STUDY MODULE DESCRIPTION FORM

Name of the module/subject **Quantum Computing**	Code **1010401151010420539**

Field of study **EDUCATION IN TECHNOLOGY AND**	Profile of study (general academic, practical) **general academic**	Year /Semester **3 / 5**
Elective path/specialty **-**	Subject offered in: **Polish**	Course (compulsory, elective) **obligatory**

Cycle of study: **First-cycle studies**	Form of study (full-time,part-time) **full-time**

No. of hours Lecture: **2** Classes: **2** Laboratory: **1** Project/seminars: **-**	No. of credits **5**
Status of the course in the study program (Basic, major, other) **other**	(university-wide, from another field) **university-wide**
Education areas and fields of science and art **technical sciences**	ECTS distribution (number and %) **5 100%**

Responsible for subject / lecturer:

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Responsible for subject / lecturer:

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Prerequisites in terms of knowledge, skills and social competencies:

1	**Knowledge**	fundamental knowledge of quantum physics and linear algebra
2	**Skills**	ability of performing elementary operations in linear algebra, ability of obtaining information from indicated sources
3	**Social competencies**	understanding of necessity of extending one?s own competences, readiness to take up cooperation in a team

Assumptions and objectives of the course:

1.Transferring to students the fundamental knowledge in quantum computing, within the frame described in program contents

2.Developing the skills of solving simple problems on the basis of the knowledge acquired, as well as the ability of planning and realization of simple quantum experiments, of configuring and use of simple functional modules for realization of these experiments

3.Developing the abilities of self-education and team work

Study outcomes and reference to the educational results for a field of study

Knowledge:

1. student can define the fundamental notions in quantum mechanics and quantum computing within the frame of program contents - [K_W02]

2. student can roughly explain the principle of quantum state manipulation (basic quantum logic operations), the idea of basic quantum algorithms, as well as describe basic architecture of quantum computers - [K_W02]

Skills:

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1. student can apply the metod of linear algebra for description of quantum states, their manipulation and measurement - [K_U04]

2. student can use with understanding the indicated sources of knowledge (the list of basic literature references), as well as obtain knowledge from other sources (including sources in English language) - [K_U01, K_U02]

3. student can plan the procedure of quantum state tomography o fan isolated qubit or a system of two qubits (in photonic polarization implementation), interpret the results of quantum state measurement, use the quantum random number generator - [K_U01, K_U04]

4. student can design, according to specification and with the use of functional modules, a simple system for preparation and coherent transformation of quantum states of single photon polarizations, can configure such a system and use it for quantum manipulation of photons? states - [K_U01, K_U04]

5. student can design and investigate exemplary systems for separation and observation of isolated single quantum objects (electromagnetic planar trap for single charged particles, single photon detector based on an avalanche photodiode) - [K_U01, K_U04]

Social competencies:

1. student can get actively involved in solving of the problems, unaided develop and extend his (her) competences - [K_K01]

2. student can cooperate within a team, fulfill the duties entrusted within the division of labor in a team, show responsibility for his (her) own work as well as for the effects of the team work - [K_K01]

Assessment methods of study outcomes

W01,W02,U02: written exam

U01: qualification test

3.0: 50.1%-60.0%

3.5: 60.1%-70.0%

4.0: 70.1%-80.0%

4.5: 80.1%-90.0%

5.0: od 90.1%

U03,U04,U05: current assessment of student?s preparation for laboratory classes and written report of laboratory classes

3.0: student can perform the exercise according to the detailed instruction

4.0: student can configure the measurement system unaided according to the schematic diagram and perform the exercise according to the instruction

5.0: student can design and configure the measurement system unaided, perform the exercise according to the instruction and perform the quantitative analysis of the results

K01: assessment of activity at auditory classes

3.0: student shows moderate involvement

4.0: student shows involvement and self-dependence

5.0: student shows involvement and self-dependence, searches for new solutions

K02: assessment of performance of a laboratory exercise

Course description

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Lecture and auditory classes:

1. Elements of quantum mechanics
   - quantum states in Hilbert space
   - orthonormal basis
   - superposition of states
   - basic properties of operators
   - quantum measurement
2. Basic notions
   - qubits ? quantum states, evolution of a quantum state, manipulation of quantum states
   - quantum correlations, entanglement
   - decoherence
3. Quantum software
   - quantum gates
   - basic quantum algorithms (Deutsch, Grover, Shor)
   - quantum error correction codes
4. Quantum hardware
   - fundamentals of implementation of a quantum computer
   - selected implementations
5. Quantum communication
   - quantum teleportation, superdense coding
   - quantum cryptography

Laboratory classes:

1. Projection measurements of polarization states of light (sigma1, sigma2, sigma3); quantum tomography of polarization states of light ? determination of the relative phase of a qubit, transformation of polarization states of light with the use of optical retarders and birefringent crystals
2. Detectors of photons: determination of parameters (count rate) of a single photon detector based on an avalanche photodiode operated in Geiger mode with passive avalanche current quenching
3. Confinement and observation of ions in an electromagnetic Paul trap
4. Test sof a quantum random number generator
5. Demonstration of quantum interference in a Mach-Zehnder interferometer; quantum eraser

Basic bibliography:

1. J. Stolze, D. Suter, "Quantum Computing. A Short Course from Theory to Experiment", Wiley-VCH, 2004
2. M. Le Bellac, "Wstęp do informatyki kwantowej", Wydawnictwo Naukowe PWN, 2011
3. http://zon8.physd.amu.edu.pl/~tanas/QC.html, R. Tanaś, a course of popular talks in quantum computing
4. "Laboratorium Podstaw Inżynierii Kwantowej", unpublished materials

Additional bibliography:

1. M. Hirvensalo, "Algorytmy kwantowe", WSiP, 2004
2. C.C. Gerry, P.L. Knight, "Wstęp do optyki kwantowej", Wydawnictwo Naukowe PWN, 2007

Result of average student's workload

Activity	Time (working hours)
1. participation in lectures	30
2. participation in auditory classes	30
3. participation in laboratory classes	15
4. preparation for auditory classes	24
5. preparation for the qualification test	6
6. preparation for laboratory classes	12
7. preparation of reports of laboratory classes	12
8. participation in consultations concerned with realization of the education process, in particular auditory and laboratory classes	3
9. preparation for the written exam	6

Student’s workload

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Source of workload	hours	ECTS
Total workload	138	5
Contact hours	78	3
Practical activities	39	1

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