LASERSKI MERILNI SISTEMI

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet:	Laserski merilni sistemi
Course title:	LASER MEASUREMENT SYSTEMS
Članica nosilka/UL Member:	UL FS

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

Univerzitetna koda predmeta/University course code:	0566820
Koda učne enote na članici/UL Member course code:	6060-M

Predavanja /Lectures	**Seminar /Seminar**	**Vaje /Tutorials**	**Klinične vaje /Clinical tutorials**	**Druge oblike študija /Other forms of study**	**Samostojno delo /Individual student work**	**ECTS**
30		30			65	5

Nosilec predmeta/Lecturer:	Matija Jezeršek

Izvajalci predavanj:	
Izvajalci seminarjev:	
Izvajalci vaj:	
Izvajalci kliničnih vaj:	
Izvajalci drugih oblik:	
Izvajalci praktičnega usposabljanja:	

Vrsta predmeta/Course	Obvezni strokovni predmet na smeri Mehatronika in

type:	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. Uvod in predstavitev predmeta - Pregled vsebine, ciljev in kompetenc - Predstavitev dela na laboratorijskih vajah - Predstavitev ocenjevanja 2. Interferenca - Kompleksni popis EM valovanja, - matematični popis, - tvorba in interpretacja interferogramov, - primeri. 3. Koherenca - Fizikalna razlaga, - Matematični popis, - vplivi na meritve. 4. Uklon svetlobe - Huygens-Fresnel-ov princip, - Fraunhoferjev uklon, - Fourierev popis, - Primeri. 5. Laserska pegavost - Fizikalna razlaga, - matematični popis, - vplivi na meritve. 6. Laserski in alternativni svetlobni izvori - NEkoherentni izvori, - koherentni izvori,	1. Introduction and presentation of the course - Subject review, goals and competencies - Presentation of lab work - Presentation of assessment 2. Interference - Complex description of EM waves, - mathematical description, - creation and interpretation of interferograms, - examples. 3. Coherence - Physical interpretation, - Mathematical description, - effects on measurements. 4. Light diffraction - Huygens-Fresnel principle, - Fraunhofer difraction, - Fourier diffraction, - Examples. 5. Laser speckles - Physical interpretation, - mathematical description, - effects on measurements. 6. Laser and alternative light sources - Non-coherent sources, - coherent sources,

- temeljne lastnosti in primerjava uporabnosti 7. Detekcijski sistemi - Točkovni, linijski in ploskovni fotodetektorji detektorji, - enobarvna, večbarvna in hiperspektralna detekcija. 8. Računalniška obdelava optičnih signalov - Digitalizacija signalov, - predobdelava, - detekcija značilk (prehodov, vrhov, kontur). 9. Interferometrija - Konfiguracije: Newton, Fizeau, Twyman-Green, Mach-Zehnder. - Strižna interferometrija - Fazno zamikanje - Primeri uporabe 10. Laserska triangulacija - Klasifikacija, - princip merjenja, - zaznava svetlobnega vzorca, - rekonstrukcija v 3D obliko, - primeri uporabe. 11. Kalibracija laserskih 3D merilnikov - Parametri modela 3D rekonstrukcije, - izmera referenčnega telesa, - kriterijska funkcija, - numerična optimizacija. 12. Konfokalni merilni sistemi - Klasifikacija po merilnih principih, - enobarvni in večbarvni merilniki razdalje, - skenirni sitemi, - primeri uporabe. 13. 3D merjenje na osnovi časa preleta - klasifikacija, - merilni principi, - enotočkovne metode, - matrične metode, - primeri uporabe. 14. Vlakenski senzorji - notranji/zunanji senzorji, - modulacija intenzitete, - faze in polarizacija, - primeri merilnikov tlakov, deformacij, temperature. 15. Lasersko merjenje hitrih pojavov - Tehnike hitrega osvetljevanja, optične konfiguracije (senčna, schlieren,	- basic features and usability comparison 7. Detection systems - Point, line and plane photodetectors detectors, - monochromatic, color and hyperspectral detection. 8. Computer processing of optical signals - Digitalization of signals, - pre-processing, - detection of features (transitions, peaks, contours) 9. Interferometry - Interferometer configurations: Newton, Fizeau, Twyman-Green, Mach-Zehnder. - Shearing interferometry - Phase-shifting techniques - Examples 10. Laser triangulation - Classification, - measurement principle, - detection of light pattern, - 3D reconstruction, - examples. 11. Calibration of Laser 3D Meters - 3D reconstruction model, - measurement of the reference body, - criterion function, - numerical optimization. 12. Confocal measurement systems - Classification by measurement principles, - monochrome and multicolor techniques, - scanning systems, - use cases. 13. Time-of-flight measurement - classification, - measurement principles, - single point methods, - matrix methods, - use cases. 14. Fiber Sensors - internal / external sensors, - intensity modulation, - phases and polarization, - examples of pressure gauges, deformations, temperature. 15. Laser measurement of ultra-fast

interferometrična). - Primeri uporabe.	phenomena - Fast lighting techniques, optical configurations (shady, schlieren, interferometric). - examples.

Temeljna literatura in viri/Readings:

1. Gasvik K.J. Optical metrology, 3rd ed. Chichester: John Wiley & Sons, 2002. [COBISS.SI-ID 11175195]
2. Malacara, Optical Shop Testing, 3rd ed., Wiley, 2007. [COBISS.SI-ID 11174427]
3. Toru Yoshizawa, Handbook of Optical Metrology: Principles and Applications, CRC Press, 2009. [COBISS.SI-ID 11174683]

Cilji in kompetence:	**Objectives and competences:**
Cilji: 1. Spoznati zakonitosti in pojave širjenja laserske svetlobe in njihovo uporabo v merilnih laserskih sistemih. 2. Spoznati metode razvoja laserskih merilnih sistemov s posebnim poudarkom na interdisciplinarnem pristopu, fizikalnem, matematičnem in numeričnem modeliranju. 3. Spoznati metode in postopke eksperimentalne evaluacije laserskih merilnih sistemov. Kompetence: 1. S1-MAG: Sposobnost za opredelitev, razumevanje temeljnih znanstvenih problemov in ustvarjalno reševanje strokovnih izzivov na področju laserskih merilnih sistemov. 2. S8-MAG in S9-MAG: Sposobnost iskanja virov, kritične presoje informacij, samostojnega nadgrajevanja pridobljenih znanj in poglabljanja znanja na področjih laserskih merilnih sistemov. Ter usposobljenost za delo v skupini in interdisciplinarno povezovanje. 3. P2-MAG: Obvladovanje temeljnih teoretičnih kakor tudi aplikativnih znanj, ki so bistvena za obvladovanje tehničnega področja	Objectives: 1. To understand the laws and phenomena of laser light propagation and their application in laser measuring systems. 2. To learn the methods of development of laser measuring systems with special emphasis on interdisciplinary approach, physical, mathematical and numerical modeling. 3. To understand the methods and procedures of experimental evaluation of laser measuring systems. Competences: 1. S1-MAG: The ability to define and understand fundamental scientific problems and to creatively deal with professional challenges in the field of laser measurement systems. 2. S8-MAG and S9-MAG: The ability to find sources, critically evaluate information, independently upgrade the attained knowledge and deepen the knowledge in the individual specialized fields of laser measurement systems. The ability for teamwork and for interdisciplinary networking. 3. P2-MAG: Using the fundamental theoretical and applied knowledge,

laserskih merilnih sistemov.	crucial for having command of technical field of laser measurement systems.

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 laserskih merilnih sistemov. Spretnosti: S2.2 Načrtovanje in vodenje delovnega procesa na podlagi ustvarjalnega reševanja problemov, povezanih z laserskimi merilnimi sistemi.	Knowledge: Z2: Thorough theoretical, methodological and analytical knowledge with elements of a research work that form a basis for very demanding professional work in the field of laser measurement systems. Skills: 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 of the laser measurement systems.

Metode poučevanja in učenja:	**Learning and teaching methods:**
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 (preklopno krmiljenje zapornice, tekočega traku, PID krmiljenje procesa, laserski merilni sistem, laserski obdelovalni sistem). P5 Uporaba študijskega gradiva v obliki e-verzij: predstavitve predavanj, zbirke nalog z vaj, navodil za izvedbo laboratorijskih vaj P14 Virtualni eksperimenti P15 Uporaba video vsebin kot priprava na vaje	P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases. P2 Presenting the content according to the explained system. P3 Auditorial exercises, in which theoretical content from the lectures is supplemented with practical examples. P4 Laboratory exercises with special-purpose didactic devices (description needs to be added, max. two lines per device). P5 Application of study material (description needs to be added, max. one line per material, e.g. textbook, e-book, printed lecture presentaions, etc.). P14 Virtual experiments. P15 Application of videos for preparations to the lectures and exercises.

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: - Practical part: 50%.
- Teoretični del: 50%.	25,00 %	- Theoretical part: 50%.
Ocena vaj: - Delo na laboratorijskih vajah (predpriprava, sodelovanje in samostojnost): 50%.	25,00 %	Exercises: - Work on exercises (preparation, colaboration, individual work): 50%.
- Poročilo o opravljenih vajah: 50%.	25,00 %	- Report for exercises: 50%.

Ocenjevalna lestvica:	Grading system:

Reference nosilca/Lecturer's references:

Matija Jezeršek:

1. VELLA, Daniele, LUKAČ, Matjaž, JERNEJČIČ, Urban, LUKAČ, Nejc, KLANEČEK, Žan, MILANIČ, Matija, **JEZERŠEK, Matija**. Measurements of hair temperature avalanche effect with alexandrite and Nd:YAG hair removal lasers. Lasers in surgery and medicine. Jan. 2023, vol. 55, iss. 1, str. 1-10, ilustr. ISSN 1096-910 https://onlinelibrary.wiley.com/doi/full/10.1002/lsm.23622, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=144340, DOI: 10.1002/lsm.23622. [COBISS.SI-ID 133764611]
2. ZUBALIC, Emil, VELLA, Daniele, BABNIK, Aleš, **JEZERŠEK, Matija**. Interferometric fiber optic probe for measurements of cavitation bubble expansion velocity and bubble oscillation time. Sensors. 2023, vol. 23, iss. 2, str. 1-10, ilustr. ISSN 1424-8220. https://www.mdpi.com/1424-8220/23/2/771, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=143898, DOI: 10.3390/s23020771. [COBISS.SI-ID 138271491]
3. KRAVANJA, Gaia, BELYAEVA, Inna A., HRIBAR, Luka, DREVENŠEK OLENIK, Irena, **JEZERŠEK, Matija**, SHAMONIN, Mikhail. Tunable drop splashing on magnetoactive elastomers. Advanced materials interfaces. June 2021, vol. 8, iss. 11, str. 1-7, ilustr. ISSN 2196-7350. https://onlinelibrary.wiley.com/doi/full/10.1002/admi.202100235, DOI: 10.1002/admi.202100235. [COBISS.SI-ID 62237187]
4. KOŠIR, Jure, VELLA, Daniele, LUKAČ, Matjaž, **JEZERŠEK, Matija**. Towards personalized and versatile monitoring of temperature fields within heterogeneous tissues during laser therapies. Biomedical optics express. 2021, vol. 12, iss. 7, str. 4530-4543, ilustr. ISSN 2156-7085.

https://www.osapublishing.org/boe/fulltext.cfm?uri=boe-12-7-4530&id=452861, https://repozitorij.uni-lj.si/IzpisGradiva.php?id=128832, DOI: 10.1364/BOE.428028. [COBISS.SI-ID 72307459]
5. ROGELJ, Luka, SIMONČIČ, Urban, TOMANIČ, Tadej, **JEZERŠEK, Matija**, PAVLOVČIČ, Urban, STERGAR, Jošt, MILANIČ, Matija. Effect of curvature correction on parameters extracted from hyperspectral images. Journal of biomedical optics. 2021, vol. 26, iss. 9, str. 096003-1-096003-21, ilustr. ISSN 1083-3668. DOI: 10.1117/1.JBO.26.9.096003. [COBISS.SI-ID 75439875]