RĪGAS TEHNISKĀ UNIVERSITĀTE

RTU Course "Metaphotonics in Telecommunications"

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General data

Code	RDE715
Course title	Metaphotonics in Telecommunications
Course status in the programme	Compulsory/Courses of Limited Choice; Courses of Free Choice
Responsible instructor	Aleksandr Shalin
Academic staff	Vjačeslavs Bobrovs
Volume of the course: parts and credits points	1 part, 4.0 Credit Points, 6.0 ECTS credits
Language of instruction	LV, EN, RU
Annotation	Metaphotonics is an emerging multidisciplinary field that deals with the manipulation of light in artificially engineered metamaterials using both electrical and magnetic interactions. Metaphotonics offers unprecedented control of both linear and nonlinear optical phenomena at the micro and nanoscale for a variety of applications, from optical switching to metamaterials with negative and near-zero refractive indices, to chiral bioimaging and cloaking. At the same time, the methods and approaches developed in this area find their application in innovative communication technologies. However, the implementation of such applications requires nanoengineering based on the physics of appropriate artificial media with electromagnetic properties in the visible and infrared wavelengths, which are designed to exceed the properties of any naturally occurring material. Within the study course, students will gain knowledge about multipole expansion, resonant metaphotonics, optical properties of metamaterials, design of new devices based on them as well as applications in communication systems.
Goals and objectives of the course in terms of competences and skills	The aim of the study course is to provide knowledge about nanophotonics and metamaterials and their applications in telecommunications. Tasks of the study course: * to provide basic knowledge and experience about nanophotonics and metamaterials; * to teach to develop and apply simple metaphotonic solutions in communication technologies; * to provide students with an idea in the modelling computer class about the actual implementation of metaphotonics in telecommunications; * to develop skills to evaluate the existing telecommunication infrastructure for further modernization by applying innovative communication technologies.
Structure and tasks of independent studies	Within the study course, students' independent work will be organized as follows: - to solve the tasks defined by the academic personnel, showing the use of the knowledge acquired in the lectures; - summarize and analyse the latest published research results on metaphotonics and applications in telecommunications; - applying the acquired knowledge to create mathematical models for metaphotonic solutions in a modelling environment.
Recommended literature	Obligātā/Obligatory: 1. Lukas Novotny, Bert Hecht. Principles of Nano-Optics, Cambridge University Press, 2006. 2. Kirill Koshelev and Yuri Kivshar. Dielectric Resonant Metaphotonics, ACS Photonics 8 (1), 102-112, 2021. 3. Alexander Baev, Paras N. Prasad, Hans Ågren, Marek Samoć, Martin Wegener. Metaphotonics: An emerging field with opportunities and challenges, Nature: Physics Reports 594, 1-60, 2015. 4. Jin-hui Chen, Yi-feng Xiong, Fei Xu & Yan-qing Lu. Silica optical fiber integrated with two-dimensional materials: towards opto-electro-mechanical technology, Light: Science & Applications 10, No.78, 2021. Papildu/Additional: 1. Arash Ahmadivand, Burak Gerislioglu, Rajeev Ahuja, Yogendra Kumar Mishra. Toroidal Metaphotonics and Metadevices, Laser Photonics Review 14, 1900326, 2020. 2. Andrey B. Evlyukhin, Tim Fischer, Carsten Reinhardt and Boris N. Chichkov. Optical theorem and multipole scattering of light by arbitrarily shaped nanoparticle, Physical Review B 94, 205434, 2016. 3. Ivan Fernandez-Corbaton, Stefan Nanz, Rasoul Alaee, and Carsten Rockstuhl. Exact dipolar moments of a localized electric current distribution, Optics Express, 23 (26), 33044-33064, 2015. 4. A.Kislov, D., A.Gurvitz, E., Bobrovs, V., A.Pavlov, A., I.Marques, M., Redka, D., Ginzburg, P., S.Shalin, A. Multipole Engineering of Attractive-Repulsive and Bending Optical Forces, Advanced Photonics Research, Vol. 1, No. 1, 1.-12.lpp., 2021. 5. Canos Valero, A., A.Gurvitz, E., A.Benimetskiy, F., A.Pidgayko, D., Samusev, A., B.Evklyuhin, A., Bobrovs, V., Redka, D.. Theory, Observation, and Ultrafast Response of the Hybrid Anapole Regime in Light Scattering, Laser & Photonics Reviews, Vol. 1, No. 1, pp.1-16., 2021. 6. V.Kuznetsov, A., Canos Valero, A., Tarkhov, M., Bobrovs, V., Redka, D., S.Shalin, A. Transparent Hybrid Anapole metasurfaces with negligible electromagnetic coupling for phase engineering, Nanophotonics, Vol. 1, No. 1, 1.-14.lpp., 2021.
Course prerequisites	Electrodynamics, wave optics, nonlinear optics, mathematical analysis, fibre optics.

Course contents

Content	Full- and part-time intramural studies	Part time extramural studies

	Contact Hours	Indep. work	Contact Hours	Indep. work
Introduction to metaphotonics. The subject and branches of metaphotonics.	4	6	0	0
Low-loss high-index materials at telecommunication wavelengths. All-dielectric photonics.	6	8	0	0
Dielectric Resonant Metaphotonics. Nanoantennas in telecommunication. Fano and Mie resonances. Bound states in the continuum (BIC).	6	8	0	0
Multipole expansion in the scattering problem. Kerker effect. Forward/backward scattering. Anapole regime.	6	8	0	0
Toroidal Metaphotonics and Metadevices. Toroidal source. Theory and practical implementation in information transmission devices.	6	10	0	0
Hybrid Metaphotonic Devices. Metamaterials. Negative refractive index. Optical properties of metamaterials.	6	10	0	0
Two-dimensional materials. Graphene. Metasurfaces.	6	10	0	0
Topological Metaphotonics: new platform for the implementation of optical communication schemes immune to disorders.	8	12	0	0
Nonlinear Metaphotonics. Microresonator-based Kerr frequency combs in telecommunications. Generation of the second (SHG) and third (THG) harmonics in dielectric nanoantennas and metasurfaces.	8	12	0	0
Devices and prospects for the practical application of advanced developments of metaphotonics.	8	12	0	0
Total:	64	96	0	0

Learning outcomes and assessment

Learning outcomes	Assessment methods
Able to competently orient in the direction of metaphotonics, knows metamaterials with a negative refractive index and their application in telecommunications.	Test.
Able to create simple metaphotonic element modelling schemes and evaluate their linear and nonlinear properties.	Practical works. Exam.
Able to create hybrid metaphotonic devices in a modelling environment using two-dimensional materials.	Practical works. Exam.
Able to model a new type of optical communication system using different types of microresonators, generating Kerr frequency combs in dielectric nanoantennas and meta-surfaces.	Practical works. Exam.

Evaluation criteria of study results

Criterion	%
Test	30
Practical works	40
Exam	30
Total:	100

Study subject structure

Part	CP	Hours per Week			Tests			Tests (free choice)		
		Lectures	Practical	Lab.	Test	Exam	Work	Test	Exam	Work
1.	4.0	2.0	2.0	0.0		*			*	