UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU

Introduction to Metamaterials, Plasmonics, and Photonic Crystals

Educational subject description sheet

Basic information

Study programme Fizyka	**Didactic cycle** 2023/24
Speciality INFORMACJA KWANTOWA I SPINTRONIKA	**Subject code** 04FIZIKSS.24KU.04359.23
Organizational unit Faculty of Physics	**Lecture languages** English
Study level Second-cycle programme	**Course type** Elective
Study form Full-time	**Block** Complementary major subjects
Education profile General academic	

Subject coordinator	Andriy Serebryannikov
Lecturer	Andriy Serebryannikov

Period	Activities and hours	Number of ECTS points
Semester 3	• Lecture: 30, Exam • Seminar: 15, Graded credit	4

Goals

Code	Goal
C1	The general objective is to give the students initial knowledge on theory and applications of metamaterials, plasmonics and photonic crystals. The lecture course is aimed to overview the basics, state-of-the-art, and perspectives in the areas of planar metamaterials, surface plasmons and photonic crystals. The emphasis will be put on physical scenarios, design approaches, and main applications. The emphasis will be also put on all-dielectric and plasmonic, gradient and unitary (multi-)functional metasurfaces and metadevices.

Subject learning outcomes

Code	Outcomes in terms of	Learning outcomes	Examination methods
Knowledge – Student:			
W1	lists the main types and explains the underlying physics of metamaterials/metasurfaces used in different parts of electromagnetic spectrum	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	"Open book" exam
W2	understands and can explain the origin and specifics of the main physical scenarios and functionality achievable by unitary and gradient metasurfaces for various applications	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	"Open book" exam, Multimedia presentation
W3	understands and can explain the basic physical scenarios, advantages, and restrictions for the selected types of plasmonic structures	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	"Open book" exam, Multimedia presentation
W4	understands the basics of and differences between one- and two-dimensional photonic crystals	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	"Open book" exam
W5	understands and can describe the specifics of the selected materials used for metamaterials/metasurfaces	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	"Open book" exam, Multimedia presentation
Skills – Student:			
U1	can properly select or refine a proper physical and/or mathematical model to solve a given theoretical or design problem	FIZ_K2_U01, FIZ_K2_U02, FIZ_K2_U03	"Open book" exam
U2	can select a proper class/type of the structures and list the basic design features depending on the required application	FIZ_K2_U01, FIZ_K2_U02, FIZ_K2_U03, FIZ_K2_U04	"Open book" exam, Multimedia presentation
U3	can perform a comparative analysis of two or more design routes to the same functionality	FIZ_K2_U01, FIZ_K2_U02, FIZ_K2_U03	Multimedia presentation

Study content

No.	Course content	Subject learning outcomes	Activities
1.	Introduction to metamaterials	W1, U1, U2	Lecture
2.	Metasurfaces -- quasiplanar functional metamaterials	W2, W3, U1, U2, U3	Lecture
3.	Selected functionalities of modern metasurfaces	W2, W3, U1, U2, U3	Lecture
4.	Specifics of choice of materials and design principles of metamaterials/metasurfaces in different parts of electromagnetic spectrum	W1, W2, W5, U2, U3	Lecture
5.	Basics of plasmonic structures (incl. plasmonic metasurfaces), surface plasmons, localized surface plasmons	W2, W3, W5, U1, U2	Lecture, Seminar
6.	Introduction to one- and two-dimensional photonic crystals and photonic-crystal slabs	W4, U1, U2, U3	Lecture, Seminar
7.	Metasurfaces with phase gradient created by shifted subwavelength resonances: deflection and focusing	W2, U1, U2, U3	Seminar

No.	Course content	Subject learning outcomes	Activities
8.	Pancharatnam-Berry (geometric) phase based gradient metasurfaces and few-layer unitary metasurfaces for polarization manipulation	W2, U1, U2, U3	Seminar
9.	Unitary metasurfaces as color filters	W2, U1, U2, U3	Seminar
10.	Metadevices for polarimetry, asymmetric transmission and angular filtering	W2, U1, U2, U3	Seminar
11.	Tunable metasurfaces	W2, U1, U2, U3	Seminar

Additional information

Activities	Teaching and learning methods and activities
Lecture	Lecture with a multimedia presentation of selected issues, Conversation lecture, Problem-based lecture
Seminar	Lecture with a multimedia presentation of selected issues, Problem-based lecture, Discussion

Activities	Credit conditions
Lecture	The final grade will be based on the results of the open book exam. Everyone will receive three questions: 1 general question and 2 questions related to the research paper(s) on one topic, selected from the provided list of the research papers. The full answer for each question yields 1 point (pt) to the score. Very good (bdb; 5,0): 3 pts Good plus (+db; 4,5): 2.5 pts Good (db; 4,0): 2 pts Satisfactory plus (+dst; 3,5): 1.5 pts Satisfactory (dst; 3,0): 1 pt Unsatisfactory (ndst; 2,0): <1 pt
Seminar	The final score (0-100%) consists of two components: (i) evaluation of the presentation (report) - 75% contribution to final score and (ii) participation in the discussions - 25% contribution to final score. Very good (bdb; 5,0): 90-100% of final score Good plus (+db; 4,5): 80-89% of final score Good (db; 4,0): 70-79% of final score Satisfactory plus (+dst; 3,5): 60-69% of final score Satisfactory (dst; 3,0): 50-59% of final score Unsatisfactory (ndst; 2,0): 0-49% of final score

Literature

Obligatory

1. R. Marques, F. Martin, and M. Sorolla. Metamaterials with negative parameters. Wiley Interscience, 2007, Ch. 1-3.
2. W. Cai and V. M. Shalaev. Optical metamaterials. New York: Springer, 2010, Ch. 2,4-6,8,9.
3. N. Engheta and R. W. Ziolkowski, eds. Metamaterials: physics and engineering explorations. John Wiley & Sons, 2006, Ch. 1,2.
4. S. A. Maier. Plasmonics: fundamentals and applications. Springer Science & Business Media, 2007, Ch. 2,3,5,8.
5. K. Sakoda, Optical properties of photonic crystals. Springer Science & Business Media, 2004, Ch. 2,4,6-8.
6. K. Achouri and C. Caloz. Electromagnetic Metasurfaces: Theory and Applications. John Wiley & Sons, 2021, Ch. 1,2,5-7.

Optional

1. I. Brener, et al., eds. Dielectric Metamaterials: Fundamentals, Designs and Applications. Woodhead publishing, 2019.
2. K. Inoue and K. Ohtaka, eds. Photonic crystals: physics, fabrication and applications. Vol. 94. Springer Science & Business Media, 2004.
3. A.V. Zayats and S.A. Maier, eds. Active plasmonics and tuneable plasmonic metamaterials. John Wiley & Sons, 2013.
4. E. Semouchkina, Dielectric Metamaterials and Metasurfaces in Transformation Optics and Photonics. Elsevier, 2021.

Calculation of ECTS points

Activities	**Activity hours***
Lecture	30
Seminar	15
Preparation for classes	16
Reading the indicated literature	20
Preparation of a multimedia presentation	18
Preparation for the exam	21
Student workload	**Hours** 120
Number of ECTS points	**ECTS** 4

* academic hour = 45 minutes

Efekty uczenia się dla kierunku

Kod	Treść
FIZ_K2_U01	The graduate can use their knowledge to formulate and solve complex and unusual problems in the field of physical sciences; select and apply appropriate methods and tools necessary to solve a given problem (including advanced IT techniques), as well as adapt existing methods and tools or develop completely new ones
FIZ_K2_U02	The graduate can find the necessary information in the professional literature, databases and other sources, in particular in scientific journals basic to physics, and perform critical analysis, synthesis and creative interpretation of the collected information
FIZ_K2_U03	The graduate can formulate and test hypotheses related to simple research problems in physics (plan and perform observations, experiments, theoretical calculations or computer simulations and critically evaluate and discuss the results obtained)
FIZ_K2_U04	The graduate can prepare, for various audiences, oral presentations and written studies presenting specialized topics in the field of physical sciences in a communicative way, as well as debate on such topics
FIZ_K2_W01	The graduate knows and understands in-depth selected facts, phenomena, concepts and theories specific to physics and complex relationships between them (constituting advanced general knowledge in the field of physical sciences and representing both key and other selected issues in the field of advanced detailed knowledge in this discipline)
FIZ_K2_W02	The graduate knows and understands in-depth selected research methods and tools as well as mathematical models used in physics
FIZ_K2_W04	The graduate knows and understands main development trends in the discipline of physical sciences