UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU

Introduction to metamaterials, plasmonics, and photonic crystals

Educational subject description sheet

Basic information

Study programme
Fizyka (Physics of Advanced Materials for Energy Processing)

Speciality
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Organizational unit
Faculty of Physics and Astronomy

Study level
Second-cycle programme

Study form
Full-time

Education profile
General academic

Didactic cycle
2024/25

Subject code
04FENS.21S.03245.24

Lecture languages
English

Course type
Elective

Block
specialty subjects

Subject coordinator	Andriy Serebryannikov
Lecturer	Andriy Serebryannikov

Period	Activities and hours	Number of ECTS points
Semester 1	• Lecture: 30, Exam	3

Goals

Code	Goal
C1	The general objective is to provide the students with initial knowledge on theory and applications of metamaterials, plasmonics and photonic crystals. The lecture course is aimed to acquaint the students with 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 and design principles and applications, including all-dielectric and plasmonic, gradient and unitary metasurfaces and metadevices.

Subject learning outcomes

Code	Outcomes in terms of	Learning outcomes	Examination methods
Knowledge – Student:			
W1	lists the main types and explain the underlying physics of metamaterials in different parts of electromagnetic spectrum	FEN_K2_W01, FEN_K2_W02, FEN_K2_W04	"Open book" exam
W2	can explain the origin and specifics of the main physical scenarios and functionality achievable in unitary and gradient metasurfaces	FEN_K2_W01, FEN_K2_W02, FEN_K2_W04	"Open book" exam
W3	explains the basic physical principles, advantages, and restrictions for the selected types of plasmonic structures	FEN_K2_W01, FEN_K2_W02, FEN_K2_W04	"Open book" exam
W4	can explain the basics of one- and two-dimensional photonic crystals	FEN_K2_W01, FEN_K2_W02, FEN_K2_W04	"Open book" exam
W5	describes the specifics of the selected materials in the connection with metamaterials/metasurfaces	FEN_K2_W01, FEN_K2_W02, FEN_K2_W04	"Open book" exam
Skills – Student:			
U1	can select a proper class of the structures and list the basic design features depending on the required application	FEN_K2_U01, FEN_K2_U02, FEN_K2_U03, FEN_K2_U04	"Open book" exam
U2	can properly select or refine a proper physical and/or mathematical model to solve a particular problem	FEN_K2_U01, FEN_K2_U02, FEN_K2_U03	"Open book" exam
U3	perform a comparative analysis of two or more different routes to the same functionality	FEN_K2_U01, FEN_K2_U02, FEN_K2_U03	"Open book" exam

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.	Specifics of choice of materials and design principles of metamaterials/metasurfaces in different parts of electromagnetic spectrum	W1, W2, W5, U2, U3	Lecture
4.	Basics of plasmonic structures (incl. plasmonic metasurfaces), surface plasmons, localized surface plasmons	W2, W3, W5, U1, U2	Lecture
5.	One- and two-dimensional photonic crystals, photonic-crystal slabs, recent trends	W4, U1, U2, U3	Lecture

Additional information

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

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

Literature

Obligatory

1. N. Engheta and R. W. Ziolkowski, eds. Metamaterials: physics and engineering explorations. John Wiley & Sons, 2006, Ch. 1,2.
2. W. Cai and V. M. Shalaev. Optical metamaterials. New York: Springer, 2010, Ch. 2,4-6,8,9.
3. R. Marques, F. Martin, and M. Sorolla. Metamaterials with negative parameters. Wiley Interscience, 2007, Ch. 1-3.
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.

Optional

1. I. Brener, et al., eds. Dielectric Metamaterials: Fundamentals, Designs and Applications. Woodhead publishing, 2019.
2. K. Achouri and C. Caloz. Electromagnetic Metasurfaces: Theory and Applications. John Wiley & Sons, 2021.
3. K. Inoue and K. Ohtaka, eds. Photonic crystals: physics, fabrication and applications. Vol. 94. Springer Science & Business Media, 2004.

Calculation of ECTS points

Activities	Activity hours*
Lecture	30
Reading the indicated literature	15
Preparation for the exam	24
Preparation of a multimedia presentation	21

Student workload	**Hours** 90
Number of ECTS points	**ECTS** 3

* academic hour = 45 minutes

Efekty uczenia się dla kierunku

Kod	Treść
FEN_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
FEN_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
FEN_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)
FEN_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
FEN_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)
FEN_K2_W02	The graduate knows and understands in-depth selected research methods and tools as well as mathematical models used in physics
FEN_K2_W04	The graduate knows and understands main development trends in the discipline of physical sciences