INTERNATIONAL HIGHER SCHOOL OF MEDICINE

Department of Natural Sciences Disciplines

SYLLABUS
Laser and optical methods in medicine

2026-2027 academic year
for students of medical faculty
2nd course 4 semester, group 2
2 credits (60 h, including auditorial 36 h, independent work – 24 h)

Lecturer: **ass.prof. G.M.Amanbaeva**
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Venue: Zoom

Practical classes: **ass.prof. G.M.Amanbaeva**
0 772 897 235 (Whatsapp)
Email: muhtar.gulnar@mail.ru

Venue: 405 of Administrative building of IHSM, 4th floor.

The Syllabus is considered
at the meeting of the department of Natural Sciences Disciplines
Protocol № 1 dated 28.08.2026
Head of the department Ch. S. Ismailova

Course Objective: The aim of the discipline *"Laser and Optical Methods in Medicine"* is to provide students with a comprehensive system of knowledge in the field of medical physics, focusing on the application of laser and optical technologies in diagnostics and treatment.

After study of the discipline the student must:

Knowledge:

- Modern physical principles of laser and optical methods applied in medicine;
- Types of lasers and optical systems used in diagnostics and therapy;
- Biophysical foundations of the interaction of laser radiation with body tissues;
- Principles of safe handling of medical laser equipment.

Skills:

- Analyze clinical problems and select the appropriate laser or optical method;
- Evaluate laser treatment parameters depending on tissue type and intended use;
- Use simulation and virtual laboratory resources to model medical procedures;
- Interpret data obtained using optical methods (spectroscopy, visualization, etc.).

Attitude:

- Application of laser and optical technologies to solve practical problems related to medicine and biophysics;
- Calculations and modeling of light interactions with biological objects;
- Design and defense of presentations and project work.

Pre-requisites. Medical Biology, Medical Physics and Higher Mathematics, Chemistry (General and Bioorganic), Biochemistry

Post-requisites. Sections of fundamental and clinical medicine related to the use of laser and optical technologies

THEMATIC PLAN OF LECTURES

№	Theme of lecture	Hours	Date
1.	Introduction to Laser and Optical Medicine	2	07.09.26
2.	Physical Foundations and Types of Laser Radiation	2	10.09.26
3.	Optical Diagnostic Methods in Medicine	2	11.09.26
4.	Physical Properties of Biological Tissues	2	11.09.26
5.	Mechanisms of Interaction Between Laser Radiation and Biological Tissues	2	12.09.26
6.	Optical Methods for the Study of Biological Tissues	2	12.09.26
7.	Types of Lasers Used in Medicine. Laser Surgery and Dermatology	2	14.09.26
8.	Laser Therapy: Photodynamic and Phototherapeutic Effects	2	14.09.26
9.	Safety in the Use of Laser Equipment in Medicine	2	17.09.26

THEMATIC PLAN OF PRACTICAL CLASSES

№	Theme of practical class	Hours	Date
1.	Laser biomedical technologies. Basic parameters of laser radiation.	2	17.09.26
2.	Determination of erythrocyte size using a He-Ne laser.	2	26.09.26
3.	Physical principles of refractometry and endoscopy.	2	03.10.26
4.	Effects of laser radiation on biological tissues. Calculation of the coagulation heat of soft biological tissues.	2	10.10.26
5.	Assessment/Test of Unit №1	2	17.10.26
6.	Laser Therapy: Parameters and Dosage	2	24.10.26
7.	Tissue Spectroscopy in Medical Diagnostics. Calculation of blood absorption coefficient.	2	31.10.26
8.	Laser Procedures in Dermatology and Cosmetology	2	07.11.26

9.	Assessment/Test of Unit №2	2	14.11.26

THEMATIC PLAN OF INDEPENDENT WORK OF STUDENTS

№	Theme of independent work	Hours	Date
Unit I	➢ Studying theoretical materials (lectures, articles, videos) ➢ Modeling physical processes ➢ Conducting laboratory exercises in an online environment ➢ Solving situational/case-based problems	12	12.10-16.10.26
Unit II	➢ Analysis of clinical cases using optical methods ➢ Solving problems in a virtual laboratory ➢ Searching for and analyzing scientific publications ➢ Preparing a report or essay on recent developments	12	09.11.-14.11.26

Recommended reading for the discipline:

1.Basic

1)Amanbaeva G.M., Ismailova Ch.S., Medical and Biological Physics. Laboratory Works (II Part), 2023.
2) Nelkon M., Advanced Level Physics. Part 3-4.,1995.
3) Jogi R. Basic Ophthalmology. 4th ed., 2009.
4) Khurana A.K., Theory and Practice Optics and Refraction. 4th ed., 2018.
5) Khurana A.K., Ophthalmology. 4th ed., 2009.
6) Svelto O. Principles of Lasers, 2020.
7) Koechner W. Solid-State Laser Engineering, 2019.

2.Additional

1) Khurana A.K., Review of Ophthalmology. 6th ed., 2015.
2) Flock S. T., Patterson M. S., Wilson B. C. Optical Techniques in Biological Research. 2020.
3) Chunlei Guo, Subhash Chandra Singh, Handbook of Laser Technology and Applications: Four Volume Set, 2024.
4) Leonard W. Fundamentals of laser technology and applications, 2023.

Resources of the information and telecommunication network "Internet"

1. https://www.lici.ir/wp-content/uploads/2019/05/Svelto-Principles-of-Lasers.pdf
2. https://link.springer.com/book/10.1007/978-3-662-15143-3?utm_source=springerlink&utm_medium=referral&utm_campaign=bookpage_about_buyonpublisherssite&srsltid=AfmBOorICWRf2ES9R1lWUArWORfUSNfZ6dwzKVS2l0Zsh_ZYNzo969iL
3. file:///C:/Users/admin/Downloads/PM254_bm1%20(2).pdf
4. https://www.lici.ir/wp-content/uploads/2019/05/Svelto-Principles-of-Lasers.pdf
5. https://link.springer.com/book/10.1007/978-3-662-15143-3?utm_source=springerlink&utm_medium=referral&utm_campaign=bookpage_about_buyonpublisherssite&srsltid=AfmBOorICWRf2ES9R1lWUArWORfUSNfZ6dwzKVS2l0Zsh_ZYNzo969iL

Grading policy and procedures for all types of work

For the period of studying the discipline, the student gains points for the relevant parameters (per unit):
current score - 40 points
independent work - 20 points
control score (final assessment of knowledge per unit) - 40 points
Maximum score - 100 (40+20+40)

Grading system for student's achievements

Grading criteria per discipline				
Maximum score	Intervals			
	«unsatisfactory»	«satisfactory»	«good»	«excellent»
Current control- 40	0-23	24-30	31-35	36-40
Interval description	The student demonstrates insufficient knowledge of a substantial portion of the curriculum, makes serious and significant errors, and	The student has mastered only the basic program material but lacks knowledge of specific features and details;	The student demonstrates developed competencies and possesses an	The student demonstrates well-developed competencies and is able to apply them in

	fails to disclose the essential content of the material. Knowledge of terminology is inadequate; the necessary theoretical foundations and the ability to apply them to practical problem-solving are lacking. An "unsatisfactory" grade is also assigned in cases where the student refuses to answer.	makes inaccuracies; violates the logical sequence in presenting the program material; the material is unsystematic and incorrectly formulated. Speech is generally correct but limited; demonstrates a minimally sufficient level of competence; solves professional practical tasks with errors, and generally provides justification for the decisions made.	adequate level of professional terminology; provides answers correctly, logically, and to the point; does not make significant mistakes or inaccuracies when answering questions; the presentation is sufficiently structured and consistent. When solving practical tasks, the student generally provides correct justification for the decisions made..	professional activities; provides answers in a comprehensive, consistent, accurate, and logically coherent manner, without errors; the response requires no additional clarification; speech is clear and demonstrates confident use of professional terminology; shows no difficulty in responding to modified tasks; knows how to solve professional practical problems; correctly justifies decisions made and is capable of independently generalizing and presenting material.
Independent work - 20	0-11	12-15	16-17	18-20
Interval description	The student failed to fully review any of the independent work assignment questions (primary and/or secondary). The student refused to prepare the independent work assignment.	The student has mastered the required course material within the program, but the answers to the questions are not sufficiently comprehensive and accurate; the answers are based solely on data from the primary literature on the subject.	The student has studied the basic and is familiar with the additional literature related to the program and uses this knowledge in answering questions; when answering additional questions, the material is presented correctly, but without sufficient logical sequence; when answering, the student uses the necessary, carefully executed graphic material (diagrams, drawings, etc.); to clarify answers, the instructor sometimes requires leading questions.	The student has studied the primary and secondary literature on the subject and competently applies this knowledge in their answers; uses course materials from related disciplines in their answers, providing various examples to support their answers; produces the necessary diagrams and charts at a high level during preparation and uses them in their answers; does not require any assistance from the instructor; strives to independently expand and update the knowledge necessary for professional work.
Control work (module) – 40	0-23	24-30	31-35	36-40
Interval description	The student has identified gaps in his knowledge of the educational material provided by the program and cannot give clear answers to basic,	The student has mastered the required course material within the program, but the answers to the questions are not sufficiently	The student fully discloses the educational material provided by the program; minor errors	The student presents the program material thoroughly, meaningfully, and in full, at a high scientific level; answers all

	additional, and leading questions.	comprehensive and accurate; the answers are based solely on data from the primary literature on the subject.	(inaccuracies) are allowed, which do not distort the content of the answers to the questions.	questions and additional questions completely and without errors.

Conduct Policy: (lateness, absence, behavior in the auditorium, late submission of work).
- Punctuality and completion of tasks.
- Mandatory attendance of classes.
- Attending class in a clean medical uniform.
- Eliminating conversations on a cell phone in the classroom.
- Active participation in the learning process.
- Doing homework on time.
- Academic detention at the time specified by the teacher.

For violations of the Conduct Policy, the total points for discipline might be reduced to 1-10 points.

Academic Ethics Policy.
- Be tolerant, respect the opinions of others.
- Formulate objections in the correct form.
- Constructively support feedback in all classes.
- Plagiarism and other forms of dishonest work are unacceptable. Plagiarism includes the following: the absence of references when using printed and electronic materials, quotes, thoughts and works of other authors or students.
- Prompting and cheating during tests, exams, classes is unacceptable as well as passing an exam for another student, unauthorized copying of materials.

For violations of the Academic Ethics Policy, the total points for the discipline may be reduced to 1-10 points.

Guidelines for the lessons of the discipline

Unit 1. Physical principles of laser operation and the main properties and effects of laser radiation

Key questions covered in lesson 1. Basic parameters of laser radiation. The basic parameters of laser radiation (wavelength, power, energy, fluence, irradiance, pulse duration, beam divergence, polarization) are fundamental for understanding its biological effects and safe medical applications.

Recommended reading for the lesson:

[1] Amanbaeva G.M., Ismailova Ch.S., Medical and Biological Physics. Laboratory Works (II Part), 2023.
[2] Nelkon M., Advanced Level Physics. Part 3-4.,1995.
[4] Khurana A.K., Theory and Practice Optics and Refraction. 4th ed., 2018.
[6] C.K. Nunez. Medical Laser Applications. – Springer, 2018.

Key questions covered in lesson 2. Laboratory work # 1 Determination of erythrocyte size using a He-Ne laser. Diffraction. Laser Light Properties. Relation Between Diffraction Pattern and Cell Size. Determine the size (diameter) of erythrocytes (red blood cells) using laser diffraction methods. Understand how coherent light interacts with microscopic particles such as cells.

Recommended reading for the lesson:

[1] Amanbaeva G.M., Ismailova Ch.S., Medical and Biological Physics. Laboratory Works (II Part), 2023.
[2] Nelkon M., Advanced Level Physics. Part 3-4.,1995.

Key questions covered in lesson 3. Laboratory work # 2 Physical principles of refractometry and endoscopy. Refractometr, Endoscopy. Understand the physical principles of refractometry for measuring the refractive index of liquids or biological fluids.Explore basic optical principles of endoscopy, including light propagation and image formation in medical instruments.

Recommended reading for the lesson:

[1] Amanbaeva G.M., Ismailova Ch.S., Medical and Biological Physics. Laboratory Works (II Part), 2023.
[3] Jogi R., Basic Ophthalmology. 4th ed. 2009
[4] Khurana A.K., Theory and Practice Optics and Refraction. 4th ed., 2018.

Key questions covered in lesson 4. Effects of laser radiation on biological tissues. Calculation of the coagulation heat of soft biological tissues. Identify tissue types and chromophores relevant for laser absorption. Determine laser parameters (wavelength, power, exposure time) for safe and effective coagulation. Calculate the coagulation heat using tissue mass, specific heat, and desired temperature increase. Analyze efficiency and safety of laser-tissue interactions.

Recommended reading for the lesson:

[1] Amanbaeva G.M., Ismailova Ch.S., Medical and Biological Physics. Laboratory Works (II Part), 2023.
[6] C.K. Nunez. Medical Laser Applications. – Springer, 2018.

[7] Vanderwerf, Dennis F. The Story of Light Science: From Early Theories to Today's Extraordinary Applications. Springer International Publishing, 2017.

Key questions covered in lesson 5. Module I.

1. What are spontaneous and stimulated transitions, and what are the Einstein coefficients?
2. What are the main properties of laser radiation: spatial and temporal coherence, monochromaticity, and divergence?
3. What is the radiation transfer equation in an amplifying medium, and what is the gain coefficient?
4. What is population inversion, the concept of negative temperature, and the main methods to create inversion in a medium?
5. What are three-level laser systems and their significance in achieving population inversion?
6. Lasers on crystals of ruby and aluminum-yttrium garnet activated by ions Nd3+.
7. Atomic lasers. Helium-neon laser.
8. Molecular lasers. Carbon dioxide laser.
9. Conditions for creating population inversion in semiconductors.
10. Amplification of radiation in the p-n junction of degenerate semiconductors. Operating principle and
11. design of an injection laser on a p-n junction.
12. Operating principle and design of a laser on a heterojunction.
13. Solid-state lasers with semiconductor pumping.
14. What are the basic principles of laser operation and the properties of laser radiation?
15. How does laser light interact with biological tissues (absorption, scattering, reflection, transmission)?
16. What are the main therapeutic applications of lasers in medicine (surgery, photocoagulation, wound healing)?
17. What are the diagnostic applications of lasers and optical methods (endoscopy, OCT, spectroscopy, refractometry)?
18. What are the safety requirements and biological effects of laser exposure on tissues?
19. How do optical fibers and lens systems enable image formation and light transmission in medical devices?
20. What are the methods for measuring optical properties of biological tissues and fluids?
21. How is laser-tissue interaction quantified, and how is thermal or photochemical effect calculated?

Unit 2. "Laser and Optical Methods in Medicine"

Key questions covered in lesson 6. Laser Therapy: Parameters and Dosage. Therapeutic semiconductor lasers. The main parameters of laser radiation used in therapy (wavelength, power, energy density, pulse duration, and frequency). laser parameters affect the depth of tissue penetration and therapeutic outcomes. The concept of dosage in laser therapy, and how is it calculated for different tissues and treatment areas. Biotissue properties (absorption, scattering, water content, chromophores). The indications and contraindications for laser therapy in medical practice. The safety of laser therapy ensured (maximum permissible exposure, protective measures, monitoring). The therapeutic effects of laser therapy assessed (healing rate, pain reduction, inflammation control). The differences between continuous wave and pulsed lasers in clinical applications.

Recommended reading for the lesson:

[4] Khurana A.K., Theory and Practice Optics and Refraction. 4th ed., 2018.

[6] C.K. Nunez. Medical Laser Applications. – Springer, 2018.

Key questions covered in lesson 7. Tissue Spectroscopy in Medical Diagnostics. Spectroscopy and main principles. The different types of spectroscopy (absorption, fluorescence, Raman, and reflectance) work in medical diagnostics. The key chromophores and biomolecules in tissues that influence spectroscopic measurements (e.g., hemoglobin, melanin, water). Light-tissue interaction (absorption, scattering, reflection, and transmission) affect the spectroscopic signal. The typical applications of tissue spectroscopy in diagnostics (e.g., cancer detection, monitoring oxygenation, assessing tissue composition). Spectroscopic data analyzed and interpreted to assess tissue health or pathology.

Recommended reading for the lesson:

[5] Khurana A.K., Ophthalmology. 4th ed. 2009

[6] C.K. Nunez. Medical Laser Applications. – Springer, 2018.

Key questions covered in lesson 8. Laser Procedures in Dermatology and Cosmetology. The main types of lasers used in dermatology and cosmetology (e.g., CO_2, Nd:YAG, diode, pulsed dye lasers). Laser parameters (wavelength, pulse duration, power, energy density) affect skin treatment outcomes. The mechanisms of laser interaction with skin tissues (absorption by chromophores, scattering, thermal effects). The primary indications for laser procedures in dermatology (e.g., tattoo removal, vascular lesions, pigmentation disorders, hair removal). The main cosmetic applications of lasers (skin resurfacing, wrinkle reduction, acne treatment, scar management).

Recommended reading for the lesson:

[2] Nelkon M., Advanced Level Physics. Part 3-4.,1995.

[4] Khurana A.K., Theory and Practice Optics and Refraction. 4th ed., 2018.

[6] C.K. Nunez. Medical Laser Applications. – Springer, 2018.

[7] Vanderwerf, Dennis F. The Story of Light Science: From Early Theories to Today's Extraordinary Applications. Springer International Publishing, 2017.

Key questions covered in lesson 9. Module II.

1. What are the main parameters of laser radiation used in therapy (wavelength, power, energy density, pulse duration, and frequency)?
2. How do different laser parameters affect the depth of tissue penetration and therapeutic outcomes?
3. What is the concept of **dosage in laser therapy**, and how is it calculated for different tissues and treatment areas?
4. How do tissue properties (absorption, scattering, water content, chromophores) influence laser energy delivery?
5. What are the indications and contraindications for laser therapy in medical practice?
6. How is the safety of laser therapy ensured (maximum permissible exposure, protective measures, monitoring)?
7. How are therapeutic effects of laser therapy assessed (healing rate, pain reduction, inflammation control)?
8. What are the differences between **continuous wave and pulsed lasers** in clinical applications?
9. What is tissue spectroscopy and what are its main principles?
10. How do different types of spectroscopy (absorption, fluorescence, Raman, and reflectance) work in medical diagnostics?
11. What are the key chromophores and biomolecules in tissues that influence spectroscopic measurements (e.g., hemoglobin, melanin, water)?
12. How does light-tissue interaction (absorption, scattering, reflection, and transmission) affect the spectroscopic signal?
13. What are the typical applications of tissue spectroscopy in diagnostics (e.g., cancer detection, monitoring oxygenation, assessing tissue composition)?
14. How are spectroscopic data analyzed and interpreted to assess tissue health or pathology?
15. What are the advantages and limitations of spectroscopic methods compared to other diagnostic techniques?
16. How do measurement conditions (wavelength, light source, detector sensitivity) impact the accuracy and reliability of tissue spectroscopy?
17. What are the main types of lasers used in dermatology and cosmetology (e.g., CO_2, Nd:YAG, diode, pulsed dye lasers)?
18. How do different laser parameters (wavelength, pulse duration, power, energy density) affect skin treatment outcomes?
19. What are the mechanisms of laser interaction with skin tissues (absorption by chromophores, scattering, thermal effects)?
20. What are the primary indications for laser procedures in dermatology (e.g., tattoo removal, vascular lesions, pigmentation disorders, hair removal)?
21. What are the main cosmetic applications of lasers (skin resurfacing, wrinkle reduction, acne treatment, scar management)?
22. How are laser procedures planned and dosed to achieve efficacy while minimizing risks?
23. What are the contraindications and potential complications of dermatological laser procedures?
24. What safety measures and protective protocols must be followed during laser treatments?
25. How is the effectiveness of laser procedures evaluated (clinical outcomes, patient satisfaction, follow-up assessment)?

Methodological instructions for the implementation of independent work on the discipline.

Unit 1: Physical Principles of Laser Operation and the Main Properties and Effects of Laser Radiation

1. Make a summary on the topic: *Principle of stimulated emission and laser generation*.
2. Prepare a table: *Types of lasers (gas, solid-state, semiconductor, liquid): active medium, wavelength, main applications*.
3. Write an essay (5–7 pages) on types of laser–tissue interactions: absorption, scattering, fluorescence, photothermal effects.
4. Draw a diagram (graphically or in PowerPoint) of absorption mechanisms of different chromophores (hemoglobin, melanin, water).
5. Create a comparison table: *Laser therapy vs. traditional physiotherapy (ultrasound, magnetotherapy, electrophoresis)*.
6. Draw the scheme of the setup for measuring erythrocyte size using a He–Ne laser.
7. Create a crossword puzzle with 15 terms related to the discipline (laser, coherence, fluorescence, photon, ablation, etc.).

Unit 2. "Laser and Optical Methods in Medicine"

1. Find and describe a clinical example of using lasers for vascular coagulation in dermatology.

2. Prepare a presentation (10–12 slides) on *"Modern laser technologies in surgery"*.
   Must include: Advantages of the laser scalpel compared to the traditional one.
3. Fields of application (ophthalmology, dentistry, dermatology).
4. Write an essay: "Laser technologies in oncology" (methods of photodynamic therapy).
5. Review at least 3 recent (last 5 years) scientific articles on the use of lasers in ophthalmology.
6. Prepare a report on: "Laser diagnostic methods in medicine: confocal microscopy, OCT, fluorescence diagnostics".