COURSE DESCRIPTION CARD - SYLLABUS

Course name
Metamaterials [S2FT2>Metamat]

Course

Field of study
Technical Physics

Year/Semester
2/3

Area of study (specialization)
–

Profile of study
general academic

Level of study
second-cycle

Course offered in
Polish

Form of study
full-time

Requirements
elective

Number of hours

Lecture
30

Laboratory classes
0

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

2,00

Coordinators

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Lecturers

Prerequisites

Knowledge of the basics of the classical theory of electromagnetism and the physics of dielectrics and magnetics in the scope of the curriculum content of the subjects at the 1st and 2nd degree of education in the field of Technical Physics. The ability to solve elementary problems in electromagnetism based on the acquired knowledge, the ability to obtain information from indicated sources.

Course objective

Acquainting students with selected issues related to electromagnetic properties of metamaterials and problems related to the propagation of electromagnetic waves in metamaterial media.

Course-related learning outcomes

Knowledge:
1. Has in-depth knowledge of electromagnetic phenomena in metamaterials.
2. Knows the inverse matrix method used for experimental determination of electromagnetic parameters of metamaterials.

Skills:

1. can formulate complex physical and technical problems concerning metamaterials and propose a strategy for their solution.
2. can select dielectric and magnetic materials in terms of their applications in metamaterials technology.

Social competences:
1. perceives the possibilities and ways of continuous updating and supplementing knowledge in the field of modern technology using materials with different electromagnetic properties.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

The following assessment thresholds apply to the methods used to verify the learning outcomes achieved:
50.1-60% dst;
60.1-70% dst+;
70.1-80% db;
80.1-90% db+;
90.1% bdb and above.
Assessment is based on individual written work and/or oral response.

Programme content

Electromagnetic waves in metamaterial media, reflection and refraction of electromagnetic waves at the border of natural and metamaterial media, complex electromagnetic parameters of metamaterials, determination of electromagnetic parameters of metamaterials (inverse problem).

Course topics

1. Maxwell's equations and material equations.
2. Wave equations in media with zero charge and electric current densities and their solutions in the form of plane waves.
3. Relations between the directions of electric and magnetic field intensity vectors and the wave vector for a plane wave.
4. Dispersion relation in a medium with zero charge and electric current densities, general definition of the refractive index and relative wave impedance.
5. Relationship between the amplitudes of electric and magnetic field intensity of a plane wave in media with positive and negative refractive index.
6. The law of energy conservation for the electromagnetic field (Poynting's theorem) and its interpretation.
7. Relationship between the wave vector and the Poynting vector in media with positive and negative electric and magnetic permeabilities.
8. Boundary conditions for the electromagnetic field at the boundary of material media.
9. Relationships between electric and magnetic field intensity vectors and wave vectors for incident, reflected and refracted waves at the boundary of material media.
10. Consequences of boundary conditions for incident, reflected and refracted plane waves at the boundary of material media - conditions concerning the amplitudes and phases of these waves.
11. The law of reflection for a plane wave.
12. The law of refraction for a plane wave.
13. Dependence of the electric field intensity amplitudes of a reflected and refracted wave on the angles of incidence and reflection for polarized waves perpendicular to the plane of incidence.
14. Dependence of the magnetic field intensity amplitudes of a reflected and refracted wave on the angles of incidence and reflection for polarized waves in the plane of incidence.
15. Fresnel formulas (reflection and transmission coefficients for the amplitudes of electric and magnetic field intensity).
16. Relationships between electric and magnetic field intensity vectors and the wave vector for a plane wave in a medium with non-zero current and electric charge densities, resulting from Maxwell's equations.
17. Dispersion relationship for a plane wave in a medium with non-zero current and electric charge densities, and complex permittivity and complex refractive index for a medium with non-zero specific

conductivity.
18. Characterization of a plane wave in a medium with a complex refractive index and complex wave vector.
19. Relationship between macroscopic and microscopic electrical parameters of particles, electrical polarizability of particles, electrical permittivity and refractive index of a dielectric medium.
20. Lorentz model (complex atomic polarizability of dielectric media).
21. Optical properties of dielectric materials (dependence of complex refractive index on frequency).
22. Classical model of electrically conductive media (complex electrical conductivity).
23. Optical properties of electrically conductive materials (dependence of the complex refractive index on frequency, plasma frequency).
24. Complex electric permittivity for a structure composed of a network of straight conductors.
25. Complex magnetic permeability of a material created by a network of conducting cylinders.
26. Complex magnetic permeability of a material created by a network of conducting double cylinders with a gap.
27. Determination of electromagnetic parameters of metamaterials based on the scattering matrix.

Teaching methods

Lecture: detailed discussion of issues and derivation of formulas using chalk and blackboard, multimedia presentation of additional materials.

Bibliography

Basic:
1. D.J. Griffith, Podstawy elektromagnetyzmu, wyd. 2, dodr. 3. Warszawa, 2011. 2. S.A. Ramakrishna, T.M. Grzegorczyk, Physics and Applications of Negative Refractive Index Metamaterials, CRC Press Taylor
& Francis Group, Boca Raton, London, New York, 2009.

Additional:
1. N. Engheta, R.W. Ziolkowski (ed.), Metamaterials: Physics and Engineering Explorations, John Wiley & Sons, Inc., 2006. 2. Tie Jun Cui, D. J. Smith, Ruopeng Liu, Metamaterials: Theory, Design, and Applications, Springer, New York, Dordrecht, Heidelberg, London.

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,00
Classes requiring direct contact with the teacher	30	1,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	20	1,00