Level of education: **Master**
Field of study: **16.04.01 Technical Physics**

Advanced Quantum and Nanophotonic Systems

QUANTUM OPTICS

Credits: 6 ECTS		
Semester		**Assessment**
2nd semester	6 ECTS	Exam

Course developers: **Vasily Kravtsov**

Quantum optics studies the properties of light and light-matter interaction from the grounds of modern quantum mechanics. You will learn the basic quantum concepts of photon and polariton, how one can entangle photons, and find out whether one can violate Heisenberg's uncertainty principle. The course aims at giving the students the fundamental picture of quantum optics through basic problems solving. We will focus on the phenomena governed by the quantum nature of light, go into the deeps of light-matter interaction, and figure out how this interaction can be enhanced in micro- and nano-resonators. The course gives an overview of the main theoretical models; however, the key experimental techniques will be discussed as well.

Requirements

Course prerequisites: Quantum mechanics, Electrodynamics, Nanophotonics.

Course structure

1. LIGHT-MATTER INTERACTION: SEMICLASSICAL APPROACH
    1.1. Two-level system in a light field. Rabi oscillations.
    1.2. Density matrix: from general properties to a two-level system.

2. QUANTUM PROPERTIES OF LIGHT
    2.1. Secondary quantization of electromagnetic field.
    2.2. Fock states and coherent states.
    2.3. Quantum noise and squeezed states.
    2.4. Beamsplitters and photodetection. HOM effect.
    2.5. Coherence of light, HBT experiments, and bunching/antibunching.

3. LIGHT-MATTER INTERACTION: FULLY QUANTUM PICTURE

3.1. Two-level system in a quantized field.
3.2. Jaynes-Cummings model: polaritons. Photon blockade.
3.3. Spontaneous relaxation: Weisskopf-Wigner theory.
3.4. Quantum theory of relaxation. Lindblad equation.
3.5. Atom in a cavity. Weak and strong coupling regime.
3.6. Local density of states and Purcell effect.
3.7. Field fluctuations and Langevin equation.

4. ADDITIONAL TOPICS

4.1. Light interaction with a three level-system.
4.2. Laser cooling and ultra-cold atoms.
4.3. Optical cavities.
4.4. Quantum entanglement. Bell inequality.
4.5. Local field operators. Quantization of light in lossy and dispersive media.

Assessment

Intermediate attestation grade is based on the homework progress.

The final grade is calculated based on the student's progress in homework problem solving, oral examination grade, and score for in-class quizzes according to the following proportions:

Maximum points for homework problem solving: 50

Maximum points for the final oral examination: 40

Maximum points for in-class quizzes: 10

Total maximum points for the course: 100

Faculty: **Faculty of Physics**

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Tags: **Optical Bloch equations; Qubits on the Bloch sphere; Field quantization; Quantum states of light; Interaction between quantum light and quantum matter; Calculation of relaxation rates**