Syllabus

1. Information regarding the programme

1.1 Higher education institution	**Babeş-Bolyai University**
1.2 Faculty	**Faculty of Mathematics and Computer Science**
1.3 Department	**Department of Computer Science**
1.4 Field of study	
1.5 Study cycle	
1.6 Study programme / Qualification	**Quantum Computing and Communication** **(în limba engleză)**

2. Information regarding the discipline

2.1 Name of the discipline (en) (ro)		Introduction into Optics and Quantum Mechanics					
2.2 Course coordinator		Coriolan Viorel TIUSAN, Sándor BORBÉLY					
2.3 Laboratory coordinator		Sándor BORBÉLY					
2.4. Year of study	1	2.5 Semester	1	2.6. Type of evaluation	E	2.7 Type of discipline	DF
2.8 Code of the discipline	PQE0002						

3. Total estimated time (hours/semester of didactic activities)

3.1 Hours per week	4	Of which: 3.2 course	2	3.3 seminar/laboratory	2
3.4 Total hours in the curriculum	40	Of which: 3.5 course	20	3.6 seminar/laboratory	20

Time allotment:	hours
Learning using manual, course support, bibliography, course notes	10
Additional documentation (in libraries, on electronic platforms, field documentation)	10
Preparation for seminars/labs, homework, papers, portfolios and essays	10
Tutorship	5
Evaluations	4
Other activities:	

3.7 Total individual study hours	35
3.8 Total hours per semester	75
3.9 Number of ECTS credits	3

4. Prerequisites (if necessary)

4.1. curriculum	1. Mathematical analysis 2. Algebra
4.2. competencies	1. Calculus including functions, series, complex numbers 2. Programming basics

5. Conditions (if necessary)

5.1. for the course	white/blackboard, projector, computer
5.2. for the seminar /lab activities	Computer, equipment from the laser physics laboratory

6. Specific competencies acquired

Professional competencies	C1 Using optics for explaining the behavior of photons in different propagation media. C2 Using the theoretical background of quantum mechanics in order explain the bahavior of microscopic systems. C3 Using the optical devices to measure and manipulate the polarization state of photons. C4 Using interdisciplinary knowledge, solution patterns and tools, making experiments and interpreting their results C5 Using the tools of quantum mechanics and optics to construct exact models describing the behavior of quantum systems.
Transversal competencies	CT1 Honorable, responsible, ethical behavior, in the spirit of the law, to ensure the professional reputation CT3 Demonstrating initiative and pro-active behavior for updating professional, economical and organizational culture knowledge.

7. Objectives of the discipline (outcome of the acquired competencies)

7.1 General objective of the discipline	Acquiring the basic understanding on how light is propagating in diferent propagation media. Understand the concept of the polarization state of the light. Understand the basic principles of quantum mechanics.
7.2 Specific objective of the discipline	Students should be able to: 1. Predict the behaviour of light beams in different propagation media. 2. Measure and manipulate the polarization states of the light. 3. Distinguis between the classical and quantum mechanical behaviour. 4. Use the toolset of quantum mechanics in order to describe/model microscopic systems. 5. Combine the toolsets of Optics and Quantum mechanics in order to desing and execute experiments testing the fundamental concepts of Quantum Mechanics.

8. Content

8.1 Course	Teaching methods	Remarks
1) Brief History of light. Light as Electromagnetic wave – plane wave solution, frequency, wavelength 2) Polarizaton states of light - linear, elliptical, and circular polarization of light – Jones vector	Projected slides complemented by blackboard calculations.	

description. Use of polarization states as binary base.

3) Twisted light – the use orbital angular momentum as higher (more than 2) dimensional basis.
4) Propagation of light in anisotropic medium – devices for the manipulation of the polarization states of light.
5) Birth of Quantum Mechanics- Planck, Einstein, Bohr. Limitations of classical physics and historical hypotheses: Black body radiation. Photoelectric effect. The problem of the stability of the hydrogen atom. Planck's quanta hypothesis. Bohr's postulates. Einstein and the corpuscular concept of light. De Broglie's hypothesis. Wave-particle duality. End of Certainty—Probabilistic Description. Heisenberg Uncertainty Relations and Bohr's Principle of Complementarity.
6) Elements of wave mechanics. The Schrödinger equation. Wave function. Schrödinger formalism and the basic postulates of quantum mechanics. Stationary states. Average values. The continuity equation. Some applications of the Schrödinger formalism: Free particle. The particle in an infinite potential well-the energy quantification. The tunnel effect. The hydrogen atom and quantum numbers. The Stern-Gerlach experiment. The Uhlenbeck-Goudsmith spin hypothesis.
7) The general formalism of quantum physics. The matrix Heisenberg and the Dirac operators' formalisms. Mathematical basis: The Hilbert space of wave functions. Linear operators. Equations with eigenvalues. Observable. Commuting observable set. The postulates of quantum mechanics. The principle of correspondence. The problematics of measurement of a quantum system and consequences. The average value of an observable. The connection with the classical physics: the Ehrenfest's theorem. The uncertainty principle revisited.
8) The electron spin and applications. Kinetic moments and Stern-Gerlach's experiments. Quantification of kinetic moments. Spin and quantum formalism, Fermi-Dirac and Bose-Einstein statistics. Magnetic moment and spin moment. Quantum manipulation and spin measurement. Stern-Gerlach cascade experiments. Elements of spin-based quantum logic. Bit and qubit. The Bloch sphere, spin ½. The spin in quantum computing and quantum cryptography. Probabilistic qubit and adiabatic computing.
9) Quantum Superposition and Entanglement. Coherent Superposition of States. Quantum Entanglement and the Bell Basis. Schrödinger 's

Cat Paradox. Quantum Teleportation. No-cloning Theorem and Quantum Copying. EPR and Bell Theorem. Hidden Variables. The Einstein–Podolsky–Rosen (EPR) Paradox and Bohr's reply. Bell's Inequality. Quantum Mechanical Prediction. Experiments to Test Bell's Inequality. 10) Interference, Michelson and Mach-Zehnder apparatus. Correlated/entangled two-photon sources. Production and properties. Single and two-photon interference experiments. Understanding the basic concepts of quantum mechanics (quantum optics) using simple experiments. The spin versus spin-photon perspectives in quantum technologies (quantum computing and quantum communications/cryptography)		

Bibliography

[1] E. Hech, A. Zajac, Optics, Global Edition

[2] F. Jenkins, A. White, Fundamentals of Optics, 4th edition

[4] A. Messiah, Quantum Mechanics

[5] B. H. Bransden, C. J. Joachain, Quantum Mechanics

[6] C. Cohen-Tannoudji, Quantum Mechanics

8.2 Laboratory	Teaching methods	Remarks
1) Linear polarization, Malus law, manipulation of the polarization direction (λ/2 plate)	Practical work in the Laser Physics Laboratory	
2) Elliptical and circular polarization	Practical work in the Laser Physics Laboratory	
3) Polarimetry	Practical work in the Laser Physics Laboratory	
4) Michelson interferometer	Practical work in the Laser Physics Laboratory	
5) Mach-Zehnder interferometer	Practical work in the Laser Physics Laboratory	
6) Single photon Michelson experiment	Practical work in the Laser Physics Laboratory	
7) Quantum eraser	Practical work in the Laser Physics Laboratory	
8) particle – wave duality: Hanbury Brown-Twiss + Michelson interferometer	Practical work in the Laser Physics Laboratory	
9) Hong-Ou-Mandel experiment	Practical work in the Laser Physics Laboratory	
10) Measurement of the g2(0) parameter	Practical work in the Laser Physics Laboratory	

Bibliography

Detailed instructions and bibliography in the intruction sheets of the experiments.

9. Corroborating the content of the discipline with the expectations of the epistemic community, professional associations and representative employers within the field of the program

The content of the discipline provides the basics foundations for the students to advance in the fields of Quantum Computing and it is consistent with courses of similar content from other foreign academic centers. To adapt to the demands of the labor market, the content of the discipline has been harmonized with the requirements of the pre-university education, research institutes and the business environment.

10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)
10.4 Course	End of year examination	Written theoretic and practical exam	75
10.5 Seminar/lab activities	Practical exam	Evaluation of experimental skills	25
10.6 Minimum performance standards			
90% of overall laboratory works, 50% achieved at the exams.			

Date

17.05.2022

Signature of course coordinator

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Signature of seminar coordinator

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Date of approval

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Signature of the head of department

Prof. dr. Laura Dioşan