Joint syllabus
«Quantum Optics Through the Exercises»

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Degree program: 010900 «Applied Physics and Mathematics»
Specialization: 010999 «Electrophysics»
Chair of Electrodynamics of Complex Objects and Nanophotonics
4th academic year of the Master’s degree
1st and 2nd semester

The first semester

Lecture 1. What is the Quantum Optics? (2 hours)
What is the Quantum Optics? Values, estimations and limits of validity. The electromagnetic field quantization in media with spectral peculiarities. The conception of the photon and vacuum fluctuations. Fock states of the field, the occupation numbers representation. The creation and annihilation operator of the photons.

Lecture 2. Coherent (Glauber) states. (2 hours)

Lecture 3. Berry phase. (2 hours)
Dynamical and geometrical phase of the oscillator. Berry phase. The interference in phase space. Coherent (Glauber) states in the theory of laser, superfluidity and magnetism.

Lecture 4. The Hanbury Brown-Twiss effect. (2 hours)

Lecture 5. The statistics of the photons. (2 hours)

Lecture 6. The Maxwell-Bloch equations. (2 hours)
The interaction of the atomic electron with electromagnetical field. The two-level atom model. The semiclassical theory, the Maxwell-Bloch equations. The rotating wave approximation. Constants of motion.

Lecture 7. The Jaynes-Cummings model. (2 hours)
The interaction of the atomic electron with electromagnetic field in the occupation number representation. The interaction of two-level atom with single mode field. The Rabi oscillations. The Jaynes-Cummings model. The «dressed» states of the field. The dynamics, preparation and collapses of the field states.

**Lecture 8.** The Weisskopf-Wigner approximation. (2 hours)

**Lecture 9.** The self-induced transparency. (2 hours)

**Lecture 10.** The Dicke superradiance. (2 hours)
The Dicke superradiance. The coherent states and the Dicke states of two-level-atom medium. The spin and the photonic echo.

**Lecture 11.** The resonance fluorescence. (2 hours)

**Lecture 12.** The non-equilibrium phase transition in the laser. (2 hours)
The non-equilibrium phase transition in the laser. The laser light as the Bose-Einstein condensate.

**The second semester**

**Lecture 1.** The quantum theory of relaxation. (2 hours)
The quantum theory of relaxation. Open quantum systems. The Heisenberg-Langevin equations. The density matrix method and the Fokker-Plank equation. The interaction of the open quantum system with the bosonic reservoir.

**Lecture 2.** The semiclassical laser theory. (2 hours)

**Lecture 3.** The quantum theory of the laser. (2 hours)

**Lecture 4.** The atomic optics. (2 hours)
The atomic optics. The mechanical action of light. The gradient force, the quantum limit of atomic recoil. The Paul trap. The laser cooling.

**Lecture 5.** The quantum electrodynamics “in cavity”. (2 hours)
The quantum electrodynamics “in cavity”. The spontaneous emission in the resonator. The single-atom maser. The Purcell factor.
Lecture 6. The optical Bloch equations. (2 hours)
The magnetic and optical resonance. The optical Bloch equations. The Bloch vector. The optical nutation and free precession. The laser mode competition and synchronization. «Spectral hole burning ». The Lamb dip and the Bennet dip.

Lecture 7. The non-linear optics. (2 hours)

Lecture 8. The phase of quantized field. (2 hours)
The commutation rules for photon numbers and field amplitudes. The phase of quantized field. The measurement of the phase. The quantum phase operator problem. «Trigonometric» phase operator. Оператор фазы Пегга-Барнетта.

Lecture 9. The quantum mechanics of the photon. (2 hours)
The quantum mechanical properties of the photon. The angular momentum. The parity. The polarization and partial polarization.

Lecture 10. The optics of quantum dots. (2 hours)

Lecture 11. The noise-induced transitions. (2 hours)

Lecture 12. What else? The scope of quantum optics and the perspectives. (2 hours)
What else? The scope of quantum optics and the modern perspectives.

References

Basic references

**Additional reading**
An academic term (or simply term) is a portion of an academic year, the time during which an educational institution holds classes. The schedules adopted vary widely. In most countries, the academic year begins in late summer or early autumn and ends during the following spring or summer. In Northern Hemisphere countries, this means that the academic year lasts from August, September, or October to May, June, or July. In Southern Hemisphere countries, the academic year aligns with the calendar year.