

SYLLABUS

1. Information regarding the programme

1.1 Higher education institution	Babeş-Bolyai University
1.2 Faculty	of Physics
1.3 Department	of Physics of the Hungarian line of study
1.4 Field of study	Physics
1.5 Study cycle	Master
1.6 Study programme / Qualification	Computational Physics

2. Information regarding the discipline

2.1 Name of the discipline	Quantum Computing						
2.2 Course coordinator	Sándor Borbély						
2.3 Seminar coordinator	Sándor Borbély						
2.4. Year of study	1	2.5 Semester	2	2.6. Type of evaluation	E	2.7 Type of discipline	DA

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	56	Of which: 3.5 course	28	3.6 seminar/laboratory	28
Time allotment:					hours
Learning using manual, course support, bibliography, course notes					23
Additional documentation (in libraries, on electronic platforms, field documentation)					29
Preparation for seminars/labs, homework, papers, portfolios and essays					30
Tutorship					9
Evaluations					3
Other activities:					
3.7 Total individual study hours	94				
3.8 Total hours per semester	150				
3.9 Number of ECTS credits	6				

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competencies	quantum mechanics, programming in Python

5. Conditions (if necessary)

5.1. for the course	•
5.2. for the seminar /lab activities	•

6. Specific competencies acquired

Specific competences	• Using in-depth knowledge of physics, mathematics, and programming in various multi- and inter-disciplinary fields. • Applying quantum physics to understand of complex scientific phenomena. • By exploiting the quantum nature of light understand, use and develop quantum communication (quantum key distribution) protocols. • Measure and manipulate the polarization state of photons. • Design and perform single photon experiments. • Use of quantum circuit construction packages. • Run quantum circuits through cloud solutions. • Understand, use and develop new quantum circuits to resolve complex (hard) computational problems. • Transform optimization problems to a form, which is solvable by adiabatic quantum computers • Use of quantum annealers for the solution of optimization problems.
Transversal competences	• Accomplishment of professional tasks in an effective and responsible manner, in compliance with the field-specific legislation and code of ethics. • Implementation of effective interdisciplinary teamwork methods at various hierarchical levels. • Effective use of information sources, as well as communication and professional-assisted training resources in both mother tongue and English.

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

7.1 General objective of the discipline	• The students should acquire basic knowledge about quantum communication and quantum cryptography. • The student should acquire basic knowledge regarding quantum circuit and adiabatic quantum computing. • The students should acquire basis skills in using cloud computing infrastructure in order to access available quantum computers (quantum optimizers).
7.2 Specific objective of the discipline	• The students should become familiar with the experimental techniques used during the manipulation and measurement of polarization states of light. • The student should become familiar with the experimental techniques used during single-photon experiments. • The student should become familiar quantum circuit logic and should be able to implement quantum computing algorithms. • The students should become familiar with concept of adiabatic computing and of the quantum annealer. • The students should form their skills for programming the applications of these methods.

8. Content

8.1 Course		Teaching methods	Remarks
1. Introduction. Quantum communication. Quantum Key Distribution.		Explication, problematization, multimedia projection, computer exemplification.	
2. No Cloning Theorem. Quantum Teleportation, Bell inequality.			
3. Quantum vs. Classical bit. Multiple qubits. Measurements on qubits. Single qubit gates. Measurement gate.			
4. Multiple qubit gates. Circuit for the generation of Bell states. Quantum circuit for teleportation.			
5. Quantum parallelism. Deutsch and Deutsch-Jozsa algorithms			
6. Simulation of quantum systems on quantum circuits. Example: 1D Schrödinger equation.			
7. Quantum Fourier transform. Phase estimation			
8. Order Finding.			
9. Factoring as an order finding problem. Quantum search problem and Grover's algorithm.			
10. Quantum error correction.			
11. Adiabatic quantum computing. Quantum annealer.			
12. Technologies for the realization of quantum computers.			
Bibliography			
1. M. A. Nielsen and I.L. Chuang, <i>Quantum Computing and Quantum Information</i>			
2. E. Rieffel and W. Polak, <i>Quantum Computing: A Gentle Introduction</i>			
3. M. A. Nielsen and I.L. Chuang, <i>Quantum Computation: A Foundation for Quantum Information</i>			
4. V. Kasirajan, <i>Fundamentals of Quantum Computing</i>			
8.2 Laboratory		Teaching methods	Remarks
1. Linear polarization. Malus Law. Manipulation of the polarization direction.		Experimental work in the laser physics laboratory. Individual programming tasks is qiskit.	
2. Polarimetry as a quantum state tomography. Elliptical and circular polarization			
3. Michelson Interferometer. The quantum eraser experiment.			
4. Characterization of the entangle single-photon pair source.			

5. Simple quantum circuits (qubit swap, bell states, quantum teleportation)		
6. Qiskit runtime		
7. Quantum Fourier Transform part I		
8. Quantum Fourier Transform part II		
9-11. Individual projects		
12. Error correcting circuits		

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

•

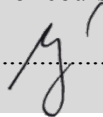
10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)
10.4 Course	Knowledge, understanding and capacity of application of quantum computing methods.	Oral exam	50
10.5 Seminar/lab activities	Individual work	Written report for each Lab (25%)+ Written report for the large project (25%)	50
10.6 Minimum performance standards			
55%			

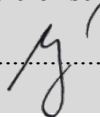
Date

..26.06.2023

Signature of course coordinator

..... 

Signature of seminar coordinator

..... 

Date of approval

.....

Signature of the head of department

.....