UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU

Advanced Techniques of Quantum Optics

Educational subject description sheet

Basic information

Study programme Fizyka	**Didactic cycle** 2023/24
Speciality INFORMACJA KWANTOWA I SPINTRONIKA	**Subject code** 04FIZIKSS.24KU.04357.23
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	Grzegorz Chimczak
Lecturer	Grzegorz Chimczak

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

Goals

Code	Goal
C1	The main aim of the course is to provide the knowledge on the mathematical tools, which are important in quantum optics, and knowledge on the scope of their applicability.
C2	Familiarizing the students with few phenomena of quantum optics (among others: the dynamical Stark effect, avoided crossing, the collective interaction of an ensemble of atoms with a field mode, enhanced sensitivities).
C3	Providing the knowledge necessary to reproduce selected results (analytical or numerical) from scientific articles published in the last few years.

Subject learning outcomes

Code	Outcomes in terms of	Learning outcomes	Examination methods
Knowledge – Student:			
W1	is familiar with the concept of rotating reference frames	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam, Project
W2	is familiar with the adiabatic elimination technique	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam, Project
W3	is familiar with the concept of the master equation and its steady-state solution	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam, Project
W4	is familiar with the concepts of quantum trajectories and conditional evolution	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam
W5	is familiar with the concept of Non-Hermitian Hamiltonians with real eigenvalues	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03, FIZ_K2_W04	Oral exam
W6	is familiar with the method of Heisenberg-Langevin equations	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam, Project
W7	is familiar with the concept of the quantum regression hypothesis	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam
W8	is familiar with the method of the Holstein-Primakoff transformation	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam
W9	is familiar with Quantum Toolbox in Python (QuTiP)	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam, Project
Skills – Student:			
U1	is able to present Hamiltonians in different rotating reference frames	FIZ_K2_U01	Project
U2	is able to simplify Hamiltonians using the adiabatic elimination technique	FIZ_K2_U01	Project
U3	can solve numerically the master equation in QuTiP	FIZ_K2_U01	Project
U4	can describe the conditional evolution of the open quantum system	FIZ_K2_U01	Project
U5	can write and solve Heisenberg-Langevin equations	FIZ_K2_U01	Project
U6	can compute the second order correlation function	FIZ_K2_U01	Project

Study content

No.	Course content	Subject learning outcomes	Activities
1.	Rotating reference frames	W1, U1	Lecture, Seminar
2.	Adiabatic elimination technique	W2, U2	Lecture, Seminar
3.	Master equation description of an open quantum system	W3, W9, U3	Lecture, Seminar
4.	Quantum trajectories	W4, W9, U4	Lecture, Seminar
5.	Parity-Time symmetric Hamiltonians	W5	Lecture

No.	Course content	Subject learning outcomes	Activities
6.	Heisenberg-Langevin equations	W6, U5	Lecture
7.	Quantum regression hypothesis and the second order correlation function	W7, W9, U6	Lecture, Seminar
8.	Holstein-Primakoff transformation	W8, W9	Lecture, Seminar

Additional information

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

Activities	Credit conditions
Lecture	Oral exam – 50% contribution to the final grade Project – 50% contribution to the final grade Assessment criteria: Very good (bdb; 5.0): >= 94% Good plus (+db; 4.5): >= 84% Good (db; 4.0): >= 74% Satisfactory plus (+dst; 3.5): >= 64% Satisfactory (dst; 3.0): >= 50% Unsatisfactory (ndst; 2.0): < 50%
Seminar	Project – 100% contribution to the final grade Assessment criteria: Very good (bdb; 5.0): >= 94% Good plus (+db; 4.5): >= 84% Good (db; 4.0): >= 74% Satisfactory plus (+dst; 3.5): >= 64% Satisfactory (dst; 3.0): >= 50% Unsatisfactory (ndst; 2.0): < 50%

Literature

Obligatory

1. C. C Gerry, P. L. Knight "Introductory Quantum Optics", Cambridge University Press, 2004
2. H. Haken "Light: Vol. 1, Waves, Photons, Atoms", North-Holland, 1986

Optional

1. C. Gardiner, P. Zoller "The Quantum World of Ultra-Cold Atoms and Light", IMPERIAL COLLEGE PRESS, 2014
2. S. Haroche and J. M. Raimond "Exploring the Quantum: Atoms, Cavities, and Photons", Oxford, England: Oxford University Press, 2006
3. D.F. Walls, G. J. Milburn "Quantum Optics", Springer Berlin, Heidelberg, 2008

Calculation of ECTS points

Activities	Activity hours*
Lecture	30

Seminar	15
Preparation of a project	20
Preparation for classes	10
Preparation for the exam	20
Reading the indicated literature	10
Student workload	**Hours** 105
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_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_W03	The graduate knows and understands in-depth selected computational methods and information technology tools and techniques used to solve complex problems in physics
FIZ_K2_W04	The graduate knows and understands main development trends in the discipline of physical sciences