# UČNI NAČRT PREDMETA/COURSE SYLLABUS

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| **Predmet:** | Laserska obdelovalna tehnologija |
| **Course title:** | LASER PROCESSING TECHNOLOGY |
| **Članica nosilka/UL Member:** | UL FS |

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

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| **Univerzitetna koda predmeta/University course code:** | 0566821 |
| **Koda učne enote na članici/UL Member course code:** | 6061-M |

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

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| **Nosilec predmeta/Lecturer:** | Matija Jezeršek, Peter Gregorčič |

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| **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. |

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

| **Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:** | **Prerequisites:** |
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| 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):** |
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| 1. Uvod<br>- Pregled vsebine, ciljev in kompetenc<br>- Predstavitev dela na laboratorijskih vajah<br>- Predstavitev ocenjevanja<br>2. Interakcija laserske svetlobe s snovjo | 1. Introduction<br>- Review of the content, goals and competencies<br>- Presentation of lab work<br>- Presentation of assessment<br>2. Interaction of laser light with matter |

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| - Makroskopski pogled,<br>- interakcija na nivoju osnovnih delcev: kovine in dielektrik.<br>- Vplivi na absorpcijski koeficient<br>3. Toplotni pojavi<br>- Absorpcija,<br>- modeli tranzientnega prevoda toplote (1D model, gaussov izvor v polneskončnem prostoru, točkovni izvor v polprostoru) taljenje, odparevanje in ionizacija<br>- hitrost laserskega odparevanja<br>4. Fotokemični pojavi<br>- Vezne energije molekul in kristalnih struktur<br>- Vdorna svetlobna globina<br>- Modifikacija in ablacija materiala<br>- UV laserji<br>- Primeri uporabe<br>5. Optodinamski pojavi<br>- Pretvorba svetlobne v mehansko energijo<br>- Pojavi v trdni snovi<br>- Pojavi v zraku (zvok, udarni val)<br>- Pojavi v tekočini<br>- Primeri uporabe: prenos snovi, laserska propulzija, diagnostične metode<br>6. Sistemski parametri laserskih obdelav<br>- Optični parametri (valovna dolžina, kvaliteta, moč, energija, repeticija,...)<br>- Tehnološki parametri (fokusiranje, materialne lastnosti, pozicioniranje, ...)<br>- Področja uporabe posameznih tipov laserjev<br>7. Lasersko vrtanje<br>- Tehnike vrtanja,<br>- Komponente sistema,<br>- Procesni parametri,<br>- Modeliranje procesa,<br>- Primeri sistemov,<br>- Prednosti in slabosti<br>8. Lasersko rezanje<br>- Tehnike rezanja,<br>- Komponente sistema,<br>- Procesni parametri,<br>- Modeliranje procesa,<br>- Primeri sistemov,<br>- Prednosti in slabosti<br>9. Lasersko graviranje<br>- Tehnike graviranja,<br>- Komponente sistema,<br>- Procesni parametri,<br>- Modeliranje procesa,<br>- Primeri sistemov,<br>- Prednosti in slabosti<br>10. Lasersko varjenje<br>- Tehnike graviranja,<br>- Komponente sistema,<br>- Procesni parametri, | - Macroscopic view,<br>- interaction at the level of basic particles: metals and dielectrics.<br>- Effects on absorption coefficient<br>3. Thermal phenomena<br>- Absorption,<br>- transient heat transfer models (1D model, Gaussian origin in semi-infinite space, point source in semi-space) melting, evaporation and ionization<br>- speed of laser evaporation<br>4. Photochemical phenomena<br>- Binding energies of molecules and crystal structures<br>- Penetration depth of light<br>- Modification and ablation of the material<br>- UV lasers<br>- Examples<br>5. Optodynamic phenomena<br>- Conversion of light into mechanical energy<br>- OD phenomena in solids<br>- OD phenomena in air (sound, shock wave)<br>- OD phenomena in liquid<br>- Uses: substance transfer, laser propulsion, diagnostic methods<br>6. System parameters of laser processing<br>- Optical parameters (wavelength, quality, power, energy, repetition,...)<br>- Technological parameters (focusing, material properties, positioning,...)<br>- Areas of application of individual types of lasers<br>7. Laser Drilling<br>- Drilling techniques,<br>- System components,<br>- Process parameters,<br>- Process modeling,<br>- Examples of systems,<br>- Pros and cons<br>8. Laser cutting<br>- cutting techniques,<br>- System components,<br>- Process parameters,<br>- Process modeling,<br>- Examples of systems,<br>- Pros and cons<br>9. Laser engraving<br>- Engraving techniques,<br>- System components,<br>- Process parameters,<br>- Process modeling,<br>- Examples of systems,<br>- Pros and cons<br>10. Laser welding<br>- Welding techniques,<br>- System components,<br>- Process parameters, |

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| - Modeliranje procesa,<br>- Primeri sistemov,<br>- Prednosti in slabosti<br>11. Laserski inženiring površin<br>- Teoretične osnove laserskega mikrostrukturiranja,<br>- vplivi na omočljivost površin,<br>- lasersko barvanje in oksidacija.<br>12. Laserski 3D tisk<br>- Laserska stereolitografija,<br>- lasersko selektivno sintranje in pretaljevanje,<br>- direktno lasersko ulivanje,<br>- primerjava z nelaserskimi tehnikami.<br>13. Laserski medicinski sistemi in posegi<br>- Interakcija laserske svetlobe s tkivi,<br>- pregled laserjev, ki se uporabljajo v medicinskih sistemih,<br>- tehnike vodenja snopa do ciljnega tkiva,<br>- primeri.<br>14. Diagnostika obdelovalnih procesov<br>- Popis procesnih parametrov,<br>- Senzorji za nadzor laserskih procesov (temperaturni, optični, zvočni/ultrazvočni),<br>- Primeri<br>15. Adaptivno krmiljenje laserskih procesov<br>- Povratne zanke v laserskih obdelavah,<br>- Krmilni algoritmi na osnovi primarnih/sekundarnih izhodnih parametrov,<br>- Primeri | - Process modeling,<br>- Examples of systems,<br>- Pros and cons<br>11. Laser surface engineering<br>- Theoretical basis of laser microstructuring,<br>- effects on surface wettability,<br>- laser painting and oxidation.<br>12. Laser 3D printing<br>- Laser stereolithography,<br>- Selective laser sintering and melting,<br>- direct laser casting,<br>- comparison with non-laser techniques.<br>13. Laser Medical Systems and Interventions<br>- Interaction of laser light with tissues,<br>- review of lasers used in medical systems,<br>- techniques for guiding the laser beam to the target tissue,<br>- examples<br>14. Diagnostics of machining processes<br>- List of process parameters,<br>- Sensors for controlling laser processes (temperature, optical, sound / ultrasonic),<br>- Examples<br>15. Adaptive control of laser processes<br>- feedback loops in laser processing,<br>- Control algorithms based on primary and secondary output parameters,<br>- Examples |

**Temeljna literatura in viri/Readings:**


1. W.M. Steen, Laser Material Processing (4th Edition), Springer Verlag, 2010
2. E. Kannatey-Asibu, Principles of laser materials processing, John Wiley & Sons, 2009
3. J.F.Ready, Industrial Applications of Lasers, 2nd. ed., Academic Press, 1997
4. Dieter Schuoecker, High Power Lasers in Production Engineering, Imperial College Press, 1999.


| **Cilji in kompetence:** | **Objectives and competences:** |
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| Cilji:<br>1. Spoznavanje principov interakcije med lasersko svetlobo in snovjo.<br>2. Seznanitev z nekaterimi laserskimi obdelovalnimi procesi in pripadajočimi optomehatronskimi sistemi.<br>3. Vpliv laserskih parametrov na učinkovitost in kakovost procesa.<br>4. Seznanitev z metodami nadzora procesa.<br>Kompetence:<br>1. S1-MAG: Sposobnost za opredelitev, razumevanje temeljnih znanstvenih problemov in | Objectives:<br>1. Understanding the principles of interaction between laser light and matter.<br>2. Introduction with some laser processing processes and associated optomechatronic systems.<br>3. Impact of laser parameters on process efficiency and quality.<br>4. Introduction with process control methods.<br>Competences:<br>1. S1-MAG: The ability to define and understand fundamental scientific problems and to creatively |

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| ustvarjalno reševanje strokovnih izzivov na področju laserskih obdelav.<br>2. S8-MAG in S9-MAG: Sposobnost iskanja virov, kritične presoje informacij, samostojnega nadgrajevanja pridobljenih znanj in poglabljanja znanja na posameznih specializiranih področjih laserskih obdelav. Ter usposobljenost za delo v skupini in interdisciplinarno povezovanje..<br>3. P2-MAG: Obvladovanje temeljnih teoretičnih kakor tudi aplikativnih znanj, ki so bistvena za obvladovanje tehničnega področja laserskih obdelovalnih tehnologij. | deal with professional challenges in the field of laser processing.<br>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 specialised fields of laser processing. The ability for teamwork and for interdisciplinary networking.<br>3. 3. P2-MAG: Using the fundamental theoretical and applied knowledge, crucial for having command of technical field of laser processing. |

| **Predvideni študijski rezultati:** | **Intended learning outcomes:** |
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| Znanja:<br>Z2: Poglobljeno teoretično, metodološko in analitično znanje z elementi raziskovanja, ki je osnova za zelo zahtevno strokovno delo na področju laserskih obdelovalnih procesov.<br>Spretnosti:<br>S2.2 Načrtovanje in vodenje delovnega procesa na podlagi ustvarjalnega reševanja problemov, povezanih z laserskimi obdelovalnimi tehnologijami. | Knowledge:<br>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 machining processes.<br>Skills:<br>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 processing technology. |

| **Metode poučevanja in učenja:** | **Learning and teaching methods:** |
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| P1 Avditorna predavanja z reševanjem izbranih - za področje značilnih - teoretičnih in praktično uporabnih primerov.<br>P2 Obravnava snovi po urejeni in vnaprej razloženi sistematiki.<br>P3 Avditorne vaje, kjer se teoretično znanje s predavanj podkrepi z računskimi primeri.<br>P4 Laboratorijske vaje z namenskimi didaktičnimi pripomočki (preklopno krmiljenje zapornice, tekočega traku, PID krmiljenje procesa, laserski merilni sistem, laserski obdelovalni sistem).<br>P5 Uporaba študijskega gradiva v obliki e-verzij: predstavitve predavanj, zbirke nalog z vaj, navodil za izvedbo laboratorijskih vaj<br>P14 Virtualni eksperimenti<br>P15 Uporaba video vsebin kot priprava na vaje | P1 Auditorial lectures with solving selected field-specific theoretical and applied use cases.<br>P2 Presenting the content according to the explained system.<br>P3 Auditorial exrecises, in which theoretical content from the lectures is supplemented with practical examples.<br>P4 Laboratory exercises with special-purpose didactic devices (description needs to be added, max. two lines per device).<br>P5 Application of study material (description needs to be added, max. one line per material, e.g. textbook, e-book, printed lecture presentaions, etc.).<br>P14 Virtual experiments.<br>P15 Application of videos for preparations to the lectures and exercises. |

| Načini ocenjevanja: | Delež/Weight | Assessment: |
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| 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%. |

**Reference nosilca/Lecturer's references:**

**Matija Jezeršek:**

1. POGAČAR, Marko, JEZERŠEK, Matija. Laser-based magnetic micro-inscription : surface heating versus deep penetration regime. Optics and laser technology. [Print ed.]. Jun. 2019, vol. 114, str. 164-170, ilustr. ISSN 0030-3992. https://www.sciencedirect.com/science/article/pii/S0030399218306601, DOI: 10.1016/j.optlastec.2019.0051. [COBISS.SI-ID 16468251]
2. KOGEJ, Peter, JEZERŠEK, Matija, MOŽINA, Janez, BABNIK, Aleš. Apparatus and method for writing a pattern in a substrate : EP2714414 (B1), 2015-10-07. [S. l.]: European Patent Office, 2015. 12 f., ilustr. [COBISS.SI-ID 12577819]
3. KOS, Matjaž, ARKO, Erih, KOSLER, Hubert, JEZERŠEK, Matija. Remote laser welding with in-line adaptive 3D seam tracking. The international journal of advanced manufacturing technology. Aug. 2019, vol. 103, iss. 9/12, str. 4577-4586, ilustr. ISSN 0268-3768. https://link.springer.com/article/10.1007/s00170-019-03875-z, DOI: 10.1007/s00170-019-03875-z. [COBISS.SI-ID 16645659]
4. GREGORČIČ, Peter, JEZERŠEK, Matija, MOŽINA, Janez. Optodynamic energy-conversion efficiency during an Er:YAG-laser-pulse delivery into a liquid through different fiber-tip geometries. Journal of biomedical optics. 2012, vol. 17, iss. 7, str. 075006-1-075006-9, ilustr. ISSN 1083-3668. DOI: 10.1117/1.JBO.17.7.075006. [COBISS.SI-ID 12358939]

**Peter Gregorčič:**

1. GREGORČIČ, Peter. Comment on "Bioinspired reversible switch between underwater superoleophobicity/superaerophobicity and oleophilicity/aerophilicity and improved antireflective property on the nanosecond laser-ablated superhydrophobic titanium surfaces". ACS applied materials & interfaces. 2020, ilustr. ISSN 1944-8244. https://pubs.acs.org/doi/10.1021/acsami.9b23462, DOI: 10.1021/acsami.9b23462. [COBISS.SI-ID 17112859]
2. SENEGAČNIK, Matej, JEZERŠEK, Matija, GREGORČIČ, Peter. Propulsion effects after laser ablation in water, confined by different geometries. Applied physics.A, Materials science & processing. Feb. 2020, vol. 126, iss. 2, str. 1-12, ilustr. ISSN 0947-8396. https://link.springer.com/article/10.1007%2Fs00339-020-3309-y, DOI: 10.1007/s00339-020-3309-y. [COBISS.SI-ID 17026587]
3. PETKOVŠEK, Martin, HOČEVAR, Matej, GREGORČIČ, Peter. Surface functionalization by nanosecond-laser texturing for controlling hydrodynamic cavitation dynamics. Ultrasonics Sonochemistry. 2020, vol. 67, str. 1-10, ilustr. ISSN 1350-4177. https://www.sciencedirect.com/science/article/pii/S1350417719313173?via%3Dihub#!, DOI: 10.1016/j.ultsonch.2020.105126. [COBISS.SI-ID 17154075]