|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | | | | | | | | | | | | | | | | | |
| **Predmet:** | | | Fotonika | | | | | | | | | | | | | | |
| **Course title:** | | | Photonics | | | | | | | | | | | | | | |
|  | | | | |  | | | | | | | |  | |  | | |
| **Študijski program in stopnja**  **Study programme and level** | | | | | **Študijska smer**  **Study field** | | | | | | | | **Letnik**  **Academic year** | | **Semester**  **Semester** | | |
| Univerzitetni študijski program druge stopnje Elektrotehnika | | | | | vse smeri | | | | | | | | 1. | | poletni | | |
| 2nd cycle master study programme Electrical Engineering | | | | | all study tracks | | | | | | | | 1. | | summer | | |
|  | | | | | | | | | | | | | | | | | |
| **Vrsta predmeta / Course type** | | | | | | | | | | | | strokovni predmet, izbirni modul D  professional course, elective module D | | | | | |
|  | | | | | | | | | | | |  | | | | | |
| **Univerzitetna koda predmeta / University course code:** | | | | | | | | | | | | 64264S | | | | | |
|  | | | | | | | | | | | | | | | | | |
| **Predavanja**  **Lectures** | **Seminar**  **Seminar** | | | **Vaje**  **Tutorial** | | | **Klinične vaje**  **work** | | | | **Druge oblike študija** | | | **Samost. delo**  **Individ. work** | |  | **ECTS** |
| **45** | **0** | | | **30** | | | **0** | | | | **0** | | | **75** | |  | **6** |
|  | | | | | | | | | | | | | | | | | |
| **Nosilec predmeta / Lecturer:** | | | | | prof. dr. Janez Krč | | | | | | | | | | | | |
|  | | | | | | | | | | | | | | | | | |
| **Jeziki /**  **Languages:** | | **Predavanja / Lectures:** | | | | slovenski / Slovene  (English possible) | | | | | | | | | | | |
| **Vaje / Tutorial:** | | | | slovenski / Slovene  (English possible) | | | | | | | | | | | |
| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | | | | | | | | |  | **Prerequisits:** | | | | | | | |
| vpis v prvi letnik podiplomskega magistrskega študijskega programa Elektrotehnika (druga stopnja) | | | | | | | | |  | enrolment in the 1st year of the 2nd cycle master study programme of Electrical Engineering | | | | | | | |
| **Vsebina:** | | | | | | | |  | | **Content (Syllabus outline):** | | | | | | | |
| UVOD:  izzivi in trendi v fotoniki, zadnja odkritja – česa se bomo dotaknili v okviru tega predmeta, sedanjost in prihodnost nanofotonike, zakaj želimo zamenjati elektron s fotonom  SVETLOBA:  svetloba in Maxwell - elektromagnetno valovanje, svetloba v snovi, razmere na spojih dveh snovi, svetloba in nanometrske strukture, Fourierjeva optika –zakaj?, elektro-optični in magneto-optični efekti in gradniki  FOTONSKI GRADNIKI:  osnove delovanja, načrtovanje in tehnologija izdelave, dejanska in možna uporaba v fotonskih vezjih:   * fotonski kristali: 1D, 2D, 3D * nanostrukture s kovinskimi delci:   metamateriali, negativni lomni količnik, plazmonski efekt   * resonatorji, filtri in modulatorji * miniaturni laserji in nanolaserji * miniaturni fotodetektorji * poskusi optičnih tranzistorjev   FOTONSKA INTEGRIRANA VEZJA:  fotonsko elektronska integracija – zakaj?, sodobni primeri izvedbe integracije in uporaba vezij z zgoraj obravnavanimi nanofotonskimi gradniki, osnove Si na izolatorju, InP, TriPleX za fotonska vezja, spoznavanje z in uporaba orodja za načrtovanje fotonskih integriranih vezij, konkretni praktični primeri, pristopi k optičnim vratom, kako naprej in kaj nas še omejuje pri optičnem računalniku  VLAKENSKI SENZORJI:  interferometrični, na osnovi fotonskih kristalov, na osnovi tekočih kristalov, plazmonska detekcija, uporaba v biomedicini in na drugih področjih  NANOFOTONSKE STRUKTURE V FOTOVOLTAIKI:  protiodbojne strukture, fotonske strukture za učinkovito vodenje in usmerjanje svetlobe v sončnih celicah, nove izvedbe odbojnikov,  praktično načrtovanje in karakterizacija nanofotonskih struktur, načrtovanje z uporabo 3D optičnega modeliranja (FEM, FDTD, RCWA), praktične karakterizacijske metode in inštrumenti (merjenje odbojnosti/prepusnosti, sipanja, kotne porazdelitve svetlobe) | | | | | | | |  | | INTRODUCTION:  challenges and trends in the field of photonics latest achievements – what of these we will learn, today in tomorrow of nanophotonics, why to use a photon instead of an electron  LIGHT:  light and Maxwell - electromagnetic waves, light and matter, optical situation at an interface of two media, light interaction with nanometer size structures, Fourier optics – why?, electro-optical and magneto-optical effects and components  PHOTONIC COMPONENTS:  operational principles, design and technologies, use in photonic circuits:   * photonic crystals: 1D, 2D, 3D, * metallic nanostructures: metamaterials, negative refractive index, plasmonic effects * resonators, filters and modulators * micro and nanolasers * micro fotodetectors * attempts towards optical transistors   PHOTONIC INTEGRATED CIRCUITS (PICs):  photonic electronic integration – why?, latest examples of integration of above mentioned photonic components in PICs, platforms on Si on insulator, InP material and TriPleX, design tools, examples of design, practical cases, towards optical gates, how to proceed and what is restricting us on the way towards optical computers  FIBER SENSORS:  interferometric, photonic crystal based, liquid crystal based, plasmonic detection, use in biomedicine and in other fields  NANOPHOTONIC STRUCTURES IN PHOTOVOLTAICS:  antireflection structures, light management photonic structures in solar cells, novel reflectors, practical design and characterisation of nanophotonic structures, design based on 3D optical modelling (FEM, FDTD, RCWA), characterisation methods and instruments, measurements of reflection/transmission, light scattering, angular distribution function) | | | | | | | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Temeljni literatura in viri / Readings:** | | | | | |
| 1. L. Chrostowski e tal., Silicon Photonics Design: From Devices to Systems, Cambridge University Press; 2015. 2. Q. Gong e tal., Photonic Crystals: Principles and Applications, Pan Stanford, 2014. 3. G. Rajan, Optical Fiber Sensors: Advanced Techniques and Applications (Devices, Circuits, and Systems), CRC Press, 2015. 4. B. E. A. Saleh e tal., Fundamentals of Photonics (2nd Edition) Wiley-Interscience; 2007. 5. 6. J. Krc and M. Topic, Optical modelling and simulations of thin-film photovoltaic devices, CRC Press, 2013. | | | | | |
| **Cilji in kompetence:** | |  | | **Objectives and competences:** | |
| * osvojiti strukture in principe delovanja sodobnih nanofotonskih gradnikov * seznanitev z arhitekturami tehnologijami in funkcionalnostmi sodobnih fotonskih integriranih vezij * osnovno znanje za načrtovanje fotonskih integriranih vezij * poznavanje izvedb in delovanja vlakenskih senzorjev * poznavanje in razumevanje fotonskih struktur v sončnih celicah * znanje za praktični pristop k načrtovanju in karakterizaciji fotonskih gradnikov | |  | | * to acquire the knowledge and operational principles of contemporary nanophotonic structures * knowledge on state-of-the-art architectures, functionalities and technologies of photonic integrated circuits * basic knowledge on practical design of photonic integrated circuits * to know the structures and operational principles of fiber sensors * knowledge on and understanding of photonic structures for light management in solar cells * practical approaches of design and characterisation of photonic devices | |
| **Predvideni študijski rezultati:** | | |  | **Intended learning outcomes:** | |
| * temeljna znanja o nanofotoniki * razumevanje delovanja in načini uporabe sodobnih fotonskih gradnikov in fotonskih integriranih vezij * sposobnost načrtovanja in karakterizacije (nano)fotonskih gradnikov * predznanja za nadaljnji študij fotonskih tehnologij | | |  | * fundamental knowledge on nanophotonics * understanding of operational principle and usage of photonic devices and PICs * ability to design and to characterise (nano)photonic structures and devices * pre-knowledge for further studies of photonic technologies | |
|  | | |  |  | |
| **Metode poučevanja in učenja:** | | |  | **Learning and teaching methods:** | |
| * predavanja (prosojnice, razlaga na tablo, interakcija s študenti), * laboratorijske vaje (praktično delo z (nano)fotonskimi elementi, načrtovanje in karakterizacija, načrtovanje fotonskih integriranih vezij) | | |  | * lectures (slides and blackboard, interaction with students) * laboratory assignments (hands on (nano)photonic structures, design, characterisation, design of PICs | |
| **Načini ocenjevanja:** | Delež (v %) /  Weight (in %) | | | | **Assessment:** |
| Način: pisni izpit in ustni izpit  Končno oceno izpita določata pisni in ustni izpit v deležu, ki je opredeljen v sosednjem stolpcu.  Dodatni pogoji pri načinu ocenjevanja:   * za pozitivno končno oceno mora študentka/študent pozitivno opraviti in pisni in ustni izpit * za pristop k ustnemu izpitu je potrebno pozitivno opraviti pisni izpit in hkrati uspešno opraviti vse laboratorijske vaje predmeta.   Ocene od 1 do vključno 5 so negativne, ocene od vključno 6 do 10 so pozitivne. | 40 % pisni /  writtten exam  60 % ustni /  oral exam | | | | Type: written exam, oral exam.  The final grade is determined based on the results of written exam and oral exam. The share of each contribution is defined in previous column.  Additional conditions:   * a condition for positive final grade is positive grade ofwritten exam and positive grade of oral exam * to take an oral exam there are two conditions: positive grade of the written exam and successfully finished all laboratory assignments   Negative grades: from 1 to 5, positive grades: from 6 to 10. |
| **Reference nosilca / Lecturer's references:** | | | | | |
| 1. KRČ, Janez, TOPIČ, Marko*. Optical modeling and simulation of thin-film photovoltaic devices*. New York: CRC Press, 2013. 2. KRČ, Janez, SEVER, Martin, KOVAČIČ, Milan, MOULIN, Etienne, ČAMPA, Andrej, LIPOVŠEK, Benjamin, STELTENPOOL, Mark, ERVEN, Rob van, HAUG, Franz-Josef, BALLIF, Christophe, TOPIČ, Marko. Design of periodic nano- and macro-scale textures for high-performance thin-film multi-junction solar cells. *Journal of optics*, ISSN 2040-8978, 2016, vol. 18, no. 6, str. 1-11, 3. JOŠT, Marko, KRČ, Janez, TOPIČ, Marko. Camera-based ARS system for complete light scattering determination/characterization. *Measurement science & technology*, ISSN 0957-0233, Mar. 2016, vol. 27, no. 3, str. 1-10. 4. SEVER, Martin, KRČ, Janez, ČAMPA, Andrej, TOPIČ, Marko. Rigorous modelling of light scattering in solar cells based on finite element method and Huygens' expansion. *Optics express*, ISSN 1094-4087, 16 Nov. 2015, vol. 23, no. 24, str. A1549-1563 5. KRČ, Janez, LIPOVŠEK, Benjamin, TOPIČ, Marko. Light management in thin-film solar cell. V: LÓPEZ, Ana Belén Cristóbal (ur.), VEGA, Antonio Martí (ur.), LÓPEZ, Antonio Luque (ur.). *Next generation of photovoltaics : new concepts*, (Springer series in optical sciences, ISSN 0342-4111, 165). Berlin; Heidelberg: Springer, cop. 2012, str. 95-129. | | | | | |