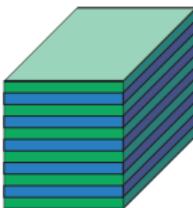
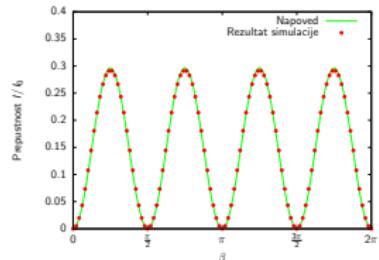
- Fotonski prepovedani pas



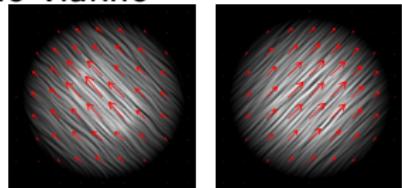
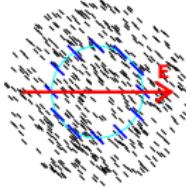
- Lom pri Brewsterjevem kotu



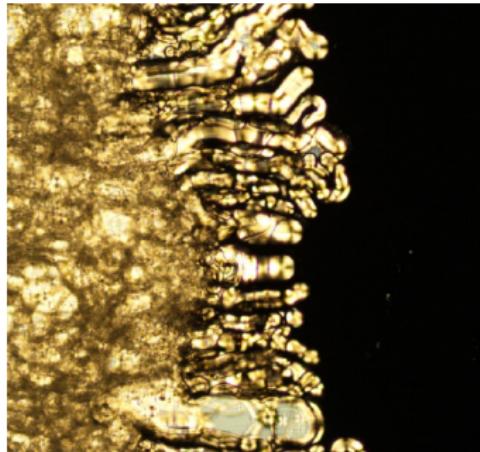
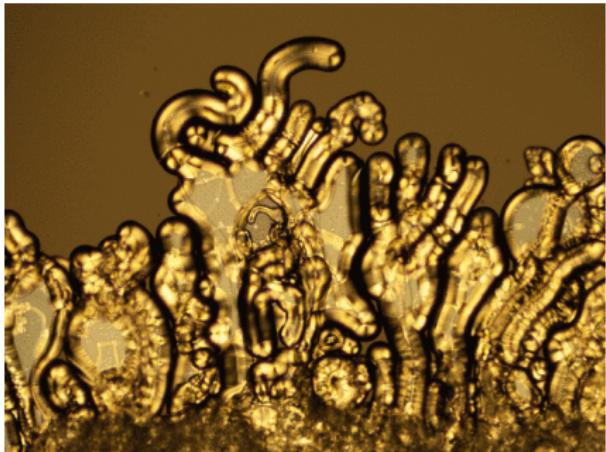
- Dvolomni kristal med prekrižanima polarizatorjema



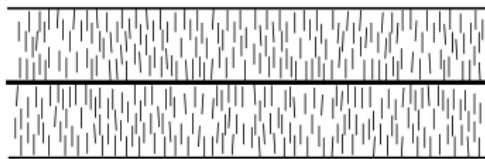
- Dvolomno vlakno



Vlakno z radialnim direktorskim profilom

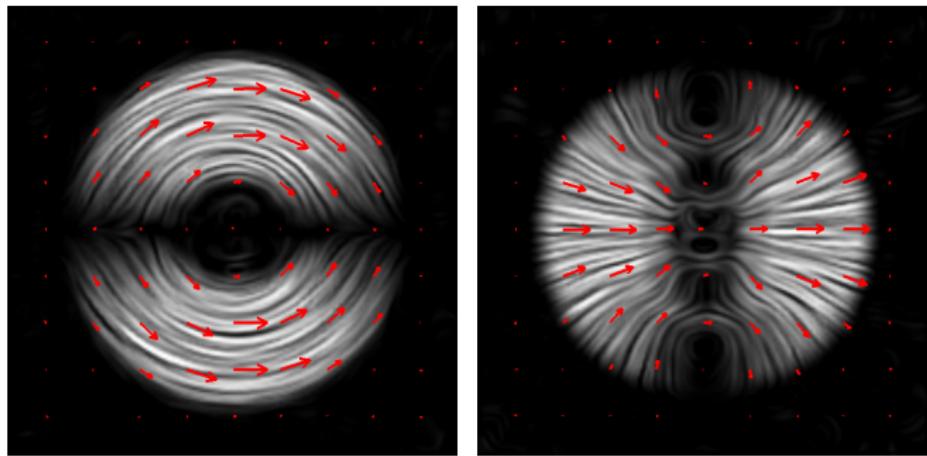
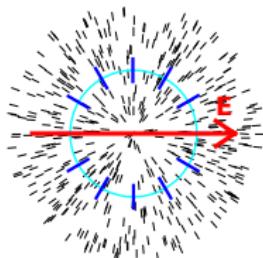


Peddireddy et al., Langmuir (2012)



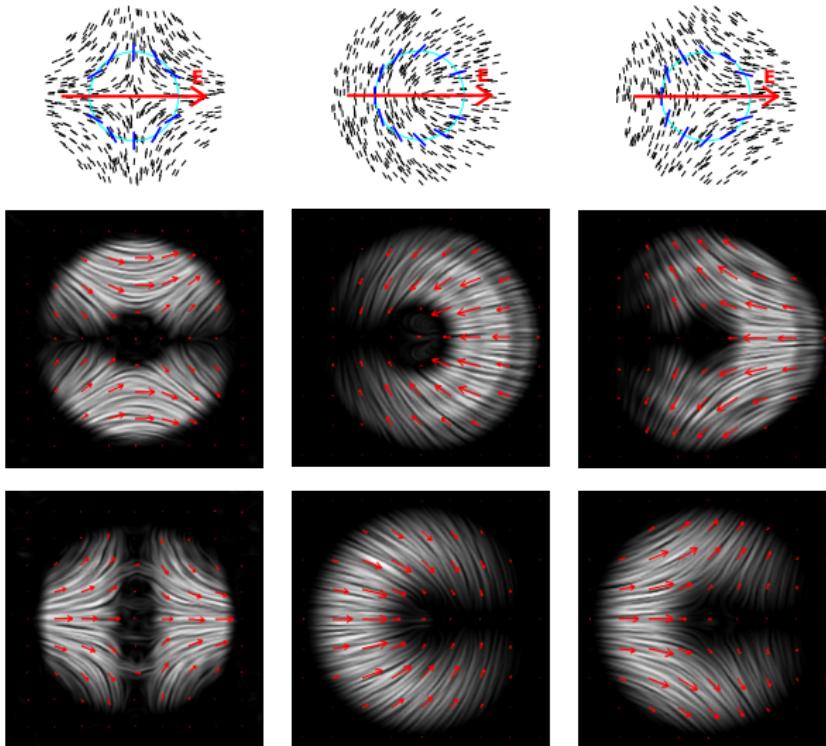
- Rast vlaken iz 8CB v vodi
- Delujejo kot valovodi

Sunek v vlaknu z radialnim direktorskim profilom



- Sunek razpade na dva stacionarna načina – redni in izredni
- “Neprava” defekta v **E** z ovojnim številom +1
- Temna območja zaradi vpadne polarizacije

Sunek v vlaknih z različnimi defekti



Parametri

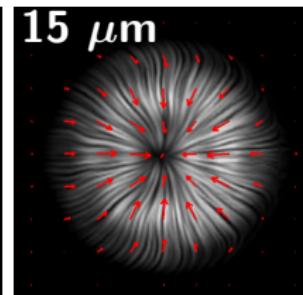
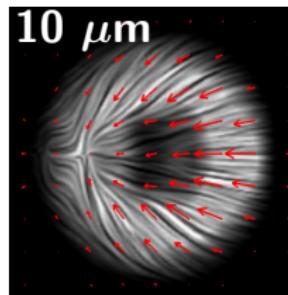
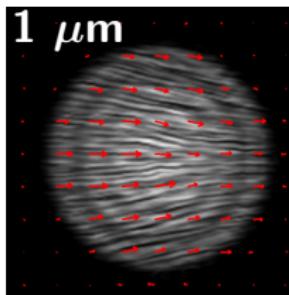
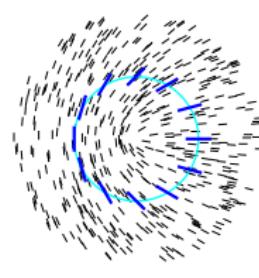
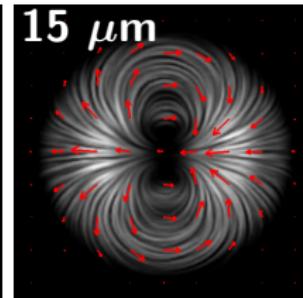
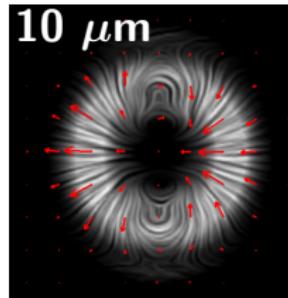
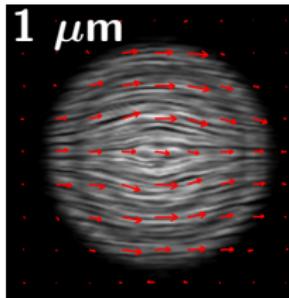
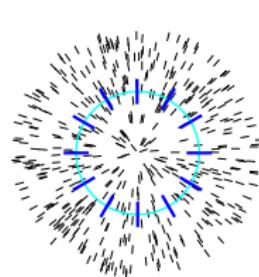
- $\lambda = 480 \text{ nm}$
- $\Delta n = 0,16$
- Premer vlakna $5 \mu\text{m}$
- Pot sunka $\sim 40 \mu\text{m}$

Opažanja

- 2 stacionarna načina
- Enako ovojno število kot defekt v TK
- Temna pega v osi
- Temne ravnine

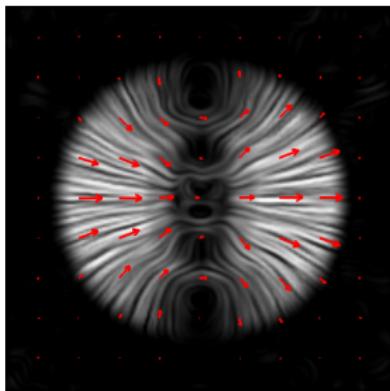
Stalna laserska svetloba

- Dvolomnost $\Delta n = 0,01 \Rightarrow$ večja značilna dolžina pojavov
- Stacionarno stanje s krajevno odvisnostjo polarizacije
- Defekt z dvakratnim ovojnim številom

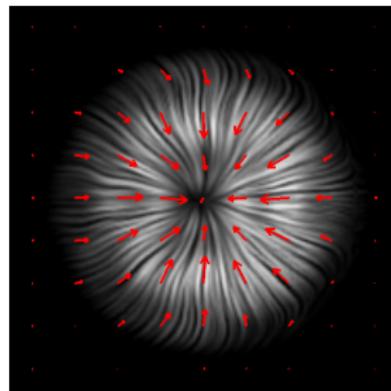


Stalna laserska svetloba

- Kombinacija dveh stacionarnih načinov, različni hitrosti
- Stacionarno stanje, polje na vsakem mestu niha
- Pretvorba v radialno polarizirano svetlobo
- Brez temnih ravnin – obrat polarizacije za 90°



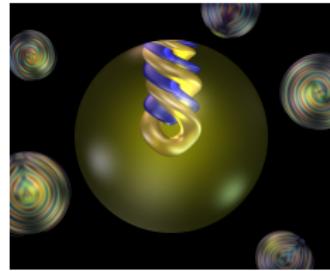
sunek



stalna svetloba

Tekočekristalne strukture

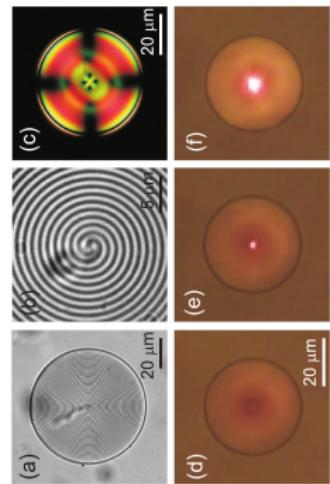
- Natančne transmisijske slike
- Povezava med teorijo in eksperimenti
- Pretvorba polarizacije svetlobe
- Tekočekristalne kapljice in vlakna kot laserji
- Mikroskopija z bližnjim poljem (*near-field*)
- Metamateriali, fotonski kristali, ...



Seč et al., Soft Matter (2012)

Razširitev metode

- Sklopitev med svetlobo in tekočim kristalom
- Stimulirana emisija, fluorescenza



Humar, Muševič, Optics Express (2010)