

1. Introduction to photon and charged beam lithographies. Radiation energy, dose, power, intensity, reversable and irreversible impact. Fundamentals of lithography: masks, technological processes, possibilities and limitations.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
2. Direct laser writing (DLW). Serial laser writing. Surface (2D) and volume (3D) material processing. Additive and subtractive fabrication methods. CAD-CAM production. Linear and non-linear absorption.	2			4			6	1 2	Reading of lecture notes and textbooks, preparation for laboratory works.
3. Non-linear/multi-photon lithography (NLL, 2PP/TPP, MPP). Non-linear absorption in volume at tight focusing conditions. Avalanche ionization and thermal accumulation. Polymerization and optical damage thresholds.	2			4			6	1 2	Reading of lecture notes and textbooks, preparation for laboratory works.
4. STED, RESOLFT, EUV, light sheet and other advanced light lithography techniques. Optical and chemical quenching of reactions. Excitation-depletion (multi-color), extreme UV, light sheet lithographies.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
5. Interference/holographic and projection lithographies, digital light processing (DLP). Multi-beam processing of materials: interference and projection exposure. Digital (dynamic) and dual (photo-photo and photo-thermo) exposures.	2			4			6	1 2	Reading of lecture notes and textbooks, preparation for laboratory works.
6. Soft-lithography (micro-replication). Micro-stamping and pattern transfer techniques, replications, elastomeric masks, thermopolymers.	2			4			6	1 2	Reading of lecture notes and textbooks, preparation for laboratory works.
7. Nanoimprint lithography (NIL). Peculiarities of nanoimprint lithography and roll-to-roll implementation.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
8. Nanosphere lithography. Nanosphere (colloid) lithography and self-organisation. Multi-step lithography.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
9. Electron beam lithography. Fabrication of masks and nano-prototyping using electron beam, advantages and limitation comparing to laser lithography.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
10. Focussed ion beam machining. Specifics of ion beam, advantages and limitations. Applications and comparison to photon beams.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
11. Atomic force/thermal probe lithography. Atomic force (contact) and thermal probe lithography.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
12. Pulsed Laser Ablation in Liquids (PLAL). Material processing in gas and liquid environments, laser assisted nanoparticle generation.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
13. Laser induced forward transfer (LIFT). Pulsed light radiation induced material transfer.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
14. Alternative 3D printing options: SLS, SLM, FDM/FFF, InkJet, Binder Jetting. Selective laser sintering/melting, thermal extrusion deposition, jet printing and binding.	2						2	4	Reading of lecture notes, textbooks and scientific literature.
15. Hybrid (additive and subtractive) precision material 3D processing. Combination of additive and subtractive laser, electron and ion beam, mask and beam based material processing methods.	2						2	2	Reading of lecture notes, textbooks and scientific literature.

16. MNFT widespread in Lithuania and worldwide, nowadays made functional structures and future perspectives. The demand of advanced micro- and nano-fabrication technologies in science and their practical applications, significant breakthroughs and trends.	2						2	2	Reading of lecture notes, textbooks and scientific literature.
Total	32				16		48	9 2	

Assessment strategy	Weight, %	Deadline	Assessment criteria
Laboratory work	40	By the end of semester	4 laboratory works, each work is defended separately. The final mark is from 0 to 4, which add to a final course mark.
Presentation and summary	10+10	By the end of semester	Presentation on selected topic, answer to questions, brief discussion. Evaluation, which will add up to 2 marks to a final course mark.
Exam	40	By the end of the course	Exam in written form, 4 questions from the whole course. Answers to each topic are marked as follows: 0 (incorrect/no answer), 0.5 (partially correct) and 1 (correct). All marks sum up.
Overall	100		The overall mark is the sum of the above items and is rounded. <5 below threshold 5 – weak 6 – satisfactory 7 – average 8 – good 9 – very good 10 – excellent

Author	Year of publication	Title	Issue of a periodical or volume of a publication	Publishing place and house or web link
Compulsory reading				
M. Malinauskas	2020	Collection of MNFT presentations		Manuscript
T. Baldacchini	2020	Three-Dimensional Microfabrication Using Two-Photon Polymerization	2nd. Ed.	Elsevier, 512 p.
J. Stampfl, R. Liska, A. Ovsianikov	2016	Multiphoton Lithography: Techniques, Materials, and Applications		386 p.
Optional reading				
E. Skliutas, M. Lebedevaite, E. Kabouraki, T. Baldacchini, J. Ostrauskaite, M. Vamvakaki, M. Farsari, S. Juodkazis, M. Malinauskas,	2021	Polymerization mechanisms initiated by spatio-temporally confined light	10, 1211-1242	Nanophotonics,
L. Jonušauskas, S. Juodkazis, M. Malinauskas	2018	Optical 3D printing: bridging the gaps in the meso-scale	20, 053001	Journal of Optics, IOP
M. Malinauskas, A. Žukauskas, S. Hasegawa, Y. Hayasaki, V. Mizeikis, R. Buividas, S. Juodkazis	2016	Ultrafast laser processing of materials: from science to industry	5, e16133	Light: Science and Applications, Nature

M. Malinauskas, M. Farsari, A. Piskarskas, S. Juodkazis	2013	Ultrafast-laser micro/nano- structuring of photopolymers: a decade of advances	533 , 1	Physics Reports, Elsevier
M. Malinauskas, G. Kiršanskė, S. Rekštytė, T. Jonavičius, E. Kaziulionytė, L. Jonušauskas, A. Žukauskas, R. Gadonas, A. Piskarskas	2012	Nanophotonics lithography: a versatile tool for manufacturing functional three-dimensional micro- /nano-objects	52 , 312	Lithuania Journal of Physic, LPS