UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU

Spin Waves in Nanostructures and Nanotextures

Educational subject description sheet

Basic information

Study programme Fizyka **Speciality** INFORMACJA KWANTOWA I SPINTRONIKA **Organizational unit** Faculty of Physics **Study level** Second-cycle programme **Study form** Full-time **Education profile** General academic	**Didactic cycle** 2023/24 **Subject code** 04FIZIKSS.22S.04363.23 **Lecture languages** English **Course type** Elective **Block** specialty subjects
Subject coordinator	Jarosław Kłos
Lecturer	Jarosław Kłos

Period	Activities and hours	Number of ECTS points
Semester 2	• Lecture: 30, Exam • Laboratories: 30, Graded credit	6

Goals

Code	Goal
C1	Discussion on the assumptions of micromagnetism; introduction of the Landau-Lifshitz equation, familiarizing students with the description of dipolar interactions (in the magnetostatic approximation) and with the formulation of exchange interactions for continuous medium.
C2	Presenting the basic information about the spin wave dynamics in confined geometries: (i) boundary conditions for spin waves, (ii) spin waves dispersion in homogeneous planes and wires.
C3	Providing the overview about the shaping of the static magnetic configuration and magnetization dynamics in periodic and quasiperiodic magnonic structures: magnonic crystals and quasicrystals, artificial spin ice systems, synthetic antiferromagnets.
C4	Providing knowledge on the mechanisms for the generation of magnetization textures (competition between dipolar, exchange interactions, and Dzyaloshinskii–Moriya interactions, the role of curvilinear geometry). Dynamics of magnetization textures: dynamics of domain walls, vortices, skyrmions.
C5	Presenting the possible application of magnonic devices.

Subject learning outcomes

Code	Outcomes in terms of	Learning outcomes	Examination methods
Knowledge – Student:			
W1	discusses the basic assumptions of micromagnetism and presents the basic properties of the Landau-Lifshitz equation.	FIZ_K2_W01, FIZ_K2_W02	Oral exam, Project, Multimedia presentation
W2	explains the concept of magnetization pinning, discusses the canonical configurations for spin wave propagation in magnetic films.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	Oral exam, Project, Multimedia presentation
W3	discusses the different ways of introducing the (quasi)periodicity in magnonic (quasi)crystals; explains the concept of frustrated configuration; presents the different mechanism of antiferromagnetic coupling in synthetic antiferromagnets.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	Oral exam, Project, Multimedia presentation
W4	describes the magnetic configurations of: magnetic vortex, Neel and Bloch domain wall, skyrmion; formulates and interprets Thiele equation for vortex dynamics.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	Oral exam, Project, Multimedia presentation
W5	outlines the advantages of magnonics for high-frequency signal processing in nanoscale.	FIZ_K2_W04, FIZ_K2_W05	Oral exam, Project, Multimedia presentation
Skills – Student:			
U1	can linearize the Landau-Lifshitz equation for basic magnonic systems.	FIZ_K2_U01, FIZ_K2_U03	Test, Project, Multimedia presentation
U2	can draw and discuss the spin wave dispersion relation for forward, backward and Damon-Eshbach configuration.	FIZ_K2_U01, FIZ_K2_U02, FIZ_K2_U03	Test, Project, Multimedia presentation
U3	is able to apply the plane wave expansion method to linearized Landau-Lifshitz equation for 1D magnonic crystal, with periodically changed anisotropy field.	FIZ_K2_U01, FIZ_K2_U02, FIZ_K2_U03	Test, Project, Multimedia presentation
U4	can calculate numerically the skyrmion number for given configuration of magnetization.	FIZ_K2_U01, FIZ_K2_U02, FIZ_K2_U03	Test, Project, Multimedia presentation

Code	Outcomes in terms of	Learning outcomes	Examination methods
U5	is able to discuss the properties of selected magnonic devices and demonstrate how they are implemented on the basis of current literature.	FIZ_K2_U02, FIZ_K2_U05	Test, Project, Multimedia presentation
Social competences – Student:			
K1	presents the results of the student project to the group; participates in the discussion on the presented results.	FIZ_K2_K01, FIZ_K2_K02, FIZ_K2_K05	Project, Multimedia presentation

Study content

No.	Course content	Subject learning outcomes	Activities
1.	Magnetization dynamics	W1, U1	Lecture, Laboratories
2.	Spin waves in confined nanostructures	W2, U2	Lecture, Laboratories
3.	Magnonic crystals and quasicrystals	W3, U3	Lecture, Laboratories
4.	Magnetic textures	W4, U4	Lecture, Laboratories
5.	Magnonic devices	W5, U5, K1	Lecture, Laboratories

Additional information

Activities	Teaching and learning methods and activities
Lecture	Lecture with a multimedia presentation of selected issues, Problem-based learning
Laboratories	Solving tasks (e.g. computational, artistic, practical), Classes method

Activities	Credit conditions
Lecture	The descriptive and theoretical topics presented in the lecture will be assessed by an oral examination; the result of the examination constitutes 50% of the final mark for the lecture. Practical mastering of the presented content will be assessed on the basis of a presentation of the results of a project carried out by students in pairs or groups of three. The evaluation of the project constitutes 50% of the final evaluation of the lecture (all students working on the same project obtain the same grade). The grades will be given according to the following scale: • Very good (bdb; 5,0): 91-100% • Good plus (+db; 4,5): 81-90% • Good (db; 4,0): 71-80% • Satisfactory plus (+dst; 3,5): 61-70% • Satisfactory (dst; 3,0): 51-60% • Unsatisfactory (ndst; 2,0): 0-50%

Activities	Credit conditions
Laboratories	50% of the final mark from the laboratories will be the result of the written test, which will focus on solving theoretical tasks. The further 50% of the final mark will be based on a mark from a presentation of a scientific article of the student's choice (from the area of magnonics). The grades will be given according to the following scale: • Very good (bdb; 5,0): 91-100% • Good plus (+db; 4,5): 81-90% • Good (db; 4,0): 71-80% • Satisfactory plus (+dst; 3,5): 61-70% • Satisfactory (dst; 3,0): 51-60% • Unsatisfactory (ndst; 2,0): 0-50%

Literature

Obligatory

1. A. Prabhakar, D. D. Stancil, Spin Waves: Theory and Applications, Springer 2009

Optional

1. A.G. Gurevich, G.A. Melkov, Magnetization Oscillations and Waves, CRC 2020
2. Edited by S. O. Demokritov, Spin Wave Confinement Propagating Waves, Second Edition, Jenny Stanford Publishing 2017
3. M. G. Cottam, Linear And Nonlinear Spin Waves In Magnetic Films And Superlattices, World Scientific Publishing 1992

Calculation of ECTS points

Activities	Activity hours*
Lecture	30
Laboratories	30
Preparation for the exam	15
Preparation for classes	30
Preparation of a multimedia presentation	25
Preparation of a project	40
Student workload	**Hours** 170
Number of ECTS points	**ECTS** 6

* academic hour = 45 minutes

Efekty uczenia się dla kierunku

Kod	Treść
FIZ_K2_K01	The graduate is ready to critically evaluate own knowledge and received content
FIZ_K2_K02	The graduate is ready to recognize the importance of knowledge in solving cognitive and practical problems and seeking expert opinion (also from other scientific disciplines) to overcome difficulties during independent problem solving
FIZ_K2_K05	The graduate is ready to responsibly perform professional roles, incorporating changing social needs, including advancing the achievements of the profession and maintaining its ethos, as well as the observance and development of the principles of professional ethics and actions to comply with these principles
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_U05	The graduate can use English in accordance with the requirements set out for level B2+ of the Common European Framework of Reference for Languages, as well as specialist English terminology in the field of physical sciences
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
FIZ_K2_W05	The graduate knows and understands the role of physical sciences in the context of fundamental dilemmas and challenges of modern civilization