Univerza v Mariboru

Fakulteta za naravoslovje in matematiko

UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	Tekoči kristali
Course title:	Liquid Crystals

Študijski program in stopnja Study programme and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Fizika 2. st.		1,2	1,2,3,4
Physics 2nd degree		1,2	1,2,3,4

Vrsta predmeta / Course type	izbirni/ optional
Univerzitetna koda predmeta / University course code:	

Predavanja Lectures	Seminar Seminar	Vaje Tutorial	Klinične vaje work	Druge oblike študija	Samost. delo Individ. work	ECTS
30	15				105	5

Nosilec predmeta / Lecturer:	Samo Kralj, Nataša Vaupotič

Jeziki / Languages:		
	Predavanja / Lectures:	slovenski/Slovenian in/and angleški/English
	Vaje / Tutorial:	slovenski/Slovenian in/and angleški/English

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisits:
Pogojev ni. Priporočljiva znanja so: predznanje klasične in moderne fizike, modelske fizike, fizike materialov in fizike mehke snovi	None. Recommended is preknowledge of classical and modern physics, physics of material and soft matter physics

Vsebina: | **Content (Syllabus outline):**

• Predstavitev poglavitnih tekočekristalnih (TK) faz. • Modelni opisi TK faz: molekularni (Maier-Saupe model) in kontinuumski pristop (Frankov in Landau-de Gennesov model). • Fazni prehodi: primerjava s faznimi prehodi para-voda-led, paramagnetna-ferromagnetna faza, dogodki med Velikim pokom. • Defekti v tekočih kristalih: i) primerjava sil med defekti v TK in silami med električnimi naboji in med kvarki, ii) dinamika defektnih mrež TK v hitrem faznem prehodu in analogija s širjenjem vesolja, iii) struktura jeder defektov, analogija s hipotetičnim magnetnim monopolom in kozmološkimi vzmetmi, iv) primerjava zvite dislokacije v smetični A fazi in defekti v supraprevodniku. • Ograjeni tekoči kristali: vpliv pojava končnih dimenzij, površine in nereda na fazno obnašanje tekočega kristala. • Smektični tekoči kristali (akiralni, feroelektrični, antiferoelektrični), zlom zrcalne simetrije, strukturna kiralnost. • Uporaba tekočih kristalov. Tekoči kristali in živa bitja (biološke celice, diferenciacija celic, transport informacij).	• Presentation of main liquid crystal (LC) phases. • Modelling of LC phases: molecular (Maier-Saupe model) and continuum (Frank and Landau-de Gennes model) type approaches. • Phase transitions: comparison with vapour-liquid-crystal, paramagnetic-ferromagnetic phase transition and evolution of the Universe after the Big Bang. • Defects in liquid crystals: i) comparison of forces among defects and forces among electric charges and quarks, ii) coarsening dynamics of defect pattern and the evolution of the Universe after the Big Bang, iii) structure of cores of defects, magnetic monopoles and cosmic strings, iv) comparison between dislocations in smectic phases and superconductors and superfluids. • Confined liquid crystals: finite size effects, influence of surface interactions and disorder. • Smectic liquid crystals (achiral, ferroelectric, antiferroelectric), chiral symmetry breaking, structural chirality. • LCs applications. LCs and life (biological cells, differentiation of cells, transport of information).

Temeljni literatura in viri / Readings:

1. P.G. de Gennes and J. Prost, The Physics of Liquid Crystals (Clarendon press, Oxford, 1998).
2. I. Muševič, R. Blinc, B. Žekš, The physics of ferroelectric and antiferroelectric liquid crystals, (World Scientific, Singapore, 2000).
3. V. Popa-Nita, Phase transitions, applications to liquid crystals, organic electronic and optoelectronic fields (Research Signpost, Kerala, 2006)

Dodatna literatura / Additional Readings:

1. http://plc.cwru.edu/tutorial/enhanced/files/hindex.html
2. Članki v Science, Nature, Scientific American.
3. Članki na: http://www.pfmb.uni-mb.si/complex/

Cilji in kompetence:

Objectives and competences:

Študenti usvojijo znanje s področja tekočih kristalov in minimalnih modelov, ki opisujejo njihovo fazno in strukturno obnašanje.

Students acquire knowledge on liquid crystals and.
minimal models describing liquid crystal phases and their structural behavior.

Predvideni študijski rezultati:

Znanje in razumevanje:
Po uspešno zaključeni učni enoti bodo študenti zmožni:

- razlikovati med različnimi tekočekristalnimi fazami in opredeliti njihove fizikalne lastnosti;
- uporabiti molekularni in kontinuumski pristop za opis ureditve v tekočekristalnih fazah;
- primerjati fazne prehode med različnimi fazami tekočih kristalov s faznimi prehodi v izotropni snovi ter faznimi prehodi med magnetnimi lastnostmi materialov;
- opredeliti, primerjati in analizirati defekte v tekočih kristalih;
- obravnavati vpliv končnih dimenzij, površine in nereda na fazno obnašanje tekočega kristala;
- zlom zrcalne simetrije povezati s strukturno kiralnostjo.

Prenesljive/ključne spretnosti in drugi atributi:
Po uspešno zaključeni učni enoti bodo študenti zmožni:

- prepoznavati analogije med tekočekristalnimi fazami in drugimi sistemi in zanje uporabiti enako matematično obravnavo;
- uporabiti znanje za kvalitativni in kvantitativni opis pojavov v biofiziki, astronomiji, fiziki delcev…;
- uporabiti znanje za tehniško uporabo tekočih kristalov.

Intended learning outcomes:

Knowledge and Understanding:
On completion of this course the student will be able to:

- differentiate between different liquid crystal phases and define their physical properties;
- use molecular and continuum approach to describe ordering in liquid crystals;
- compare phase transitions in liquid crystals to phase transitions in isotropic matter and phase transitions among magnetic properties of materials;
- define, compare and analyse defects in liquid crystals;
- study the effect of finite dimensions, surfaces and disorder on the phase behaviour of liquid crystals;
- breaking of chiral symmetry connect to structural chirality.

Transferable/Key Skills and other attributes:
On completion of this course the student will be able to:

- recognise analogies between liquid crystals' phases and other systems and use equal mathematical description to study them;
- use the knowledge to qualitatively and quantitatively describe effects in biophysics, astronomy, particle physics;
- use the knowledge for technological description of liquid crystals.

Metode poučevanja in učenja:

Learning and teaching methods:

Predavanja, seminarji, razlaga, razgovor, delo s tekstom, metoda pisnih in grafičnih del, problemsko učenje, študija primera, raziskovalno učenje, uporaba programskih orodij.	Lectures, seminars, explanation, discussion, work with text, work with graphic elements, case study, problem based learning, inquiry based learning, use of software tools.

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Pisni izpit	70%	Written exam
Seminarska naloga	30%	Seminar paper

Reference nosilca / Lecturer's references:

Samo Kralj:

1. ZIDANŠEK, Aleksander, HÖLBL, Arbresha, RANJKESH SIAHKAL, Amid, CORDOYIANNIS, George, KUTNJAK, Zdravko, KRALJ, Samo. Impact of random-field-type disorder on nematic liquid crystalline structures. The European physical journal. E., Soft matter. 2022, vol. 45, no. 7, str. 63-1-63-12, ilustr. ISSN 1292-895X. DOI: 10.1140/epje/s10189-022-00217-y. [COBISS.SI-ID 116649731]
2. DUBTSOV, Alexander, PASECHNIK, Sergey V., SHMELIOVA, Dina V., UMANSKII, B. A., KRALJ, Samo. Dual-frequency electrically driven nematic microstructures confined to biaxial porous polymer membranes. Applied physics letters. [Print ed.]. 2021, vol. 119, no. 22, str. 221903-1-221903-5. ISSN 0003-6951. DOI: 10.1063/5.0069056. [COBISS.SI-ID 88021763]
financer: ARRS, Programi, P1-0099, SI, Fizika mehkih snovi, površin in nanostruktur; ARRS, Projekti, J1-2457, SI, Fazni prehodi proti koordinaciji v večplastnih omrežjih
3. MESAREC, Luka, IGLIČ, Aleš, KRALJ-IGLIČ, Veronika, GÓŹDŹ, Wojciech, VIRGA, Epifanio Giovanni, KRALJ, Samo. Curvature potential unveiled topological defect attractors. Crystals. May 2021, no. 5, 539, str. 1-16, ilustr. ISSN 2073-4352. https://www.mdpi.com/2073-4352/11/5/539, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=135428, DOI: 10.3390/cryst11050539. [COBISS.SI-ID 63076611]

Nataša Vaupotič:

1. VAUPOTIČ, Nataša, POCIECHA, Damian, RYBAK, Paulina, MATRASZEK, Joanna, ČEPIČ, Mojca, WOLSKA, Joanna M., GÓRECKA, Ewa. Dielectric response of a ferroelectric nematic liquid

crystalline phase in thin cells. Liquid crystals. [Online ed.]. [in press] 2023, 12 str. ISSN 1366-5855. DOI: 10.1080/02678292.2023.2180099. [COBISS.SI-ID 147790083]

2. GRABOVAC, Timon, GÓRECKA, Ewa, ZHU, Chenhui, POCIECHA, Damian, VAUPOTIČ, Nataša. Unmasking the structure of a chiral cubic thermotropic liquid crystal phase by a combination of soft and tender resonant X-ray scattering. Soft matter. Nov. 2022, vol. 18, iss. 42, str. 8194-8200, ilustr. ISSN 1744-6848. DOI: 10.1039/d2sm01030e. [COBISS.SI-ID 127668483]

3. POCIECHA, Damian, VAUPOTIČ, Nataša, MAJEWSKA, Magdalena, CRUICKSHANK, Ewan, WALKER, Rebecca, STOREY, John M. D., IMRIE, Corrie T., WANG, Cheng, GÓRECKA, Ewa. Photonic bandgap in achiral liquid crystals - a twist on a twist. Advanced materials. [Online ed.]. 2021, vol. 33, no. 39, str. 2103288-1-2103288-7. ISSN 1521-4095. DOI: 10.1002/adma.202103288. [COBISS.SI-ID 80061955]