COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Methods of Advanced Microscopy	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: prof. Roland Tomašiūnas **Other(s):**	Faculty of Physics

Study cycle	Type of the course unit (module)
First (master studies)	Compulsory

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
Lectures, seminars, laboratory tasks	I (autumn) semester	Lithuanian/English

Requirements for students	
Prerequisites: Knowledge of basic physics at the level of first-cycle studies as well as material science course.	**Additional requirements (if any):** Knowledge of semiconductor physics or solid state physics.

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	140	64	76

Purpose of the course unit (module): programme competences to be developed		
...		
Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
Ability of the students to apply theoretical knowledge while selecting the right microscopy for the investigations, to acquire practical skills to prepare samples, to work with a scanning electron microscope, to use supplementary units of the microscope, to analyse the obtained images, to use high tension and vacuum equipment. Acquaintance with the microscopes and microscopy research conducted in the visiting laboratories at Vilnius university and Center for Physical Sciences and Technology.	Laboratory works	Control questions, quality evaluation of the preparatory work, of the ability to acquire practical skills, of the justification of obtained results and formulation of conclusions.
Ability of the student to keep the track of latests investigations and applications of microscopy, deliver to the audience a selected scientific publication, to discuss with colleagues on microscopy topics.	Seminars	Evaluation, also collegial, of the ability to analyse and deliver to the audience scientific and commercial communication.
Acquisition of theory knowledge required for understanding the (i) phenomena of near field optical microscopy, (ii) the interaction of forces/ fields in the scanning tip microscopy, (iii) the results of scanning tunnelling spectroscopy, (iv) the functioning the electron microscope, (v) to acquire	Lectures	Exam.

and to analyse images and electron diffraction results, (vi) to execute main functions controlling the work of scanning electron microscope, (vii) to perform material science analysis of microscopy investigation results.		
Ability of the student to work with scientific and commercial literature, lecture material, preparatory work for the laboratory tasks and delivery of presentations.	Self-study	While laboratory work, seminars, exam.

Content: breakdown of the topics	**Contact hours**							**Self-study work: time and assignments**	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work placement	**Contact hours**	**Self-study hours**	**Assignments**
1. Scanning near-field optical microscopy (SNOM). Theoretical background. SNOM technique.	1						**1**	**1**	Search for supplementary material in the literature and analysis. Repetition for exam.
2. Confocal scanning microscopy. Optical schemes. 4Pi confocal scanning microscopy. Ways to improve the resolution.	1						**1**	**1**	Search for supplementary material in the literature and analysis. Repetition for exam.
3. Non-linear optical microscopy. Second harmonic generation microscopy. Sum frequency generation microscopy. Third harmonic generation microscopy. Coherent anti-Stokes Raman scattering microscopy. Non-linear optical microscopies in the near field. Two- and three-photon excitation fluorescence microscopy. Scientific and commercial systems.	3						**3**	**3**	Search for supplementary material in the literature and analysis. Repetition for exam.
4. Super-resolution microscopy. Qualities and perspectives of STORM, PALM and STED. Differences in transition schemes of STED, GSD and RESOLFT methods. Structured illumination super-resolution microscopy. Cryo-electron microscopy. Why super-resolution become so exceptional?	2						**2**	**2**	Search for supplementary material in the literature and analysis. Repetition for exam.
5. Atomic force microscopy (AFM). Working procedure and technical solutions. Tips and resolution. Features to create an image. Physics about forces in atomic force microscopy. Dynamic atomic force microscopy. Harmonic oscillator. Amplitude modulation method. Frequency modulation method. Commercial atomic force microscopes.	4						**4**	**4**	Search for supplementary material in the literature and analysis. Repetition for exam.
6. Magnetic force microscopy. Theoretical background. Measurement regimes. Formation of an image and analysis. Technical solutions. Why magnetic force microscopy celebrates revival?	2						**2**	**2**	Search for supplementary material in the literature and analysis. Repetition for exam.
7. Scanning tunneling microscopy (STM). Theoretical background. Inelastic tunneling through vacuum. Structure of the scanning tunneling microscope. Tip production and preparation. Sample	4						**4**	**4**	Search for supplementary material in the literature and analysis. Repetition for

surface preparation. Scanning tunneling spectroscopy.									exam.
8. Transmission electron microscopy (TEM). Historical overview. Structure and working procedure. Characteristics of an optical system. Beam condenser. Image formation system. Beam diffraction and analysis. Reciprocal space. High resolution transmission electron microscope (HRTEM).	6						**6**	**6**	Search for supplementary material in the literature and analysis. Repetition for exam.
9. Scanning electron microscopy (SEM). Structure and working procedure. Electron beam control. Image formation and pixel. Focusing peculiarities. Minimal spot. Contrast and minimal current. High resolution scanning electron microscope. Kind of contrast.	4						**4**	**4**	Search for supplementary material in the literature and analysis. Preparation for the laboratory work.
10. Other advanced microscopies. X-ray microscopy. Acoustic microscopy. Microscopy of organic materials. Surface wave microscopy. Photon force microscopy etc.	1						**1**	**1**	Search for supplementary material in the literature and analysis. Repetition for exam.
11. Material and device analysis: an overview. Microspectroscopy (FT-IR, UV-VIS-NIR, Raman, Auger). X-ray microanalysis and fluorescence. Material microanalysis and crystal structure investigation using TEM and SEM. EELS. EBSD. XEDS. EBIC.	3						**3**	**3**	Search for supplementary material in the literature and analysis. Preparation for the laboratory work.
12. Historical microscopes. Microscopy of the future. T.Musoptin. Historical overview and development of microscopes during XIX-XX centuries.	1						**1**	**1**	Search for supplementary material in the literature and analysis.
13. Presentation-discussion about recent commercial journals on microscopy (Imaging and Microscopy, Microscopy and Analysis, Microscopy Today etc., also internet sources) (each student – one journal).			8				**8**	**20**	Analysis of the dedicated journal and searching for supplementary material in the literature. Preparing the presentation.
14. Presentation-discussion about recent investigations on microscopy topic published in outstanding scientific journals, like Physical Review Letters, Nature, Science, Advanced Materials (each student – one publication).			8				**8**	**20**	Analysis of the dedicated publication and searching for supplementary material in the literature. Preparing the presentation.
15. Get acquainted and practiced individually with a scanning electron microscope Apollo 300 equipped with EDX and EBIC.					8		**8**	**2**	Analysis, selection and preparation of samples for experiments. Learning about functioning of the scanning electyron microscope and its supplementary units.
16. Get acquainted with modern microscopy technique and been introduced with the latest achievements at scientific centers in Vilnius (AFM at the Institute of Physical Chemistry, Physics Faculty, Vilnius University; AFM, SNOM, confocal microscopes and SEM at the Institute of Photonics and Nanotechnology, Physics Faculty, Vilnius University; TEM and SEM+FIB at the Center for					8		**8**	**2**	Get acquainted in advance with the microscopies used at visiting labs.

Physical Sciences and Technology).									
Total	**32**		**16**		**16**		**64**	**76**	

Assessment strategy	**Weight,%**	**Deadline**	**Assessment criteria**
Seminars rating	25	All course	Obligatory exercise. Ability to deliver a presentation is evaluated according to qualities of "speech", "picture", "research", "informative", "marketing", if applicable, "respond to questions", "asking questions".
Laboratory work rating	25	All course	Obligatory exercise. Ability (i) to learn working with a scanning electron microscope, (ii) to take part in the introductory lecture, while visiting the other labs. Assessment of how fast student gets acquainted with the main functions of the scanning electron microscope, the quality of obtained images, including of junctions, if applicable, of estimated elemental composition and distribution, ability to vary the conditions of inspection and to explain the result and the reason of failure. Discussion activity in the introductory lecture.
Exam	50	During the exam session	Assessment of understanding, completeness of answer, mistakes.

Author	**Year of publication**	**Title**	**Issue of a periodical or volume of a publication**	**Publishing place and house or web link**
Compulsary reading				
Peter W. Hawkes, John C. H. Spence.	2006	Science of Microscopy	2 Vol., 1100 p.	Springer Science + Business Media, LLC, New York (available in Vilnius University Library)
Douglas B. Murphy Davidson, Michael W.	2012	Fundamentals of Light Microscopy and Electronic Imaging	384 psl.	John Wiley & Sons, New Jersey (2001 available in Vilnius University Library, o 2012 - in the database of Vilnius University Library)
Nikodem Tomczak, Kuan Eng Goh	2010	Scanning Probe Microscopy	255 p.	World Scientific Publishing Co Pte Ltd, Singapore (available in the database of Vilnius University Library)
Anatoly Zayats, David Richards	2008	Nano-Optics and Near-Field Optical Microscopy	378 p.	Artech House Inc., Norwood, MA (available in the database of Vilnius University Library)
Roland Tomašiūnas	2008	Šiuolaikiniai mikroskopijos metodai medžiagotyrai (in Lithuanian)	162 p.	Progretus, Vilnius (available in Vilnius University Library, also ask R.Tomašiūnas)
Optional reading				
Nan Yao, Zhong L. Wang	2005	Handbook of Microscopy for Nanotechnology.	742 p.	Kluwer Academic Publishers, New York (available in Vilnius University Library)
David B. Williams, C. Barry Carter	2009	Transmission Electron Microscopy	760 p.	Springer Science + Business Media, LLC, New York (ask R.Tomašiūnas)
Te Sun Han, Peter Torok, Fu-Jen Kao	2003	Optical Imaging and Microscopy	395 p.	Springer-Verlag, Berlin Heidelberg (available in Vilnius University Library)