



## COURSE DESCRIPTION CARD - SYLLABUS

Course name

Quantum computing [S1ETI2>IK]

### Course

Field of study	Year/Semester
Education in Technology and Informatics	2/4
Area of study (specialization)	Profile of study
–	general academic
Level of study	Course offered in
first-cycle	Polish
Form of study	Requirements
full-time	compulsory

### Number of hours

Lecture	Laboratory classes	Other
30	15	0
Tutorials	Projects/seminars	
30	0	

### Number of credit points

6,00

### Coordinators

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### Lecturers

### Prerequisites

Fundamental knowledge of quantum physics and linear algebra. Ability of performing elementary operations in linear algebra, ability of obtaining information from indicated sources. Understanding of necessity of extending one's own competences, readiness to take up cooperation within a team.

### Course objective

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.

### Course-related learning outcomes

Knowledge:

1. student can define the fundamental concepts in quantum mechanics and quantum computing within the frame of program contents
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

Skills:

1. student can apply the method of linear algebra for description of quantum states, their manipulation and measurement
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)
3. student can plan the procedure of quantum state tomography of an 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
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

Social competences:

1. student can get actively involved in solving of the problems, unaided develop and extend his/her competences
2. student can cooperate within the team, fulfill the duties entrusted within the division of work in the team, show responsibility for his/her own work as well as for the effects of the team work

### Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

written test

written 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: from 90.1%

current evaluation 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

evaluation of activity at tutorials

3.0: student shows moderate commitment

4.0: student shows commitment and self-dependence

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

evaluation of realization of a laboratory exercise

### Programme content

Lecture and tutorials:

elements of quantum mechanics in the matrix approach (evolution, manipulation, quantum correlations, including entanglement), elements of quantum software and hardware, elementary introduction to quantum communication

Laboratory classes:

basic problems related to quantum information processing - practical aspects

### Course topics

1. Elements of quantum mechanics
  - quantum states in Hilbert space
  - orthonormal basis
  - superposition of states
  - basic properties of operators

- quantum measurement
- 2. Basic concepts
  - qubits - quantum states, evolution of a quantum state, manipulation of quantum states
  - quantum correlations, entanglement
  - decoherence
- 3. Quantum software
  - quantum gates
  - selected basic quantum algorithms (Deutsch, Grover, Shor)
  - quantum error correction codes (elementary introduction)
- 4. Quantum hardware
  - fundamentals of implementation of a quantum computer
  - selected implementations
- 5. Quantum communication
  - quantum teleportation (elementary introduction)
  - quantum cryptography (elementary introduction)

#### Laboratory classes:

1. Demonstration of quantum interference in a Mach-Zehnder interferometer; quantum eraser
2. Nondemolition measurement - quantum Zeno effect
3. Projection measurements of polarization states of light ( $\sigma_1$ ,  $\sigma_2$ ,  $\sigma_3$ )
4. quantum tomography of polarization states of light
5. Synthesis of polarization states of light
6. Tests of a quantum random number generator
7. Detectors of photons: calibration of a photodetector in a photovoltaic regime
8. Optically detected magnetic resonance (ODMR)

### Teaching methods

1. Lecture: presentation illustrated with animations and examples, solving of simple problems
2. Tutorials: solving of problems, discussion
3. Laboratory: realization of experiments, evaluation of results, discussion

### Bibliography

#### Basic:

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:

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

### Breakdown of average student's workload

	Hours	ECTS
Total workload	150	6,00
Classes requiring direct contact with the teacher	75	3,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	75	3,00