POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

COURSE DESCRIPTION CARD - SYLLABUS

Course name
Quantum technology [S1MiKC1>TK]

Course

Field of study
Microelectronics and digital communications

Year/Semester
3/6

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
15

Other
0

Tutorials
15

Projects/seminars
0

Number of credit points

3,00

Coordinators

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Lecturers

Prerequisites

Basic knowledge of mathematics, EM field theory, optics and optical telecommunications, ability to synthesize digital circuits, knowledge of Boolean algebra, understanding phenomena of quantum physics

Course objective

The aim of the course is to present contemporary knowledge in the field of quantum communication, as well as the possibilities and limitations of quantum computers. Students will acquire skills in implementing quantum computing and quantum communication algorithms.

Course-related learning outcomes

Knowledge:
The student knows the basic laws of quantum mechanics and understands the fundamental experiments that prove quantum theory. The student knows the methods of representing the state of qubits, basic quantum gates, understands the consequences of reading the state of a qubit, knows the

essence of superposition and entanglement of qubits, the essence of superdense coding and quantum teleportation, knows selected quantum cryptography protocols, knows the consequences of the interaction of a qubit with the environment, understands the need for quantum error correction. The student knows the mathematical apparatus behind quantum computations. They know several quantum optimization and quantum search algorithms, they know machine learning applications of quantum computing.

Skills:
The student is able to design quantum circuits and interpret the logic gates' operations on qubits, and can perform basic calculations on quantum states in respective algebraic field. They can utilize IBM quantum composer to design quantum circuits.
The student is able to implement selected quantum cryptography protocols and quantum protection codes in selected programming language. They can conduct experiments on quantum computer and its simulator.

Social competences:
The student understands the need to ensure the confidentiality of data transmission and appreciates the possibilities of quantum communication in this area. They also understand the risk of breaking the encryption protocols currently used due to the development of quantum computing. The student is convinced that quantum computers can solve some complex optimization problems faster than classical computers.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Knowledge acquired in the lecture is verified by an exam, typically consisting of several open-ended questions (typically 5), scored differently. The pass threshold is 50% of points. Skills acquired during tutorials are judged by the on-going assessment of students' activity and a written test, typically consisting of several tasks to be solved (typically 5), scored differently. Skills acquired during laboratory classes are verified on the basis of completed exercises, tasks and mini-projects. It is required to obtain at least 50% of the maximum number of points or to complete the presented exercises at least halfway. Grading scale: <50% - 2.0; 50% to 59% - 3.0; 60% to 69% - 3.5; 70% to 79% - 4.0; 80% to 89% - 4.5; 90% to 100% - 5.0.

Programme content

linear algebra, postulates of quantum mechanics, quantum optics, quantum gates and circuits, quantum algorithms, quantum cryptography protocols, quantum error correction, conducting experiments on quantum computers

Course topics

Lecture:
Part 1 (15 hours): selected experiments justifying quantum theories used in quantum teleinformatics (1 hour), proof of the quantum nature of light - experiment (1), Hanbury-Brown-Twiss experiment (1), correlation function for single-photon detectors (1), Grangier-Roger-Aspect experiment (1), triple coincidence detection scheme (1), single-photon interference - experimental realization (1), quantum treatment of polarization - description of the experiment (1), quantum eraser - practical implementation (1), SPDC spontaneous parametric down-conversion (1), parametric scattering (1), single-photon detectors (1), photon pair source setup (1), practical setup of single photon Michelson interferometer (1), setup illustrating Malus's law for single photons and setup for single photon double slit experiment (1)
Part 2 (15 hours): qubit representations (1), multi-qubit systems (1), superposition and entanglement (1), unitary operations (1), no-cloning theorem (1), quantum gates (1), phase manipulations (1), Grover algorithm (1), Quantum Fourier Transform and its applications (2), Deutsch, Deutsch-Jozsa and Shor algorithms (2), teleportation and superdense coding (1), quantum protective coding (1), quantum noise and decoherence (1)
Tutorials: linear algebra essentials (2), matrix representation of qubit states (2), eigenvectors and eigenstates (2), unitary operators (2), measurement base (1), phase estimation (1), density matrices and mixed states (2), final test (2)

Laboratory: software used in the lab (1), rules of conducting experiments on quantum computers (1), observation of quantum phenomena (2), development of the code and implementation of selected quantum algorithms: search and optimization algorithms (3), quantum key distribution algorithms (3), teleportation (2), and error correction algorithms (2), observation of quantum noise (1)

Teaching methods

Traditional slide-based lecture, enriched with discussion and demonstration of algorithm execution. Tutorials: solving tasks on board. Laboratory: developing quantum circuits and running them on a simulator and - if possible - on a quantum computer

Bibliography

Basic:
Richard P. Feynman., Robert B. Leighton , Matthew Sands Feynmana wykłady z fizyki Tom 3 Mechanika kwantowa, Wydawnictwo Naukowe PWN 2014
Michael A. Nielsen, Isaac L. Chuang Quantum Computation and Quantum Information, Cambridge University Press 10th Anniversary Edition 2021Ch. Bernhardt, "Obliczenia kwantowe dla każdego", PWN, 2020
Eric R. Johnston, Nicholas Harrigan, Mercedes Gimeno-Segovia, "Komputer kwantowy: programowanie, algorytmy, kod", Helion 2021
Quiskit user's manual (https://docs.quantum.ibm.com/)

Additional:
Noson S. Yanofsky, Mirco A. Mannucci, "Quantum Computing for Computer Scientists", Cambridge University Pres, 2013
On-line course on quantum algorithms provided by IBM (https://learning.quantum.ibm.com/)
Scientific papers suggested by the teacher

Breakdown of average student's workload

	Hours	ECTS
Total workload	90	3,00
Classes requiring direct contact with the teacher	60	2,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	30	1,00