1. Annotation

The main goal of the course is to study by students basic physical principles, main quantum electrodynamical (QED) phenomena and mathematical apparatus of quantum electrodynamics and quantum optics. Students must know theory and experimental data on interaction of radiation with matter. Particularly will be discussed: quantum theory of electromagnetic field, problem of phase in QED, coherent and squeezed states, relativistic quantum theory of electrons and positrons, Klein paradox, diagram technique, divergences and renormalization of mass and charge of electron, Lamb shift, cavity quantum electrodynamics (including last achievements), dynamical Casimir effect, basics of united theory of electromagnetic and weak interactions etc.

2. Structure and Content

### Part 1. The classical theory of radiation.

2. The difficulties of the classical theory of radiation.
3. Hamiltonian form of the classical radiation theory.
| Part II. The first stage of development of the quantum theory of light. | 1. Thermodynamics of equilibrium radiation. Planck’s Formula.  
2. Einstein’s work on the quantum theory of radiation.  
1) Field entropy and the photon hypothesis. Corpuscular properties of light.  
2) Fluctuations of the electromagnetic field. Photon statistics.  
3) Phenomenological theory of light emission and absorption.  
3. Wave-particle dualism. Einstein’s paradoxes. The consistency of quantum mechanics and the need quantization of the electromagnetic field. |
| --- | --- |
| Part III. Quantum theory of free electromagnetic field. | 1. The basic postulates of quantum theory. The correspondence principle of Bohr.  
2. Quantization of the free electromagnetic field. Representation of occupation numbers. Creation and annihilation operators of photons. Uncertainty relations for the number of photons and field strength.  
3. Zero oscillations of the electromagnetic field and their manifestation.  
6. Uncertainty relation for electric and magnetic fields. The works of Landau – Peierls and Bohr-Rosenfeld, and discussion about local description of the quantized field.  
8. Einstein-Podolsky-Rosen Paradox.  
9. Quantum teleportation. |
2. Solutions of the Dirac equation for a free particle. States with negative energy. Schrödinger’s "jitter" of the electron.  
3. Transition to the non-relativistic limit. Physical meaning of relativistic corrections (spin-orbit interaction, Thomas correction, etc.).  
4. Solution of the Dirac equation for a hydrogen-like ion. Instability of the vacuum when the charge of nucleus is larger than critical one. Klein paradox.  
### Part V. Quantum theory of the interaction of radiation with matter.

2. Emission and absorption of photons. Spontaneous and induced processes.
3. Natural width of spectral lines.
4. Resonance fluorescence.
6. Optical properties of Bose condensate of atoms in traps.
7. The Breit Equation.

### Part VI. Quantum electrodynamics in the optical cavity.

2. Control of the Lamb shift in the optical microcavity.
3. The problem of preparation of a given state of the electromagnetic field in the resonator.
5. Dynamic Lamb effect.

### Part VII. A manifestation of the weak interaction in optics.

1. Fundamentals of the unified theory of electromagnetic and weak interaction.
2. Weak interaction and optical manifestation of parity nonconservation in atoms and molecules.

3. Assignments

4. Grading

**Grading Scale**

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5. Basic Information

6. Textbooks and Internet Resources
### Required Textbooks

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<th>ISBN-13 (or ISBN-10)</th>
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### Recommended Textbooks

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<tr>
<td></td>
<td>V. N. Gribov, Quantum electrodynamics, RKhD, Moscow, 2001.</td>
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7. Facilities

8. Learning Outcomes

**Do you want to specify outcomes in another framework?**

Knowledge-Skill-Experience is good enough

9. Assessment Criteria

10. Additional Notes

**Free Style Comments (if any)**

Additional literature