

Subject card

Subject name and code	Quantum Optics, PG_00159205						
Field of study	Quantum Information Technology						
Date of commencement of studies	October 2025		Academic year of realisation of subject		2025/2026		
Education level	Master's studies		Subject group				
Mode of study	full-time studies		Mode of delivery		at the university		
Year of study	1		Language of instruction		English		
Semester of study	2		ECTS credits		6.0		
Learning profile	academic		Assessment form		exam		
Conducting unit							
Name and surname of lecturer (lecturers)	Subject supervisor		dr Konrad Schlichtholz				
	Teachers		dr Konrad Schlichtholz Anuradha Tonipe				
Lesson types	Lesson type	Lecture	Tutorial	Laboratory	Project	Seminar	SUM
	Number of study hours	30.0	30.0	0.0	0.0	0.0	60
	E-learning hours included: 0.0						
Learning activity and number of study hours	Learning activity	Participation in didactic classes included in study plan		Participation in consultation hours		Self-study	SUM
	Number of study hours	60		0.0		30.0	90
Subject objectives	The aim of this lecture is to introduce various concepts and mathematical tools of quantum optics necessary in contemporary research in the field of optical quantum technologies.						
Learning outcomes	Course outcome		Subject outcome		Method of verification		
	[QITL3_K02] is aware of the decisive role of experiment in the verification of physical theories; is aware of the existence of the scientific method in acquiring knowledge		The student is aware of the importance of the experimental verification of quantum optics theories and of the role of the scientific method in the analysis, interpretation, and critical evaluation of research results concerning quantum systems and phenomena.		[SK4] test/exam - oral or written		
	[QITL3_W04] knows advanced methods of theoretical and mathematical physics necessary in creating models of quantum mechanics		The student has advanced knowledge of the theoretical and mathematical methods used to describe and model phenomena in quantum optics, including the formalism of electromagnetic field quantization and the dynamics of open quantum systems.		[SW4] test/exam - oral or written		

Subject contents	-Second quantization -Fock space representation of states -Phase-space methods for description of states -Gaussian and non-Gaussian states and operations -Interferometry -Field-matter interaction -Non-linear quantum optics -Entanglement in quantum optics -Information encoding in continuous and discrete variables -Universal quantum computing in quantum optics -Metrology in optical systems		
Prerequisites and co-requisites			
Assessment methods and criteria	Subject passing criteria	Passing threshold	Percentage of the final grade
	passing tutorials	51.0%	50.0%
	exam	51.0%	50.0%
Recommended reading	Basic literature	[1] Introductory quantum optics / Christopher Gerry, Peter Knight. [2] Mathematical Methods of Quantum Optics / by Ravinder R. Puri. [3] Quantum Optics/ Stanisław Kryszewski	
	Supplementary literature	none	
	eResources addresses	Supplementary https://arxiv.org/pdf/2311.08445 - Lecture Notes on Quantum Computing http://arxiv.org/abs/1110.3234v1 - Gaussian Quantum Information https://arxiv.org/pdf/0805.2853 - Multi-photon entanglement and interferometry	

Example issues/ example questions/ tasks being completed	1. Quantization of the Electromagnetic Field and State Representations • Second quantization of the electromagnetic field. • Creation and annihilation operators and their properties. • Fock space, number states, coherent states, and thermal states. • Physical interpretation of the photon number. 2. Phase-Space Representation of Optical States • Wigner, Husimi (Q), and Glauber–Sudarshan (P) functions. • Relationships between phase-space representations. • Characteristics of Gaussian and non-Gaussian states. • The significance of the negativity of the Wigner function as an indicator of nonclassicality. 3. Light–Matter Interaction and Nonlinear Quantum Optics • The Jaynes–Cummings model. • Spontaneous and stimulated emission. • Spontaneous parametric down-conversion (SPDC) and four-wave mixing. • Generation of squeezed light and entangled states. 4. Entanglement and Quantum Information Processing with Light • Entanglement in optical systems. • Information encoding using discrete-variable and continuous-variable systems. • Linear optical quantum gates and the KLM scheme. • Universal quantum computing with optical systems. 5. Interferometry and Quantum Metrology • Mach–Zehnder and Michelson interferometers. • The Standard Quantum Limit (SQL) and the Heisenberg limit. • The use of squeezed and entangled states to enhance measurement sensitivity. • Applications of quantum metrology in optical measurements and quantum sensing.
Work placement	Not applicable

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