ITMO

QUANTUM INFORMATICS AND QUANTUM ALGORITHMS THEORY

Course Workload		Assessment form (examination/ graded test/ ungraded test)
ECTS	Hours	
3	108	Exam

During this course, students will learn numerical methods for modelling problems in quantum optics and information theory; methods of theoretical physics for solving problems of quantum information; methods of modelling quantum simulators, modern trends, achievements and research directions of quantum technologies in relation to the problems of creating systems of quantum information processing; fundamental differences and limitations between the classical and quantum states of the light field; the main approaches and models for the theoretical description of the phenomena of quantum optics and quantum information; the scope of the basic laws of quantum optics and informatics; methods for constructing models of quantum simulators for various problems of quantum technologies; the foundations of the nonrelativistic quantum theory of light and the interaction of light with matter; statement of problems of quantum optics and quantum information.

Course structure:

1. MATHEMATICAL FOUNDATIONS OF QUANTUM INFORMATION
   - 1.1. Basic postulates of quantum theory and Dirac description.
   - 1.2. Projective postulate and reduction of a quantum state.
   - 1.3. Uncertainty ratio, standard quantum measurement limit.
   - 1.4. Physical carriers of quantum information.

2. COMPLEXITY THEORY OF QUANTUM ALGORITHMS
   - 2.1. Hierarchy of algorithmic complexity.
   - 2.2. Turing machine, cellular automata in quantum informatics.

3. QUANTUM COMPUTING
   - 3.1. Information qubits concept.
   - 3.2. Quantum logic and nondistributive Hesse lattices.
   - 3.3. Quantum logical operations on qubits.

4. PHYSICAL SOURCES OF QUANTUM INFORMATION AND COMMUNICATION CHANNELS
   - 4.1. Quantum parametric processes.
   - 4.2. Quantum processes in a medium with cubic nonlinearity.
   - 4.3. Interaction of two-level systems with photons — quantum theory, the Janes-Cumings model.
   - 4.4. Spontaneous emission.

5. ENTANGLED STATES AS A RESOURCE OF QUANTUM INFORMATION

5.1. The Einstein-Podolsky Rosen paradox.
5.2. Classic correlations and Bell's inequalities.
5.3. Cooking and measuring entangled states.

6. BASIC QUANTUM INFORMATION PROCESSING ALGORITHMS

6.1. Quantum teleportation.
6.2. Shor's and Grover's quantum algorithms.
6.3. Quantum walks.

7. QUANTUM CRYPTOGRAPHY

7.1. Principles of coding quantum information by photons.
7.2. Transmission of quantum information with a public key.

8. QUANTUM METROLOGY

8.1. Michelson interferometer.
8.2. Mach-Zehnder interferometer.
8.3. Heisenberg limit.
8.4. First order coherence degree.

9. QUANTUM ALGORITHMS FOR SYSTEMS WITH A LARGE NUMBER OF PARTICLES

9.1. Coherent states and quantum statistics.
9.2. Compressed states.
9.3. Optimal cloning of information on quantum states.
9.4. States of the Schrödinger cat and its applications in quantum information.

10. THE MODERN MARKET FOR QUANTUM TECHNOLOGIES

10.1. Technological issues of creating quantum computers and quantum "microcircuits".
10.2 The market for quantum technologies.