UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Fotonika in laserski izvori
Course title:	PHOTONICS AND LASER SOURCES
Članica nosilka/UL Member:	UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri
Strojništvo - Razvojno raziskovalni program, druga stopnja, magistrski	Mehatronika in laserska tehnika (smer)	1. letnik	2. semester

Univerzitetna koda predmeta/University course code:	0566816
Koda učne enote na članici/UL Member course code:	6059-M

Predavanja	Seminar	Vaje	Klinične vaje	Druge oblike študija	Samostojno delo	ECTS
30		30			65	5

Nosilec predmeta/Lecturer:	Rok Petkovšek, Vid Agrež
Vrsta predmeta/Course type:	Obvezni strokovni predmet na smeri Mehatronika in laserska tehnika, ki je izbirni strokovni predmet na ostalih smereh./Compulsory specialised course in the study of Mechatronics and laser technology, which is an elective specialised course in other fields of study.

Jeziki/Languages:	Predavanja/Lectures:	Slovenščina
	Vaje/Tutorial:	Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	Prerequisites:
Izpolnjevanje pogojev za vpis v Magistrski študijski program II. stopnje Strojništvo - Razvojno raziskovalni program.	Meeting the enrollment conditions for the Master's study programme of Mechanical Engineering - Research and Development program.

Vsebina:	Content (Syllabus outline):
1. Svetloba elektromagnetno valovanje 1 - Intenziteta, moč in energija - Radiometrija - Fotometrija - Lastnosti laserske svetlobe - Merjenje	1. Light the Electromagnetic Radiation 1 - Intensity, power and energy - Radiometry - Photometry - Laser light properties - Measurement

2. Svetloba elektromagnetno valovanje 2 - Maxwellove enačbe - Valovna enačba - Poyntigov vektor - Polarizacija 3. Gaussovi snopi - Osnovni Gaussov snop (rešitev valovne enačbe) - Snopi višjih redov - Primerjava z rodovi v optičnih vlaknih - Kvaliteta snopa 4. Lom, odboj in optične preslikave - Odbojni in lomni zakon - Fresnelove enačbe - Brewsterjev kot - Totalni odboj - Preslikave Gaussovih snopov z ABCD matrikami - ABCD matrike osnovnih optičnih elementov - Razširjevalnik žarka - Optični resonator 5. Optična vlakna - Vodenje svetlobe - Enorodovna in večrodovna optična vlakna - Numerična odprtina - Vlakna in polarizacija - Posebna vlakna - Izgube - Disperzija 6. Optični modulatorji - Amplitudna modulacija - Fazna modulacija - Elektrooptična modulacija - Akusto optični modulator 7. Nelinearni optični pojavi - Uvod v nelinearne pojave - Nelinearnost drugega reda - Podvojevane frekvence – SHG - Optično parametrično ojačevanje – OPA - Nelinearnost tretjega reda 8. Ojačevanje svetlobe v snovi - Mehanizmi interakcije - (Einsteinovi koeficienti) - Zasedbene enačbe - Tri nivojski in štiri nivojski istem 9. Uvod v laserje - Osnovni gradniki - Aktivni medij / dopanti - Opis delovanja kontinuirnega laserja - Opis z zasedbenimi enačbami - Longitudinalni nihajni načini 10. Vrste/tipi laserjev - Trdninski - Diskasti - Polprevodniški - Vlakenski in hibridni	2. Light the Electromagnetic Radiation 2 - Maxwell's equations - Wave equation - Poynting vector - Polarization 3. Gaussian beams - Fundamental Gaussian beam (wave equation solution) - High order modes - Comparison to optical fibers modes - Beam quality 4. Refraction, reflection, and optical imaging - Law of reflection and refraction - Fresnel’s equations - Brewster’s angle - Total reflection - Evolution of Gaussian beams with ABCD matrices - ABCD matrix of basic optical elements - Beam expander - Optical resonator 5. Optical fibers - Guiding light - Single mode and multi mode optical fibers - Numerical aperture - Fibers and polarization - Special fibers - Losses - Dispersion 6. Optical modulators - Amplitude modulation - Phase modulation - Electro-optic modulation - Acousto-optic modulator 7. Nonlinear optical phenomena - Introduction to nonlinear optics - Second-order nonlinearity - Frequency doubling – SHG - Optical parametric amplification – OPA - Third-order nonlinearity 8. Light amplification - Mechanisms of interaction - Einstein coefficients - Rate equations - Three and four level systems 9. Introduction to lasers - Basic elements - Active medium / dopants - Description of continuous laser - Description with rate equations - Longitudinal laser modes 10. Types of lasers - Solid state lasers - Disk lasers

- Plinski: HeNe, CO2, Argon - Ostali tipi: barvilni, kemični 11. Vlakenski laserji - Aktivna vlakna z dvojnim ovojem - Gradniki vlakenskih laserjev - Vlakenski ojačevalnik - Sistem MOPA - Primeri vlakenskih laserjev 12. Laserji s kratkimi pulzi - Preklop ojačenja - Relaksacijske oscilacije - Preklop kvalitete 13. Laserji z ultrakratkimi pulzi - Ultrakratki pulzi - Osnovni koncepti - Uklepanje faz laserskih nihanj - Merjenje ultrakratkih pulzov 14. Interakcija ultrakratkih laserskih pulzov s snovjo - Osnovni mehanizem interakcije - Hladna ablacija - Večfotonska interakcija 15. Napredni laserski sistemi in njihova uporaba - Ultrahitre laserske obdelave - Pulzi na zahtevo - Sinhronizacija laserskega vira za potrebe aplikacij	- Semiconductor lasers - Fiber and hybrid lasers - Gas lasers: HeNe, CO2, Argon - Other types: dye, chemical 11. Fiber lasers - Double clad active fibers - Building blocks of fiber lasers - Fiber amplifiers - MOPA system - Fiber lasers examples 12. Short pulsed lasers - Gain switching - Relaxation oscillations - Q-switching 13. Ultrashort pulsed lasers - Ultrashort pulses - Basic concept - Mode locking - Measuring ultrashort pulses 14. Ultrashort pulse interaction with matter - Basic principle of interaction - Cold ablation - Multiphoton absorption 15. Advanced laser systems and applications - Ultrafast laser processing - Pulses on demand - Synchronization of laser source for the needs of application

Temeljna literatura in viri/Readings:

1. V. Degiorgio, I. Christiani, “Photonics, A Short course”, Springer, 2016
2. G. A. Reider, “Photonics: An Introduction”, Springer, 2016
3. B. E. A. Saleh in M. C. Teich, “Fundamentals of photonics”, John Wiley and sons, Inc., 2007
4. J. Landers, “Photonics: Concepts, Technology and Applications”, Blackwell’s, 2019
5. A. Sennaroglu, “Photonics and Laser Engineering: Principles, Devices, and Applications”, McGraw-Hill Education, 2010

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Spoznavanje osnovnih in poglobljenih vsebin na področju fotonike in laserjev 2. Uporaba pridobljenega znanja na področju fotonike za reševanje računskih nalog iz obravnavanih vsebin 3. Uporaba drugih virov (poleg predpisane literature) za reševanje problemov/nalog. 4. Spoznavanje eksperimentalnih sitemov in metod na področju fotonike. Kompetence: 1. S1-MAG: Sposobnost za opredelitev in razumevanje	Objectives: 1. Getting to know basic and advanced topics from the field of photonics and lasers 2. Use of acquired knowledge from the field of photonics to solve computational problems 3. Use of other sources (besides the prescribed literature) to solve problems / tasks. 4. Knowledge of experimental systems and methods in the field of photonics. Competences: 1. S1-MAG: The ability to define and understand

temeljnih problemov na področju fotonike. 2. S7-MAG: Usposobljenost za uporabo pridobljenih znanj pri samostojnem reševanju tehničnih problemov na področju fotonike. 3. S8-MAG: Sposobnost iskanja virov, kritične presoje informacij, samostojnega nadgrajevanja pridobljenih znanj in poglabljanja znanja na področju fotonike v strojništvu. 4. S10-MAG: Sposobnost uporabe sodobnih raziskovalnih metod in postopkov. Zmožnost raziskovanja in prenašanja spoznanj v prakso. 5. P2-MAG: Obvladovanje temeljnih teoretičnih kakor tudi aplikativnih znanj, ki so bistvena za obvladovanje tehničnega področja strojništva. 6. P4-MAG: Sposobnost fizikalnega, matematičnega in numeričnega modeliranja problemov z razvito sposobnostjo kritične analize rezultatov.	fundamental scientific problems in photonics. 2. S7-MAG: The qualification to use the attained knowledge to autonomously solve technical problems in photonics. 3. S8-MAG: The ability to find sources, critically evaluate information, independently upgrade the attained knowledge and deepen the knowledge in the field of photonics in mechanical engineering. 4. S10-MAG: The ability to use modern research methods and procedures. Capacity to research and transfer the findings into practice. 5. P2-MAG: Using the fundamental theoretical and applied knowledge, crucial for having command of technical field of mechanical engineering. 6. P4-MAG: The ability for physical, mathematical and numerical modelling of problems, including a developed ability to critically analyse the results.

Predvideni študijski rezultati:	**Intended learning outcomes:**
Znanja: Z2: Poglobljeno teoretično, metodološko in analitično znanje z elementi raziskovanja, ki je osnova za zelo zahtevno strokovno delo na področju fotonike in laserskih izvorov. Spretnosti: S2.1 Obvladovanje zelo zahtevnih, kompleksnih delovnih procesov in metodoloških orodij na specializiranih področjih. S2.2 Načrtovanje in vodenje delovnega procesa na podlagi ustvarjalnega reševanja problemov, povezanih s področjem izobraževanja in usposabljanja. S2.3 Sposobnost izvirnih dognanj/stvaritev in kritične refleksije.	Knowledge: Z2: Thorough theoretical, methodological and analyitical knowledge with elements of a research work that form a basis for very demanding professional work in the field of photonics and laser sources. Skills: S2.1 Mastering very demending and complex work processes and methodological tools in specialised professional fileds. S2.2 Planning and managing of the working process on the basis of creative solving of problems that are linked to the teaching and training content. S2.3 Ability of unique innovations and critical reflections.

Metode poučevanja in učenja:	**Learning and teaching methods:**
Klasične oblike poučevanja: P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov. P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki. P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri. P4 Laboratorijske vaje z namenskimi didaktičnimi pripomočki (osnovni mehanski, električni, optični itd. merilniki). P5 Uporaba študijskega gradiva v obliki (knjige, skripte,	*Conventional teaching methods:* P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases. P2 Presenting the content according to the explained system. P3 Auditorial exrecises, in which theoretical content from the lectures is supplemented with practical examples. P4 Laboratory exercises with special-purpose didactic devices (basic mechanical, electric, optical, measuring devices). P5 Application of study material (books, printed lecture

zapiskov, e-knjige). *Moderne in prožne oblike poučevanja:* P6 Interaktivna predavanja.	presentaions, e-books, , etc.). *Contemporary and flexible teaching methods:* P6 Interactive lectures.

Načini ocenjevanja:	**Delež/Weight**	**Assessment:**
Skupno oceno predmeta tvorita ocena teorije in vaj. Ocena teorije: - Računski del: 50%.	25,00 %	The course grade is combined of an exercise grade and a theory grade. Theory: - Calculus part: 50%.
- Teoretični del: 50%.	25,00 %	- Theoretical part: 50%.
Ocena vaj: - Delo na laboratorijskih vajah (predpriprava, sodelovanje in samostojnost): 50%.	25,00 %	Laboratory excercises: - Work on laboratory exercises (preparation, colaboration, individual work): 50%.
- Poročilo o opravljenih vajah: 50%.	25,00 %	- Report on laboratory exercises: 50%.

Reference nosilca/Lecturer's references:

Rok Petkovšek

1. **PETKOVŠEK, Rok**, NOVAK, Vid, AGREŽ, Vid. High power fiber MOPA based QCW laser delivering pulses with arbitrary duration on demand at high modulation bandwidth. Optics express. 2015, vol. 23, no. 26, str. 33150-33156, ilustr. ISSN 1094-4087. DOI: 10.1364/OE.23.033150. [COBISS.SI-ID 14385947]
2. AGREŽ, Vid, **PETKOVŠEK, Rok**. Highly adaptable gain-switched fiber laser with improved efficiency. Optics express. 2019, vol. 27, no. 9, str. 12100-12109, ilustr. ISSN 1094-4087. https://www.osapublishing.org/oe/abstract.cfm?uri=oe-27-9-12100, DOI: 10.1364/OE.27.012100. [COBISS.SI-ID 16599835]
3. ŠUŠNJAR, Peter, AGREŽ, Vid, **PETKOVŠEK, Rok**. Photodarkening as a heat source in ytterbium doped fiber amplifiers. Optics express. 2018, vol. 26, no. 5, str. 6420-6426, ilustr. ISSN 1094-4087. https://www.osapublishing.org/oe/fulltext.cfm?uri=oe-26-5-6420&id=382306, DOI: 10.1364/OE.26.006420. [COBISS.SI-ID 15925531]
4. AGREŽ, Vid, **PETKOVŠEK, Rok**. Gain switch laser based on micro-structured Yb-doped active fiber. Optics express. Mar. 2014, vol. 22, no. 5, str. 5558-5563, ilustr. ISSN 1094-4087. DOI: 10.1364/OE.22.005558. [COBISS.SI-ID 13369371]

Vid Agrež

1. **AGREŽ, Vid**, PETKOVŠEK, Rok. *Highly adaptable gain-switched fiber laser with improved efficiency*. Optics express. 2019, vol. 27, no. 9, str. 12100-12109, ilustr. ISSN 1094-4087. https://www.osapublishing.org/oe/abstract.cfm?uri=oe-27-9-12100, DOI: 10.1364/OE.27.012100. [COBISS.SI-ID 16599835]
2. ŠUŠNJAR, Peter, **AGREŽ, Vid**, PETKOVŠEK, Rok. *Photodarkening as a heat source in ytterbium doped fiber amplifiers*. Optics express. 2018, vol. 26, no. 5, str. 6420-6426, ilustr. ISSN 1094-4087. https://www.osapublishing.org/oe/fulltext.cfm?uri=oe-26-5-6420&id=382306, DOI: 10.1364/OE.26.006420. [COBISS.SI-ID 15925531]
3. PETKOVŠEK, Rok, NOVAK, Vid**, AGREŽ, Vid**. *High power fiber MOPA based QCW laser delivering pulses with arbitrary duration on demand at high modulation bandwidth*. Optics express. 2015, vol. 23, no. 26, str. 33150-33156, ilustr. ISSN 1094-4087. DOI: 10.1364/OE.23.033150. [COBISS.SI-ID 14385947]
4. PETKOVŠEK, Rok, **AGREŽ, Vid**. *Single stage Yb-doped fiber laser based on gain switching with short pulse duration*. Optics express. Jan. 2014, vol. 22, iss. 2, str. 1366-1371, ilustr. ISSN 1094-4087. DOI: 10.1364/OE.22.001366. [COBISS.SI-ID 13354779]
5. ČERNE, Luka, NOVAK, Jure, **AGREŽ, Vid**, PETKOVŠEK, Rok. *Optimization of a supercontinuum source based on tapered ordinary fibers*. Laser physics. [Print ed.]. Jan. 2019, vol. 29, nr. 2, str. 1-6, ilustr. ISSN 1054-660X.

http://iopscience.iop.org/article/10.1088/1555-6611/aaf640/pdf, DOI: 10.1088/1555-6611/aaf640. [COBISS.SI-ID 16453659].