Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Basics of Semiconductor Electronics/Основы полупроводниковой электроники

Purpose of the course:

The aim is to give students knowledge about the basic physical principles of description of semiconductor materials, the basics of mathematical and numerical modeling of processes occurring in semiconductors and semiconductor structures, review of standard (classical) semiconductor structures and devices based on them.

Tasks of the course:

-Knowing the necessary fundamentals of semiconductor theory;

-studying methods of describing electron transport in semiconductors;

-gaining knowledge of standard semiconductor devices.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

-basic principles of describing charge transport in semiconductors

-basic principles of standard semiconductor devices operation

be able to:

-Calculate the volt-current characteristics of devices (diodes, field-effect transistors)

master:

-calculate characteristics of semiconductor structures

-Methods for calculating the characteristics of semiconductor nanoelectronic devices

-the basic methods of solving the equations of electrodynamics and electron transport (Boltzmann equation, diffusion-drift and hydrodynamic equations) as applied to semiconductor devices

-methods for estimating the parameters of charge carriers (energy spectrum, mobility, free path) in low-dimensional systems

Content of the course (training module), structured by topics (sections):

1. Band structure and statistics of charge carriers in semiconductors

Band structure of semiconductors, electrons and holes. Effective mass and its origin. Direct-gap and indirect-gap semiconductors - examples of silicon, germanium and gallium arsenide. Carrier statistics and calculation of the Fermi level. Doped semiconductors, estimate of donor level energy. Carrier concentration in doped semiconductor vs temperature. Heavily doped semiconductors.

2. Low-dimensional systems

The concept of heterostructure. Dimensional quantization and quantum wells. Two-dimensional semiconductors based on mono- and bi-layers: graphene, bilayer graphene, transition metal chalcogenides. Band structure of basic two-dimensional materials. Application of the tight binding method for calculations of the band structure.

3. Kinetic theory of transport in semiconductors: general concepts

Boltzmann kinetic equation for the single-particle distribution function. Collisions of carriers with impurities, phonons, and with each other. Quantum mechanical calculation of the scattering probability. The collision integral in the kinetic equation for various scattering mechanisms.

4. Electrical conductivity of semiconductors

Transport relaxation time and its microscopic calculation for scattering by impurities and phonons. Calculation of conductivity in uniform fields and its dependence on temperature for semiconductors and metals. Electrical conductivity of graphene. Diffusion of charge carriers and electrochemical potential. Relation between mobility and diffusion coefficient.

5. Thermo- and galvano-magnetic phenomena

Kinetic equation in the presence of a temperature gradient. Calculation of electronic thermal conductivity and Seebeck coefficient (example of electrons in graphene). Operating principle of a thermoelectric generator and a Peltier element. Kinetic equation in a magnetic field. Hall effect and calculation of Hall resistance. Features of the Hall effect in a two-dimensional system. A method for measuring the carrier mobility using the Hall effect.

6. "Advanced" methods for solving the kinetic equation

Variational principle for the distribution function. Calculation of the graphene conductivity limited by electron-hole scattering using the variational principle. Hydrodynamic approach to kinetic equation. Analysis of electrical and thermal conductivity near the neutrality point in graphene.

7. Recombination of charge carriers in semiconductors

Origins of nonequilibrium electrons and holes: photoexcitation and electrical injection of carriers. The concept of quasi-Fermi levels. Microscopic mechanisms of recombination of electrons and holes: radiative recombination, Auger process, recombination with phonon emission. Calculation of the rate and characteristic time of radiative recombination.

8. Contact phenomena in semiconductors

P-n-junction and its band diagram. Calculation of the field distribution in the p-n-junction (Poisson's equation). Depletion layer width. Metal-semiconductor contact (Schottky contact), calculation of its band diagram. Features of screening in two-dimensional systems, features of two-dimensional p-n-junctions and Schottky contacts, methods of their calculation.

9. Current-voltage characteristic of the p-n junction

Macroscopic equations of drift and diffusion for electrons and holes, their simplification for the doped and depleted regions. Shockley theory for the recombination-limited current. Behavior of p-n junction under reverse bias. Applicability limits of the drift-diffusion theory for ultrashort p-n-junctions. Application of p-n-junctions for rectification (detection) of radiation.

10. Current-voltage characteristic of "metal-semiconductor" structure

Drift-diffusion theory for the transport of majority carriers. Microscopic boundary conditions at the contact with the metal (surface recombination). Current limitation by carrier injection and diffusion in a semiconductor. Applications of Schottky contacts.

11. Metal-oxide semiconductor field-effect transistors (MOSFETs)

Electrostatics of MOS - structures, dependence of the carrier concentration on the gate voltage. Inversion layer. The principle of field-effect transistor operation. Drift-diffusion model of carrier transport in a field-effect transistor. Nonlinear section of current-voltage characteristic and current saturation mechanisms: velocity saturation and channel cutoff. Characteristics of a graphene-based field effect transistor.

12. Miniaturization of MOS transistors and scaling laws

The cutoff frequency of the field-effect transistors as a logic switch mode and as a signal amplifier. External and internal factors affecting the cutoff frequency. Dependence of the cutoff frequency on the channel length for drift-diffusion and ballistic transport modes. Scaling laws for frequency and power dissipation. The problem of threshold voltage reduction. Effects of doping density fluctuations and structural parameters in nanoscale field-effect transistors.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Chinese/Китайский язык

Purpose of the course:

The formation and development of intercultural, professionally-oriented communicative competence of students at the elementary level to solve communicative problems in the professional, business, socio-cultural and academic spheres, as well as for the development of professional and personal qualities of bachelor graduates.

Tasks of the course:

Achieving the elementary level of intercultural professionally-oriented communicative competence in the course of studying the discipline "Chinese language" requires to solve a number of tasks which consist in the consistent mastering a set of sub-competencies. The main of the latter are:

– linguistic competence: the ability to understand other people's speech and express oneself in Chinese;

– sociocultural competence: the ability to take into account in communication speech and non-speech behavior adopted in China;

– social competence: ability to interact with communication partners using the relevant strategies;

– discursive competence: knowledge of the rules for building oral and written discourse messages, the ability to build such messages and understand their meaning in the speech of other people;

– strategic competence: the ability to use the most effective strategies in solving communicative problems;

– subject competence: knowledge of subject information when organizing one’s own utterance or understanding of the utterance of other people;

– compensatory competence: he ability to overcome the communication barrier through the use of well-known speech and meta-language means;

– pragmatic competence: the ability to choose the most effective and expedient way of expressing thoughts, depending on the conditions of the communicative act and the task.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

– Basic facts, realities, names, sights, and traditions of China;

– historical, social, political and cultural events in China;

– phonetic, lexical and grammatical, stylistic features of the Chinese language and its difference from the native language;

– main features of written and oral forms of communication.

be able to:

– Generate adequate oral and written texts in the context of a specific communication situation;

– realize the communicative intention with the aim of influencing the communication partner;

– adequately understand and interpret the meaning and intention of the author in the perception of oral and written authentic texts;

– identify similarities and differences in the systems of native, first foreign (second foreign) and Chinese languages;

– show tolerance, empathy, openness and friendliness when communicating with representatives of another culture.

master:

– Intercultural professionally-oriented communicative competence in different types of speech activity at the elementary level;

– sociocultural competence for successful understanding in the conditions of communication with representatives of another culture;

– various communication strategies;

– learning strategies for organizing their learning activities;

– strategies of reflection and self-esteem to self-improve personal qualities and achievements;

– different methods of memorization and structuring of digestible material;

– Internet technologies to select an optimal mode of obtaining information;

– presentation technologies for providing information.

Content of the course (training module), structured by topics (sections):

1. Introductory-phonetic and introductory-hieroglyphic course. Meeting Chinese colleagues, fellow students, neighbours.

Introduction into the basics of Chinese pronunciation (putonghua) and the basic rules of calligraphy and hieroglyphics.

Communicative tasks: to perceive by ear and reproduce words, word combinations, phrases according to the pronunciation norm of the Chinese language. To read words, word combinations and phrases both written in pinyin and in hieroglyphs, according to the pronunciation norm of the Chinese language. To compose phrases, including everyday life phrases, according to the lexical and grammatical norms of the Chinese language. To use courtesy phrases. Participate in a dialogue-inquiry and dialogue-incitement to action. To take part in the role-playing game “Meet the Chinese colleagues”.

Pronunciation: The sound-letter standard for recording Chinese words is pinyin, following the basic requirements for pronouncing Chinese sounds and distinguishing all Chinese sounds by ear. Following the rules of the tone system of the Chinese language, the main types of intonation of Chinese sentences.

Vocabulary: phrases of greeting and farewell, fixed expressions, courtesy phrases. Names of the countries, cities in China and the world. Common last names, social roles, educational supplies.

Grammar: the main communicative types of sentences - narrative (affirmative/negative), interrogative (general and special question), imperative, exclamatory and their structures (word order, topic and comment (subject and predicate, inverted object etc.). A sentence with a quality predicate, quality adjective in the commentary position. Negative sentence form with quality predicate, quality adjective in the commentary position. Sentences with a linking verb是shì, the position of the negation 不bù in a sentence with a linking verb是shì, interrogative sentences with particles吗 ma, 吧ba, 呢 ne. Attribute in the possessive meaning. Particle的 de. Order of attributes in a Chinese sentence. Personal pronouns in Chinese, their functions and usage. Demonstrative and interrogative pronouns in Chinese. Interrogative sentences with interrogative pronouns. Word order in an interrogative sentence with an interrogative pronoun. A sentence with a verb predicate (action verb in the commentary position). Adverbs也yěand都dōu, their place in a sentence with regard to the predicate. The combination of the adverb都dōu with the negation不bù.

Writing: basic rules of calligraphy. The basics of hieroglyphics, mastering graphemes and hieroglyphs in accordance with the lexical and grammatical material studied. Writing short written statements according to the communicative task.

2. Getting to know the university campus, orientation in the city.

Buildings inside the campus, the insides of the building, different institutions and their location relative to each other, orientation in space and in cardinal directions. Using the acquired knowledge and skills in speech.

Communicative tasks: to perceive by ear and reproduce words, word combinations, phrases according to the pronunciation norm of the Chinese language. To understand the main content of various authentic pragmatic and journalistic audio and video texts on relevant topics. To extract the necessary/requested information from various audio and video texts on the relevant topics. To read words, word combinations, phrases and small texts, written both in pinyin and in hieroglyphs, according to the pronunciation norm of the Chinese language. To read authentic texts of various styles using various reading strategies/types in accordance with the communicative task. To compose phrases and short texts according to the lexical and grammatical norms of the Chinese language. To use courtesy phrases. To participate in a dialogue-inquiry and dialogue-incitement

to action, to make a dialogue-exchange of views and a combined dialogue, including elements of different types of dialogues. To talk, to reason within the studied topics and problems, and give examples and arguments. To describe events, to state facts and what one has read/heard een. To describe the university campus, ways to get to one's destination. To take part in the role-playing tour around the campus. To talk about locations and movement directions.

Pronunciation: meeting the basic requirements for pronouncing Chinese sounds and differentiating all of Chinese sounds by ear. Following the rules of the Chinese language tone system. The main types of intonation of Chinese sentences, the melody and rhythm of Chinese sentences of different types, phrasal accent.

Vocabulary: fixed expressions, courtesy phrases. Date, time, time of day, days of the week, postpositions (locatives) to specify spatial relationships.

Grammar: the main communicative types of sentences - narrative (affirmative/negative), interrogative (general and special question), imperative, exclamatory, and their structure schemes. Sentences of presence and possession with the verb有yǒu. Location indications with verbs在и 是 Postpositions ("adverbs of place") specifying spatial relationships (前边qiánbiān, 后边hòubiān, 上边shàngbiānetc.), in the function of a subject, an object and an attribute. Sentences of location (verb在zài, verb有yǒu, linker是shì).

Writing: mastering graphemes and hieroglyphs according to the lexical and grammatical material studied. Writing messages or written statements in according to the communicative task.

3. Everyday life at work and at home, telling the exact time, plans for the nearest future.

Discussing the daily timetable, class schedule, plans for the nearest future, appointing a meeting. Using the acquired knowledge and skills in speech.

Communicative tasks: to perceive by ear and reproduce words, word combinations, phrases according to the pronunciation norm of the Chinese language. To understand the main content of various authentic pragmatic and journalistic audio and video texts on relevant topics. To extract the necessary/requested information from various audio and video texts on the relevant topics. To read words, word combinations, phrases and small texts, written both in pinyin and in hieroglyphs, according to the pronunciation norm of the Chinese language. To read authentic texts of various styles using various reading strategies/types in accordance with the communicative task. To compose phrases and short texts according to the lexical and grammatical norms of the Chinese language. To use courtesy phrases. To participate in a dialogue-inquiry and dialogue-incitement to action, to make a dialogue-exchange of views and a combined dialogue, including elements of different types of dialogues. To talk, to reason within the studied topics and problems, and give examples and arguments. To describe events, to state facts and what one has read/heard een. To talk about the past experience in the everyday and professional life. To tell the exact time, the beginning and the ending of events, class schedule, plans for the nearest future.

Pronunciation: meeting the basic requirements for pronouncing Chinese sounds and differentiating all of Chinese sounds by ear. Following the rules of the Chinese language tone system. The main types of intonation of Chinese sentences, the melody and rhythm of Chinese sentences of different types, phrasal accent.

Vocabulary: fixed expressions, telling the exact time, days of the week, part of the day, adverbs of time today, tomorrow, yesterday, counting from 1 to 100, address, phone number.

Grammar: the main communicative types of sentences - narrative (affirmative/negative), interrogative (general and special question), imperative, exclamatory and their structure schemes. Adverbial modifier of time; ways to specify time and date. Ordering adverbial modifiers of time in a sentence. Special question to the adverbial modifier of time. The verb 有 and the negation没有. Interrogative words几и 多少, phrasal particles吧и 呢.

Writing: basic rules of calligraphy. The basics of hieroglyphics, mastering graphemes and hieroglyphs in accordance with the lexical and grammatical material studied. Writing small written statements according to the communicative task.

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4. Talking about address, phone number, travel route. Shopping. Family. The weather.

Talking to the shop assistant, discussing the planned purchase, its price and quantity. Talking about the family members and pets. Discussing seasons and the weather in Russia and China, the air temperature. Discussing preferences.

Communicative tasks: to perceive by ear and reproduce words, word combinations, phrases according to the pronunciation norm of the Chinese language. To understand the main content of various authentic pragmatic and journalistic audio and video texts on relevant topics. To extract the necessary/requested information from various audio and video texts on the relevant topics. To read words, word combinations, phrases and small texts, written both in pinyin and in hieroglyphs, according to the pronunciation norm of the Chinese language. To read authentic texts of various styles using various reading strategies/types in accordance with the communicative task. To compose phrases and short texts according to the lexical and grammatical norms of the Chinese language. To use courtesy phrases. To participate in a dialogue-inquiry and dialogue-incitement to action, to make a dialogue-exchange of views and a combined dialogue, including elements of different types of dialogues. To talk and reason within the topic studied and give examples and arguments. To describe events, to state facts and what one has read/heard een. To construct mini-dialogs with the shop assistant about the planned purchase, its price and quantity. To make dialogs about the family members. To discuss climate peculiarities of Chine and the speaker’s country, the weather in different seasons, temperature conditions.

Pronunciation: meeting the basic requirements for pronouncing Chinese sounds and differentiating all of Chinese sounds by ear. Following the rules of the Chinese language tone system. The main types of intonation of Chinese sentences, the melody and rhythm of Chinese sentences of different types, phrasal accent.

Vocabulary: fixed expressions, courtesy phrases, purchase, goods, shops, money, counting words for different objects, money, family members. Family members and pets. Seasons of the year, the weather, natural phenomena.

Grammar: the main communicative types of sentences - narrative (affirmative/negative), interrogative (general and special question), imperative, exclamatory and their structure schemes. Interrogative words几и 多少. Numerals二and 两. Using counting words depending on the noun.

Quality predicate and special question to a quality predicate with the interrogative word怎么样.

Writing: mastering graphemes and hieroglyphs according to the lexical and grammatical material studied. Writing messages or written statements in according to the communicative task.

5. Talking about present moment of action. Daily and weekly class schedule, plans for tomorrow.

Discussing free time, home tasks, present actions. Discussing plans for the nearest future, at first and then. Using the acquired knowledge and skills in speech.

Communicative tasks: to perceive by ear and reproduce words, word combinations, phrases according to the pronunciation norm of the Chinese language. To understand the main content of various authentic pragmatic and journalistic audio and video texts on relevant topics. To extract the necessary/requested information from various audio and video texts on the relevant topics. To read words, word combinations, phrases and small texts, written both in pinyin and in hieroglyphs, according to the pronunciation norm of the Chinese language. To read authentic texts of various styles using various reading strategies/types in accordance with the communicative task. To compose phrases and short texts according to the lexical and grammatical norms of the Chinese language. To use courtesy phrases. To participate in a dialogue-inquiry and dialogue-incitement to action, to make a dialogue-exchange of views and a combined dialogue, including elements of different types of dialogues. To talk, to reason within the studied topics and problems, and give examples and arguments. To describe events, to state facts and what one has read/heard een. To discuss present actions, to talk about the class schedule and about what happens every day, every week etc. To discuss planned actions for the nearest future and their sequence.

Pronunciation: meeting the basic requirements for pronouncing Chinese sounds and differentiating all of Chinese sounds by ear. Following the rules of the Chinese language tone system. The main types of intonation of Chinese sentences, the melody and rhythm of Chinese sentences of different types, phrasal accent.

Vocabulary: fixed expressions, courtesy phrases. Time expressions from … till ..., present moment, every day, days of the week, at first, then, institutions and purposes to visit those.

Grammar: the main communicative types of sentences - narrative (affirmative/negative), interrogative (general and special question), imperative, exclamatory and their structure schemes. Adverbs of present tense现在and正在, expressions每...都, time period expression从...到, 先...然后… .

Modal verb 打算, talking about the purpose of a trip using a serial verb construction去 商店 买东. Adverb一起. General question with an affirmative-negative predicate.

Writing: mastering graphemes and hieroglyphs according to the lexical and grammatical material studied. Writing messages or written statements in according to the communicative task.

6. Discussing the product before purchasing, friend's birthday, choosing a present, talking about preferences.

Talking about choosing the color of the clothes, about preferences. Discussing a purchase, its benefits and drawbacks. Choosing a birthday present for a friend, discussing different options and people's preferences. Using the acquired knowledge and skills in speech.

Communicative tasks: to perceive by ear and reproduce words, word combinations, phrases according to the pronunciation norm of the Chinese language. To understand the main content of various authentic pragmatic and journalistic audio and video texts on relevant topics. To extract the necessary/requested information from various audio and video texts on the relevant topics. To read words, word combinations, phrases and small texts, written both in pinyin and in hieroglyphs, according to the pronunciation norm of the Chinese language. To read authentic texts of various styles using various reading strategies/types in accordance with the communicative task. To compose phrases and short texts according to the lexical and grammatical norms of the Chinese language. To use courtesy phrases. To participate in a dialogue-inquiry and dialogue-incitement to action, to make a dialogue-exchange of views and a combined dialogue, including elements of different types of dialogues. To talk, to reason within the studied topics and problems, and give examples and arguments. To describe events, to state facts and what one has read/heard een. To discuss a product before purchase, its benefits and drawbacks. To discuss a present for a friend and help with the choice. To give advice and arguments.

Pronunciation: meeting the basic requirements for pronouncing Chinese sounds and differentiating all of Chinese sounds by ear. Following the rules of the Chinese language tone system. The main types of intonation of Chinese sentences, the melody and rhythm of Chinese sentences of different types, phrasal accent.

Vocabulary: fixed expressions, courtesy phrases, colors and shades, properties of objects, expression "a little…" (有一点儿...), vocabulary related to birthdays.

Grammar: the main communicative types of sentences - narrative (affirmative/negative), interrogative (general and special question), imperative, exclamatory and their structure schemes. Attributive construction with the 的, adverb 有一点儿... and adverb 挺, alternative question with the conjunction 还是, attribute with the "prefix" 可 (可送的，可看的，可去的).

Writing: mastering graphemes and hieroglyphs according to the lexical and grammatical material studied. Writing messages or written statements in according to the communicative task.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Digital Transformation: Social and Economic Challenges/Цифровая трансформация: социальные и экономические вызовы

Purpose of the course:

To familiarize students with contemporary processes of digital transformation, what consequences they might have and challenges they will lead to, to provide students theoretical tools for understanding these processes, and optimally reacting to challenges they arise.

Tasks of the course:

- To provide an overview of theoretical approaches to economic transformation;

- to work out framework for transition analysis;

- to introduce students into main social and economic challenges caused by digital transformation and what dramatic consequences they might lead to;

- to familiarize students with possible economic outcomes and to show what economic policy should be to overcome all problems, avoid disastrous scenarios and get use of all the bounties digital transformation can bring.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

- Core approaches to economic transformation;

- criteria used to determine stages of economic development;

- key problems of traditional economic methodology being applied to digital economy analysis.

be able to:

- Analyze social and economic phenomena caused by digital transformation;

- analyze transitional dynamics and predict possible economic outcomes for world economy, national economy, and the student himself/herself;

- determine main social and economic challenges digital transformation arises;

- provide policy options for a changing world.

master:

- Tools for economic transition analysis;

- tools of critical economic thinking.

Content of the course (training module), structured by topics (sections):

1. Economic Transformation: Literature Survey

Various criteria of stage determination and approaches to transformation. Critique of postindustrialism. Resource scarcity and economic transformation. Vital resources and stages of development. Transitional dynamics and transformational crises. Digital economy and economics dead-end.

2. Economic Methodology: Are Our Tools Good Enough?

Resource scarcity and science without subject. Methods that we use and why they do not work anymore. Economic transformation: basic methodology.

3. Digital Economy: Challenges We Face

Resource scarcity, heterogeneity and foodchain structure of world economy. Great capital vs. labor (knowledge) battle. Monopolization and inequality. Global capital model failure. World without jobs. Challenges for science: areas of research.

4. Economic Policy in New World

Economic Policy Analysis: Are Our Tools Good Enough? Three Possible Outcomes: Capitalist (Disastrous), Revolutionary (Utopian), Regulatory (Second Best). New Challenges – New Policy. Economic Policy Mechanism

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Electronic Transport in 2D Materials/Электронный транспорт в двумерных материалах

Purpose of the course:

1. To learn and master the modern solutions to problems of physics of 2D electronic systems.

2. To develop practical and creative skills for the independent organization of progressive experimental research.

Tasks of the course:

1. To study the electronic bandstructures of classical 2D crystals.

2. To introduce general research methodologies of an electronic state investigation in various 2D crystals and van der Waals heterostructures.

3. To introduce mechanisms of quantum electronic transport in various 2D crystals and various van der Waals heterostructures.

4. To hold theoretical knowledge of common fabrication methods of 2D crystals and van der Waals heterostructures.

5. To study the working principles of advanced electronic and optoelectronic devices based on 2D crystals and van der Waals heterostructures.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

1. General research methodologies for studying electronic states and quantum phenomena in various 2D crystals, van der Waals heterostructures, and corresponding 2D systems.

2. Principal mechanisms of quantum electronic transport in various 2D crystals, van der Waals heterostructures, and corresponding 2D systems.

3. Working principles of advanced electronic and optoelectronic devices based on 2D crystals and van der Waals heterostructures.

be able to:

1. Derive dispersion laws, electronic densities of states and charge carrier densities of classical 2D crystals.

2. Derive electrostatic parameters of various van der Waals heterostructures consisting of classical 2D crystals.

3. Evaluate electronic characteristics (charge carrier mobility, mean free path, and so on) of classical 2D crystals integrated into various van der Waals heterostructures.

master:

1. General knowledge of research and technological advances in the field of electronic transport properties in 2D systems.

2. Theoretical knowledge of common fabrication methods of 2D crystals and van der Waals heterostructures.

3. Attainments necessary for solving current research and technological problems.

Content of the course (training module), structured by topics (sections):

1. Solid State Fundamentals, towards 2D crystals

1. Introduction to the theory of electronic transport in 2D crystals. Classical Drude model of electrical conduction, Boltzmann transport equation, diffusive and ballistic transport regimes, notes on electron liquids, Euler and Navier-Stokes equations for kinetic-hydrodynamic transport regime.

2. Introduction to the theories of quantum tunnelling and capacitance in 2D crystals. The stationary point and effective transfer Hamiltonian approaches.

2. Graphene Fundamentals, an experimentalist perspective

3. Graphene monolayer. Tight-binding approach to the electronic band structure of monolayer graphene, Dirac cones and pseudospin degree of freedom, chiral electrons and Klein paradox, anomalous quantum Hall effect.

4. Graphene bilayer. Tight-binding approach to the electronic band structure of Bernal bilayer graphene, neutrality points and trigonal warping, electric field tunable electronic bandgap and Mexican hat of electronic band structure, Berry phase and unconventional quantum Hall effect.

5. Hexagonal and rhombohedral graphite. Tight-binding approach to the electronic band structure of rhombohedral graphite, bandgap induced by displacement field, electronic phase separation and stacking order of individual layers, surface and bulk states.

3. Hexagonal boron nitride for graphene, enabling remarkable electronic properties

6. Hexagonal boron nitride for graphene encapsulation. Notes on viscosity, Hall viscosity of electron fluid in graphene and its constrictions.

7. Graphene and hexagonal boron nitride twists. Electronic bandstructure and cloning of Dirac fermions, formation of superlattices and moiré patterns, notes on direct visualization methods: AFM and STM.

8. Graphene and hexagonal boron nitride twists at high magnetic fields, Hofstadter butterfly, mini-zone formation, recurring Bloch and high order fractal states.

9. Graphene and hexagonal boron nitride for vertical tunnelling transistors. Phonon-assisted inelastic resonant tunnelling, impurity-assisted sequential and twist-controlled resonant tunnelling transitions. Valley tuning and chiral quantum state of graphene electrons.

10. Graphene quantum dots. Single-electron charging, Coulomb blockade and size quantization, planar and vertical single-electron transistors based on graphene quantum dots.

11. Graphene double-layers. Counterflow currents, Coulomb drag and magneto-Coulomb drag, indirect exciton condensation at high magnetic fields.

12. Graphene p-n junctions. Electron flow focusing, Veselago lensing, transverse magnetic focusing, and electronic transport with snake trajectories.

4. Introduction to 2D Semiconductors, superconductors, and ferromagnets

13. Introduction to 2D semiconductors: MoX_2 and WX_2 (X = S, Se). Electronic band structure, direct electronic bandgap monolayers, spin-orbit and -valley couplings, interlayer interactions and quantum Hall effect.

14. Introduction to 2D superconductors: NbX_2 (X = S, Se). Electronic band structure, critical temperatures, and superconducting energy gaps.

15. Introduction to 2D ferromagnets: CrX_3 (X= I, Br). Electronic band structure, interlayer coupling strength, magnetic anisotropy, Curie temperatures, and magnon states.

5. Special topics on today's frontier

16. Established fabrication methods of 2D crystals and van der Waals heterostructures.

17. Introduction to electronic properties of the magic-angle twisted bilayer (MATBG) graphene systems*.

18. Introduction to electronic properties of the magic-angle twisted trilayer (MATTG) graphene systems*.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

English Language. Intercultural Communication/Английский язык. Межкультурная коммуникация

Purpose of the course:

Formation of cultural and linguistic competence as a basis for a respectful intercultural attitude towards spiritual, national, and other values of other countries and nations; development of graduate students' cultural sensitivity, the ability to correctly interpret specific manifestations of communicative behavior in different situations; intercultural contacts, practical skills and abilities in communicating with representatives of other cultures, the ability to correctly interpret specific manifestations of communicative behavior and tolerant attitude to them; mastering intercultural interaction up to the necessary and sufficient level to solve communicative and social problems in different cultural, everyday, academic and professional tasks, in communication with representatives of other cultures.

Tasks of the course:

To form the learner's ability to solve communicative tasks by language means in various situations of intercultural communication, to interact on the interpersonal and professional level in a foreign language, considering the peculiarities of the culture of the language being studied, as well as the ability to overcome intercultural differences in situations of everyday, social and professional communication; to develop the ability to reflect on one's own and other cultures, which initially prepares one to have a respectful attitude to cultural manifestations of the target language; to expand the knowledge on the corresponding culture for deep understanding of diachronic and synchronic relations between one' own and the culture of the target language; to acquire new insights into the conditions of socialization and enculturation in one's own and other cultures, social stratification, and sociocultural forms of interaction in shared cultures.

To achieve the goals and objectives of mastering the discipline, students must master a foreign language professional communicative competence, including:

Ethnographic competence: the ability to understand the country of the studied language, its history and culture, everyday life, prominent representatives, traditions and manners; the ability to compare the history, culture, customs of their own and other cultures, understanding of cultural specificity and the ability to explain the causes and origins of a particular cultural characteristic.

Linguistic competence: the ability to correctly construct grammatical forms and syntactic constructions in accordance with the norms of the studied language.

Sociolinguistic competence: the ability to use and transform language forms in accordance with the situation of foreign-language communication.

Sociocultural competence: the ability to consider verbal and non-verbal behavior of the studied language country in communication.

Social competence: the ability to interact with communication partners, possession of appropriate strategies.

Discursive competence: the ability to understand and achieve coherence of individual statements in meaningful communicative models.

Strategic competence: the ability to use the most effective strategies in solving communicative tasks.

Object competence: knowledge of meaningful information when organizing one's own statement or understanding other people's statements.

Subject-professional competence: the ability to operate with knowledge in real world communication with representatives of the studied culture, showing empathy as the ability to understand the norms, values and motives of behavior of representatives of another culture.

Communicative competence: the ability to establish and maintain contacts with representatives of different age, social and other groups of both their own and other cultures, the ability to be a mediator between their own and other cultures.

Pragmatic competence: the ability to choose the most effective and expedient way of expressing thoughts, depending on the conditions of the communicative act and the task set.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

- interrelation, mutual influence and interaction of language and culture;

- the role of language as an organic part of culture in human life, behavior and communication with speakers of other languages and other cultures, national individuality and identity of peoples;

- the concept of a cultural and anthropological view of a person, his/her way of life, ideas, attitudes, customs, system of values, perception of the world - his/her own and others';

- the influence of culture through language on human behavior, worldview and life in general;

- the history of emergence, development stages and teaching methods of intercultural communication;

- the meaning of the concept of "culture", its role in the communication process, as well as the relationship with such concepts as "socialization", "inculturation", "acculturation", "assimilation", "behavior", "language", "identity", "global citizenship";

- the impact of various social transformations on cultural identity changes;

- the specifics of how other cultures are perceived, the causes of prejudice and stereotypes in intercultural encounters;

- mechanisms of forming intercultural tolerance and dialogue of cultures;

- types, kinds, forms, models, structural components of intercultural communication;

- the norms and styles of intercultural communication;

- features of mentality and national customs of different cultures, cultural standards of ethnic, political and economic plans;

- linguistic worldview of native speakers of foreign languages, their distinctive features of outlook and understanding of the world;

- ethical and moral norms of behavior in a culturally different environment;

- language standards of oral communication culture, ethical and moral norms of behavior adopted in the country of the studied language; stereotypes and ways to overcome them; norms of etiquette in the country of the studied language;

- methods of systematic and critical analysis; methods of developing an action strategy for identifying and solving a conflict situation;

- stages of the project life cycle; stages of project development and implementation; methods of project development and management;

- team building techniques; methods of effective team management; basic leadership theories and leadership styles;

- rules and patterns of personal and business oral and written communication; modern communication technologies in Russian and foreign languages; existing professional communities for professional interaction;

- regularities and peculiarities of social and historical development of different cultures; peculiarities of intercultural society diversity; rules and methods of effective intercultural interaction;

- methods of self-assessment, self-control and self-development

be able to:

- apply the techniques of studying cultural systems and intercultural situations;

- perceive, analyze, interpret and compare cultural facts;

- determine the role of basic cultural concepts in intercultural communication;

- find adequate solutions in various intercultural communicative situations;

- analyze the peculiarities of intercultural communication in a team;

- reflect on the reference system of one's own culture;

- recognize and correctly interpret nonverbal signals in the process of intercultural communication;

- compose a communicative portrait of a representative of another linguistic culture;

- discover the meanings of concepts and actions in an intercultural situation;

- analyze coincidences and differences in communicative behavior from the perspective of the cultures in contact;

- adequately implement one' s communicative intentions when communicating with representatives of other linguistic cultures;

- switch when encountering another culture based not only on linguistic, but also on non-linguistic norms of behavior;

- identify the causes of communicative problems and apply ways to overcome them;

- take the position of a partner in intercultural communication and identify possible conflicts as conditioned by the values and norms of one' s culture;

- successfully overcome barriers and conflicts in communication and achieve mutual understanding;

- reveal the relationship and mutual influence of language and culture;

- be tolerant of other cultures and languages;

- analyze the main stages and regularities of the historical development of society to form their civic position;

- respect and preserve the historical heritage and cultural traditions;

- use models of social situations, typical scenarios of interaction of participants of intercultural communication;

- guide the principles of cultural relativism and ethical norms, which imply rejection of ethnocentrism and respect for the diversity of foreign language culture and value orientations of foreign-language societies;

- overcome the influence of stereotypes and carry out intercultural dialogue in general and professional lines of communication;

- model possible communicative situations between representatives of different cultures and societies;

- apply methods of systematic approach and critical analysis of problem situations; develop action strategies, make concrete decisions to implement them;

- develop a project taking into account the analysis of alternative options for its implementation, determine the target stages, the main directions of work; explain the goals and formulate tasks related to the preparation and implementation of the project; manage the project at all stages of its life cycle;

- develop a plan of collective and organizational communications in preparation and implementation of the project; formulate tasks for team members to achieve the set goal; develop a team strategy); apply effective styles of team leadership to achieve the set goal;

- apply communicative technologies, methods and ways of business communication in practice for academic and professional interaction;

- determine theoretical and practical significance of cultural and linguistic factors in the interaction of different philosophical and academic traditions;

- understand and tolerate intercultural diversity of society; analyze and take into account the diversity of cultures in the process of intercultural interaction;

- solve the problems of personal and professional development, determine and implement the priorities of improvement of own activity; apply the methods of self-assessment and self-control.

master:

- norms of etiquette and behavior when communicating with representatives of other cultures;

- principles of tolerance in resolving intercultural conflicts;

- methods of communicative research, the ability to apply the acquired knowledge in research activities, oral and written communication;

- communicative strategies and tactics characteristic of other cultures;

- skills for proper intercultural communication, independent analysis of intercultural conflicts in the process of communication with representatives of other cultures and ways to resolve them;

- the ability to correctly interpret specific manifestations of verbal and nonverbal communicative behavior across cultures;

- oral and written communication skills in Russian and foreign languages to solve interpersonal and intercultural communication issues;

- skills of operating with a focus on ethical and moral norms of behavior accepted in a foreign cultural society;

- the necessary interactive and contextual knowledge, allowing to overcome the influence of stereotypes and adapt to changing conditions in contact with representatives of different cultures

- methodology of systematic and critical analysis of problematic situations; methods of setting a goal, determining the ways to achieve it, developing action strategies

- methods of project development and management; methods of resource and project efficiency evaluation;

- the ability to analyze, design and organize interpersonal, collaborative and organizational communication in a team to achieve an objective; methods of organization and management of the team;

- methods of interpersonal business communication in Russian and foreign languages, with the use of professional language forms, tools, and modern communication technologies;

- methods and skills of effective intercultural interaction;

- technologies and skills for managing one's own cognitive activity and improving it on the basis of self-assessment, self-control and principles of lifelong learning.

Content of the course (training module), structured by topics (sections):

1. Topic 1. Culture and language

The fundamental principles of intercultural communication and dialogue of cultures. Cultural worldview: an understanding of the values, norms, and morals of one's own culture and those of others. Types of relations between cultures. Linguistic system. The communicative function of language. Various forms of language communication. Human speech as a means of transmitting and receiving the bulk of vital information. The correlation between human speech and the language system as a whole. The meaning of language in peoples' cultures. Language as a unique means of storing and passing information, as well as controlling human behavior. The relationship between language, culture and communication. Language culture, language personality communication, identity, stereotypes of consciousness, world pictures, etc.

Communicative tasks: to carry out communication in oral and written forms: explaining the values and ethical norms of one's own culture and those of other cultures; discussing the characteristics and types of relationships between cultures; discussing the importance of taking into account the differences in the means of communication and the communication styles of other cultures; expressing hypotheses and one's own perspective on the interaction between language and culture.

2. Topic 2. Typology of cultures

The fundamental principles of intercultural communication and dialogue of cultures. Cultural worldview: an understanding of the values, norms, and morals of one's own culture and those of others. Types of relations between cultures. Parametric model of culture by G. Hofstede. Theory of cultural standards by A. Thomas. Differentiation of cultures by R. Lewis and F. Trompenaars. Perceptual stereotypes, prejudices and their functions, importance for intercultural communication. Tolerance in intercultural communication.

Communicative tasks: to carry out communication in oral and written forms: explaining the differences in various types of cultures; discussing the specifics of cultural standards, models, concepts; describing the values, norms, and morals of one's own culture and those of other peoples; analyzing coincidences and differences in communicative behavior from the perspective of contacting cultures; taking the partner's position in intercultural communication and identifying possible conflicts as conditioned by values and norms of his/her culture; discussing possible problems in communication with the representative of another culture and ways to resolve them in case analysis.

3. Topic 3. The essence and types of intercultural communication

Existing cultural differences between different people. Overcoming intercultural differences as the main goal of interpersonal communication. Cognitive, social and communication styles of intercultural communication. Verbal and nonverbal communication. Forms and methods of verbal and nonverbal communication. Paraverbal communication. National and cultural characteristics of verbal and nonverbal communicative behavior in different cultures.

Communicative tasks: to carry out communication in oral and written forms: describing events, concepts (space, time, personality, life, etc.) in terms of one' own and other cultures; discussing means of verbal and nonverbal intercultural communication; finding similarities and differences in ways of intercultural communication, typical for foreign and one' own cultures; modeling features of communicative behavior of representatives of one' own and other cultures in a role play.

4. Topic 4. Intercultural scientific communication

Forms of academic and intercultural communication: oral, written, formal, informal. Academic communication: intercultural aspect. Intercultural academic communication and the problems of translation. Academic text as a subject-sign model in a monocultural and intercultural environment. Difficulties and contradictions that occur in the perception and understanding of foreign-language texts.

Communicative tasks: to carry out communication in oral and written forms: describing similarities and differences in foreign-language and native-language academic communication; using cultural standards in situations of oral and written intercultural academic communication; transforming academic texts (from oral to written, from formal to colloquial, etc.); translating academic texts with regard to cultural context and genre tyle affiliation.

5. Topic 5. International academic mobility

Academic mobility as a means of intercultural communication. The importance of intercultural communication for academic mobility. Features of social and academic adaptation in the context of academic mobility. Intercultural communication and communicative competence in the process of academic mobility.

Communicative tasks: to carry out communication in oral and written forms: discussing the benefits of international academic mobility; giving examples of academic mobility in foreign-language and native-language cultures; solving issues related to cultural adaptation in an international academic environment; participating in a role play on typical situations of international academic mobility.

6. Topic 6. Intercultural communication in business

Etiquette and business communication features in different countries. General principles of business etiquette. National principles of business negotiations. Comparing the etiquette of business negotiations. European and Asian communication styles. General features of business etiquette in Asian countries. The influence of different cultural factors on business development of companies planning to enter foreign markets. Communication strategies for achieving mutual understanding in international business. Working with Chinese partners. Knowledge of cultural characteristics as a competitive advantage. Participating in international projects and programs. Working in an international team.

Communicative tasks: to carry out communication in oral and written forms: describing corporate cultures, norms of business etiquette and behavior accepted in the native and foreign countries; solving common problem situations in intercultural business communications; using effective interpersonal communication strategies in intercultural business communications; writing a business e-mail to a foreign partner taking into account his/her cultural affiliation; negotiating with representatives of another linguistic culture.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

English Language. Leadership and Communication in Science, Industry and Academia/Английский язык. Лидерство и коммуникация в науке, индустрии и образо

Purpose of the course:

Formation and development of social, business, cultural and professionally-oriented communicative competencies in accordance with the Common European Framework of Reference for solving communicative tasks in the socio-cultural, academic and professional-business spheres of activity, as well as for the development of professional and personal qualities of master's graduates.

Tasks of the course:

To form the learner's ability to solve communicative tasks by language means in various situations of intercultural communication, to interact on the interpersonal and professional level in a foreign language, considering the peculiarities of the culture of the language being studied, as well as the ability to overcome intercultural differences in situations of social and professional communication. To achieve the goals and objectives of studying the course, students are to master a foreign language general professional communicative competence, including:

Linguistic competence: the ability to correctly construct grammatical forms and syntactic constructions in accordance with the norms of the studied language.

Sociolinguistic competence: the ability to use and transform language forms in accordance with the situation of foreign-language communication.

Sociocultural competence: the ability to consider verbal and non-verbal behavior of the studied language country in communication.

Social competence: the ability to interact with communication partners, possession of appropriate strategies.

Discursive competence: the ability to understand and achieve coherence of individual statements in meaningful communicative models.

Strategic competence: the ability to use the most effective strategies in solving communicative tasks.

Object competence: knowledge of meaningful information when organizing one's own statement or understanding other people's statements.

Pragmatic competence: the ability to choose the most effective and expedient way of expressing thoughts, depending on the conditions of the communicative act and the task set.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

- methods of system and critical analysis;

- methods of developing an action strategy to identify and solve a problem situation;

- stages of the project life cycle;

- stages of project development and implementation; methods of project development and management;

- methods of forming teams;

- methods of effective team management, characteristics of communicative behavior in the process of intercultural communication;

- basic leadership theories and leadership styles;

- rules and patterns of personal and business foreign language oral and written communication;

- modern communication technologies in Russian and foreign languages, culturally determined features of communication in the process of intercultural communication;

- existing professional communities for professional interaction;

- patterns and features of socio-historical development of various cultures;

- features of the intercultural diversity of society;

- rules and technologies of effective intercultural interaction; methods of self-assessment, self-control and self-development.

be able to:

apply methods of a system approach and critical analysis of problem situations;

- to search for solutions to the problem situation and develop a strategy of actions to achieve the goal, to make certain decisions for its implementation, using the skills of foreign language oral and written speech;

- to assess the impact of the decisions taken on the external environment of the planned activity and the relationships of the participants in this activity;

- to develop a project considering the analysis of alternative options for its implementation, to determine the target stages, the main directions of work;

- formulate goals and objectives, relevance, significance related to the preparation and implementation of the project, expected outcomes and possible areas of their application, using the skills of foreign language oral and written speech;

- manage the project at all stages of its life cycle;

- organize and coordinate work with due account for the diversity of the project participants' cultures;

- develop a plan of group and organizational communications during the preparation and implementation of the project;

- formulate tasks for team members to achieve the goal; develop a team strategy using the skills of foreign language oral and written speech;

- apply effective team leadership styles to achieve the set goal;

- exchange business information in oral and written forms in the language being studied;

- to present the results of academic, scientific and professional activities at various events, including international;

- to put into practice communication technologies, methods and patterns of business communication for academic and professional interaction;

- to identify the specifics of the philosophical and scientific traditions of the main world cultures, to understand and tolerate the intercultural diversity of the society;

- analyze and consider the diversity of cultures in the process of intercultural interaction;

- to solve the tasks of personal and professional development, to determine and implement priorities for improving the own activities;

- apply methods of self-assessment and self-control; apply methodologies of improving and preserv health in the process of life.

master:

- methodology of system and critical analysis of problem situations;

- methods of setting goals, determining ways to achieve it, developing strategies for actions using foreign language oral and written speech skills;

- methods of project development and management, forecasting the results of activities using the skills of foreign language oral and written speech;

- methods of assessing the need for resources and the effectiveness of the project using the skills of foreign language oral and written speech;

- ability to analyze, design and organize interpersonal, group and organizational communications in a team to achieve a goal;

- methods of organizing and managing a team, applying the skills of intercultural interaction in the language being studied;

- methodology of interpersonal business communication in the language being studied, using professional language forms, means and modern communication technologies for academic, scientific and professional interaction;

- methods and skills of effective intercultural interaction;

- skills necessary for writing translation and editing various academic texts (abstracts, essays, reviews, articles, etc.);

- ability to determine theoretical and practical significance of the cultural and linguistic factor in the interaction of various philosophical and scientific traditions;

- technologies and skills to manage the own cognitive activity and improve it based on self-assessment, self-control and principles of self-education throughout life.

Content of the course (training module), structured by topics (sections):

1. Topic 1. The new reality of the leadership concept

Leadership in modern society, science, industry, education. Modern concepts of leadership. Types of leadership and personal characteristics of a leader. Leadership technologies. A team as a social group. Principles of team building, roles and tasks within the team. The role of a leader in a team, leadership communication. Effective and dysfunctional models of leadership communication. Organization of interpersonal, group and organizational communications in a team. Team and motivation, feedback.

Communicative tasks: to carry out communication in oral and written forms:

to discuss basic principles of teamwork; to discuss effective team interaction; to give arguments for the definition of "team spirit"; to collaborate, cooperate, express the own point of view, constructively overcome differences, use the potential of the group and achieve collective results; to use methods of communicative interaction and significantly increase the effectiveness of a multinational team; to establish the most effective rules of communication when interacting with the team; ask clarifying questions, leading the interlocutor to his opinion; conduct interviews, building a system of effective interaction when discussing a given topic; mediate when disagreements arise and successfully resolve them; create an atmosphere of friendliness and openness; convincingly express judgment and influence the opinion of the interlocutor; recognize the needs and interests of the interlocutor and build on them in the process of dialogue.

2. Topic 2. The phenomenon of scientific leadership in the modern world

Scientific leadership and its historical transformations. Scientific potential and leadership in science. Communicative nature of leadership in science as a specific model. World leaders in science and technology. The Strategic Academic Leadership program "Priority 2030" is leadership in the creation of new scientific knowledge. Goals of the program. Objectives of the program. Priorities of the program.

Communicative tasks: to carry out communication in oral and written forms:

to describe and discuss effective models of leadership communication; to discuss conditions conducive to competitiveness and scientific leadership; to reason the choice of effective methods in scientific communication; to discuss their features; to discuss the main characteristics of the chosen method; to evaluate models of leadership communication and effective methods in scientific communication; to describe and discuss the goals, objectives and priorities of the academic leadership program; to describe stages of the research project.

3. Topic 3. Leadership in academia, science and industry

Successful career at the university. The program "Leaders of Russia". The program "School of Rectors". Development of strategic plans for the development of the university. The connection of science, technology and education in universities. Personnel reserve. Research leadership. Creation of scientific schools. Scientific projects in education. The MIPT project "Talents in the Regions". Institute of mentoring in science, education, entrepreneurship. Practices of scientific, educational and corporate volunteering.

Communicative tasks: to carry out communication in oral and written forms:

discuss the principles of modern scientific leadership, functions and competencies of a leader in education, science, industry; discuss responsibility for the results and consequences of their scientific activities; give arguments for the definition of "scientific ethics"; coordinate the efforts of all project participants (team, working group), delegate authority; predict the possible development of the technological system in terms of influence the impact of technology on society; to reveal the relationship between the leadership style and the effectiveness of innovation; analyze the results of the implementation of large-scale projects in the field of science and education and their impact on the scientific and technological development of the country; determine the conditions for the disclosure of leadership potential; use effective strategies of the communicative behavior of a leader in science, education and industry.

4. Topic 4. Scientific, educational and scientific-technical projects

Features of the team of a scientific, educational, scientific and technical project. Professional communication in the project team. Goals, objectives, content, basic requirements for the implementation of the project, expected results; scientific, scientific-technical and practical value. Opportunities and solutions, necessary resources for the implementation of the project.

Communicative tasks: to carry out communication in oral and written forms:

discuss the implementation stages of a scientific, technological and business project; discuss the principles of the distribution of roles in the project team; form a team united by a common professional trajectory based on the principles of team building; create a group project taking into account the genre features of the research plan, business plan, technological solution, etc.; make arguments in favor of choosing one or another shared workspace, identify adequate interpersonal communication strategies in the team and use them while preparing a group project; to have a convincing influence on team members; to give rational arguments in defense of their position; to conduct a discussion based on the principles of eco-friendly communication: adequately express agreement and disagreement, use effective strategies for interacting with an unfriendly audience, create a productive working atmosphere, avoiding conflicts and disagreements; to choose the appropriate way of presenting a project; to defend the project by providing verbal and non-verbal influence on experts and representatives of a wide audience; substantiate the relevance, theoretical, practical, social significance of the project, its investment attractiveness and competitive advantages.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

First Principles Simulations and Modeling/Первопринципные методы расчета свойств материалов

Purpose of the course:

To form an idea of the features of calculations in multielectronic systems.

Tasks of the course:

Familiarity with the methodology of calculations, understanding the limitations and limits of the applicability of different approaches. Acquaintance with the concept of elementary excitations in the system, correlation energy. Introduction to optical excitations in a system of many electrons.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

The concept of correlation energy, the concepts of elementary excitations in a system of many electrons.

be able to:

Evaluate electron-electron interaction effects; evaluate the effect of many-electron effects on the optical properties of a system.

master:

Fundamentals of numerical methodology in many-electron systems.

Content of the course (training module), structured by topics (sections):

1. The theory of the mean self-consistent field

Introduction. Problem statement. The theory of the average self-consistent field. The Hartree and Hartree-Fock equations. The theory of the electron density functional. The main limitations of these approaches.

2. Coulomb interaction shielding and plasmons in metals

The Hartree-Fock approximation as the first order of perturbation theory. Screening of the Coulomb interaction in an electron gas. The long-range effect of the Coulomb interaction. Long-wave density perturbations, plasmons, and the RPA approximation.

3. Electron-optical excitations

Pairing of the electromagnetic wave with surface plasmons. Surface Plasmon Polariton. Surface plasmons on a structured surface.

4. Many-Body Perturbation Theory

The Green function and the basics of diagram technique. Diagram decomposition of the Green's function.

5. Numerical packages for calculations within the mean self-consistent field method and beyond

Quanyum Espresso, VASP, BerkeleyGW, Octopus.

6. The Green's function

Free Green's function. The total Green function. Dyson's equation. Actually energy part. The vertex part. Spectral representation of the Green's function. A quasi-partical description of an electronic system.

7. Typical diagrams in solids. The GW method

The Hedin equations. The GW method. Plasma pole approximation.

8. System response

Definition. Causality. Kramers-Kronig relations. The system response function.

9. The DFT+U method

"Re-localization" of electrons in DFT. Mottov insulators. The Hubbard model. DFT+U (LDA+U).

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Fundamentals of Optical Radiation Propagation and Scattering/Основы распространения и рассеяния оптического излучения

Purpose of the course:

To provide students with a general understanding of the fundamental aspects of the propagation, radiation, and scattering of light in particular, and electromagnetic radiation in general. Teach students the universal methods of describing light scattering by objects and nanostructures, and demonstrate the universal patterns observed in the interaction of optical radiation with resonant nanostructures.

Tasks of the course:

- Mastering the basics of electromagnetism

- Teach methods for describing the propagation and emission of electromagnetic radiation in homogeneous space and waveguides

- Teach students the universal methods for describing the scattering of optical radiation by resonant nanostructures

- Gaining knowledge about the geometric and polarization characteristics of light and their transformation upon scattering by objects

- Teaching students the skill of employing the learned methods for solving practical problems

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

- Fundamentals of the mathematical apparatus for describing the electromagnetic field (Maxwell's equations, wave equation, Green's tensor, Poynting's theorem, scattering matrix)

- Basic approaches to describing the propagation and scattering of optical radiation

- Various classes of localized solutions (waveguide modes, leaky modes, resonances, bound states within the continuum) and classes of resonant optical effects observed in resonant nanostructures

be able to:

- Find the dispersion laws of optical modes of homogeneous media and waveguide structures

- Calculate the fields of the simplest radiating systems in a homogeneous medium

- Calculate eigenmodes and eigenfrequencies of basic nanostructures (layers, cylinders, spheres)

- Simulate light scattering by an arbitrary resonant nanostructure at a basic level

master:

- General methods for solving problems of propagation of radiation of electromagnetic waves (search for the spectrum of waveguide modes, calculation of radiation);

- Methods of searching for optical eigenmodes and natural frequencies of resonant nanostructures

- Analytical methods for describing the scattering of optical radiation by generalized resonant structures

Content of the course (training module), structured by topics (sections):

1. Maxwell's equations, material relations, wave equation

Basic mathematical relations of electromagnetism: Maxwell's equations, wave equation, Helmholtz equation. Harmonic form of equations. Equivalence principle. Material relations, Lorentz and Debye models. Causality.

2. Radiation problem, Green's tensor, eigenmodes

Maxwell's equations with a source, formulation of the radiation problem. Green's function concept. Eigenmodes, expansion of the Green's function of closed structures in terms of eigenmodes.

3. Symmetries and conservation laws in optics

Poynting's theorem, Poynting's vector, energy conservation law. T-invariance and reciprocity of electromagnetic systems. Scaling invariance principle.

4. Plane waves in homogeneous media; isofrequencies

Solutions of Maxwell's equations in homogeneous isotropic space. Plane waves; evanescent waves. Waves in media with a negative refractive index. Dispersion of waves in anisotropic materials, Fresnel equation.

5. Scattering of waves at the interface; transfer matrix method

Transmission and reflection of a plane wave at the interface between two media, Fresnel's formula. Transfer matrix method for isotropic media.

6. Standing waves, cylindrical beams, spherical harmonics

Superposition of plane waves, standing waves. Non-diffracting beams, Bessel beams. Scalar and vector spherical harmonics.

7. Waveguiding structures; waveguide mode classes

The problem of waveguide modes. Classification of waveguide modes: localized, leaky, and anti-waveguide modes.

8. Waveguide modes of planar and cylindrical systems

Waveguide modes of a flat and cylindrical metal waveguide. Dielectric layer and cylinder modes.

9. Surface waves; waveguiding in a thin layer

Waveguide solutions at the interface between two media. Wave conduction by a thin conductive layer. Dyakonov waves.

10. Modes of periodic structures; photonic crystals

Waveguide modes of periodic structures, Bloch's theorem, photonic crystals, band gap.

11. Radiation problem; Green's tensor of free space; dipole radiation

Statement of the radiation problem. Finding the Green's tensor for a homogeneous isotropic space. Radiation of an electric and magnetic dipole.

12. Multipole decomposition; radiation near the surface

Decomposition of the field of the radiating system into spherical harmonics. Multipole decomposition of current. Radiation of a dipole near the interface between two media.

13. Radiation intensity, density of states

The power of the dipole radiation, the relationship with the density of states, the Purcell factor.

14. Scattering problem, Lippmann-Schwinger equation; scattering matrix

Statement of the scattering problem, Lippmann-Schwinger integral equation; scattering channels, scattering matrix.

15. Eigenmodes, resonances; zeros and poles of the scattering matrix

The concept of eigenmodes and resonances. Complex frequency plane, natural frequencies; zeros and poles of the scattering matrix.

16. Coupled mode theory

Phenomenological theory of coupled modes for describing the response of resonant systems. The case of several modes and several scattering channels.

17. Exactly solvable scattering problems

Scattering matrices of the interface, layer, eigenvalues and eigenmodes Connection of complex eigenmodes with the waveguide problem.

18. Non-Hermitian optics: absorbers and lasers

Physics of systems with attenuation and amplification; ideal absorbers, coherent absorbers; linear theory of lasers.

19. Bound states within the continuum

Physics of bound states in the continuum, methods of their occurrence, modeling within the framework of the theory of coupled modes.

20. Exceptional points

Singular points of Hamiltonians, examples of singular points in non-Hermitian systems. PT symmetry, laser absorber.

21. Scattering by a compact object; scattering cross sections; sphere scattering

Description of field scattering by a compact object. Decomposition of a plane wave in spherical harmonics. Scattering cross sections, scattering amplitude. Optical theorem. The problem of scattering by a sphere, resonances of spheres.

22. Cloaking and super-scattering

Suppression of scattering by a compact object; anapol. Super-scattering by nanoparticles.

23. Coupled dipole method; diffraction by arrays

Coupled dipole method. Scattering by two bound atoms. Light scattering by a periodic array, diffraction orders, diffraction singularities.

24. Light polarization; Jones matrices

Polarization of the electromagnetic field, polarization ellipse, Stokes parameters, Poincaré sphere. Jones matrices.

25. Spin and orbital moment; chirality of light

Angular moment of light, division into spin and orbital angular momentum. Spin-orbital coupling. Density of chirality, chirality operator. Dual structures. Relationship between chirality and spin.

26. Polarization conversion; classification of polarization effects

Polarization effects in the interaction of light with planar periodic structures. Symmetry classification of periodic structures.

27. Classification of magneto-electric media; simple chiral media

Classification of magneto-electric media. The case of a bi-isotropic chiral medium, rotation of polarization and circular dichroism.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

German for Scientific Purposes/Немецкий язык для научных целей

Purpose of the course:

Formation and development of social, business, intercultural and professionally-oriented communicative competencies for solving communicative tasks in the socio-cultural, academic and professional-business spheres of activity, as well as for the development of professional and personal qualities of a graduate.

Tasks of the course:

To form the learner's ability to solve communicative tasks by language means in various situations in the academic and professional sphere, to acquire knowledge in a wide range of fields of science, to make an in-depth analysis of information and to form his opinion both orally and in writing.

To achieve the goals and objectives of mastering the discipline, students must master a foreign language professional communicative competence, including:

Linguistic competence: the ability to correctly construct grammatical forms and syntactic constructions in accordance with the norms of the studied language.

Sociolinguistic competence: the ability to use and transform language forms in accordance with the situation of foreign-language communication.

Sociocultural competence: the ability to consider verbal and non-verbal behavior of the studied language country in communication.

Social competence: the ability to interact with communication partners, possession of appropriate strategies.

Discursive competence: the ability to understand and achieve coherence of individual statements in meaningful communicative models.

Strategic competence: the ability to use the most effective strategies in solving communicative tasks.

Object competence: knowledge of meaningful information when organizing one's own statement or understanding other people’s statements.

Domain expertise: the ability to operate with knowledge in conditions of real communication with the studied culture representatives, manifestation of empathy as the ability to understand the norms, values and motives of behavior of another culture representatives.

Communicative competence: the ability to establish and forge contacts with representatives of various age, social and other groups of native and other linguistic cultures, the ability to be a mediator between the own and foreign-language cultures.

Pragmatic competence: the ability to choose the most effective and expedient way of expressing thoughts, depending on the conditions of the communicative act and the task set.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

- features of speech activities in German;

- the main phonetic, lexical and grammatical phenomena and structures used in oral and written speech when communicating in German, their difference from the native language for the reasoned and logical construction of statements that allow the application of the studied language in everyday, academic, scientific, business and professional communication;

- features of foreign-language academic communication, techniques for extracting and delivering foreign-language information for academic purposes;

- fundamentals of organizing written communication, types of written communicative tasks and functions of written communication tools;

- specifics of using verbal and non-verbal means in situations of foreign-language communication;

- types and features of written texts and oral presentations, general content of complex texts on abstract and specific topics, features of foreign-language texts, universal patterns of structural organization of the text, including highly specialized texts;

- rules of using various technical means for the purpose of searching and extracting foreign-language information, basic rules of determining the relevance and reliability of foreign-language sources, analysis and synthesis of information;

- world achievements, discoveries, events from the field of history, culture, politics, social life;

- general forms of teamwork organization; special aspects of behavior and interests of other participants; fundamentals of strategic planning of the team to achieve the goal;

- standard types of communicative tasks, goals and objectives of business negotiations, socio-cultural features of business negotiations, their communicative-pragmatic and genre features;

- vocabulary and terminology for academic, scientific and professional communication.

be able to:

- understand and use language tools in all types of speech activities in German;

- conduct discussions in German in various spheres of communication: everyday life, socio-cultural, socio-political, professional;

- verbally implement a communicative intention in order to influence a communication partner to start, conduct/maintain and finish a dialogue-asking about what he saw, read, dialogue-exchanging opinions and observing the norms of speech etiquette, if necessary using strategies to restore a failure in the communication process (re-questioning, paraphrasing, etc.);

- extract general and detailed information when reading authentic scientific and scientific-journalistic German-language texts;

- provide information based on the read text in the form of a prepared monologue (presentation on the proposed topic);

- understand monologue and dialogue statements in direct communication and in audio/video recordings;

- understand communicative intentions of the received written and oral messages;

- expand the proposed argument in the form of illustrations, details, explanations;

- use modern information technologies for professional activity, business communication and self-development;

- convey in Russian the content of German-language scientific and scientific-journalistic texts in the field of professional activity;

- select literature on the topic, compile a bilingual glossary, translate and review special literature, prepare scientific reports and presentations based on the read special literature, explain the own point of view and tell about plans;

- carry out oral and written foreign language communication in accordance with the student's field of professional activity;

- use the techniques and principles of building public speech for the report;

- recognize and differentiate linguistic and speech phenomena, distinguish basic and secondary information when reading texts and listening to speech, use standard means of oral and written communication in interpersonal communication; apply adequate communicative means in standard interaction situations on professionally oriented topics;

- use graphic editors, create easily perceived visual materials;

- describe graphical information (circular histogram, table, column and line graphs); write a short article on a given topic;

- write a summary, a review, a short article-advice on the proposed topic;

- abstract and annotate foreign-language professional texts;

- present research results in a written and oral form;

- apply information and communication technologies in communication and speech activity in a foreign language;

- identify and formulate problems that arise in the process of learning a foreign language; evaluate the student's capabilities, the realism and adequacy of the planned ways and ways to achieve the planned goals.

master:

- intercultural professionally oriented communicative competence in different types of speech activity;

- various communication strategies: educational strategies for organizing educational activities; strategies of reflection and self-assessment in order to improve personal qualities and achievements; strategies for perception, analysis, creation of oral and written texts of various types; Internet technologies for choosing the optimal mode of obtaining information; different methods of memorizing and structuring the acquired material;

- presentation technologies for information communication;

- method of searching and analyzing information from various sources in the professional field;

- skills of annotating and abstracting original scientific and scientific-journalistic articles;

- methods of assessing and self-assessing the results of foreign language learning activities;

- methods of identifying and realizing individual language capabilities, personal and professionally significant qualities in order to improve them;

- the ability to understand the speech of native speakers at a fast rate and respond adequately considering cultural norms of international communication;

- the ability to create clear, logical monologue and dialogue statements in various situations of everyday and professional communication, using the necessary set of communication tools;

- techniques of public speech and business and professional discourse in German.

Content of the course (training module), structured by topics (sections):

1. Topic 1. Flexible skills

Social and emotional intelligence. Personal and social skills. A relationship with the self. Skills and abilities to recognize emotions, understand the intentions, motivation and desires of other people and their own, managing emotions in order to solve practical problems. Inner harmony. Self-understanding. Self-regulation. Motivation. Empathy. Creativity. Sociability. Corporationism. Criticism. Key characteristics of a successful person. Success of the individual. Overcoming difficulties.

Communicative tasks: to carry out communication in oral and written forms: to build logical statements about personal and social skills, to describe various situations using illustrations; to use aphorisms in communication and be able to interpret them; to discourse upon ways of achieving success, possibilities of developing internal potential, life prospects, life meaningfulness, formation of responsibility assumed voluntarily; to talk about ways of self-improvement.

2. Topic 2. Communication in the modern world

Communication in society. Culture of communication based on common values: honesty, respect, mutual trust. Types and forms of communication. Means of communication. Social network.

Communicative tasks: to carry out communication in oral and written forms: to search, receive, transmit and exchange information, to apply in practice various types of information messages: statements, texts, images, sound messages, signals, signs, forum messages, conducting discussions, expressing one's own opinion, reviewing texts, description of illustrations; reasoned essay.

3. Topic 3. Ecology, nature, society

Modern environmental problems. Interaction of nature and society. Environmental protection. Biosphere and humans. Ecological consciousness.

Communicative tasks: to carry out communication in oral and written forms: to exchange opinions on the role of ecology and modern humans' attitude to nature; to discourse upon the dependence of public health on environmental factors; to discuss the impact of environmental factors on the generation of the future; to make descriptive essays on the subject; to draw conclusions, formulate an opinion on the role of society in the preservation of natural habitats on the planet.

4. Topic 4. Social and ethical issues in science, industry, and consumption

Globalization of consumption and social consequences. Science for sustainable development. Production and consumption. Conscious consumption. Principles and strategies of minimalism. Consumer culture. Consumption as a new form of control in society.

Communicative tasks: to carry out communication in oral and written forms: to discuss the problems of consumption globalization to meet the needs of the individual, society, the state; to express a reasoned opinion about the role of science and the impact of economic development on consumer attitudes to the world; to discuss socio-ethical issues and social consequences of consumerism.

5. Topic 5. The New Digital World

Global technological processes related to digitalization. Digital technologies – the Internet of Things. The digital world of science and business. Immersion in the digital world. Safe gadgets. Young hackers. The influence of the digital world on the perception of modern life.

Communicative tasks: to carry out communication in oral and written forms: to be able to search for the necessary information on the topic; to prepare reports on the topic; to express their own judgments about the advantages, limitations and prospects of using digital technologies, and their capabilities; to participate in a group discussion; to exchange opinions on technological innovations for solving various problems using technical means of the digital world; to compose essay-reasoning on the proposed topic.

6. Topic 6. Industry 4.0: on the way to "digital" production

Integration and cooperation with the use of digital technologies and increased flexibility in the organization of work. Transformation of economic sectors and types of activities and its impact on employment. Creating new markets and new forms of work through digital platforms. Problems

related to big information data. Relation between the use of human and machine labor (devaluation of experience, individual support). Possibility of flexible working conditions in terms of time and location. Profound changes in the structures of organizations.

Communicative tasks: to carry out communication in oral and written forms: to discuss flexibility in the organization of work in the context of the Work 4.0 concept; to talk about transformation of economic sectors and its impact on employment and activities in the world of labor; to recognize needs and interests of the interlocutor and base on them in the process of dialogue; to make messages about the creation of new markets and new forms of work through digital platforms; to express the own point of view, to speak constructively about the relationship between the use of human and machine labor; to make messages about the choice of a strategy for flexible working conditions; to be able to justify the chosen strategy; to prepare a report on the proposed topic.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Introduction to Quantum Metrology/Основы квантовой метрологии

Purpose of the course:

Provide students with knowledge of basics of the quantum metrology.

Tasks of the course:

Widen the scope of students in the field of quantum mechanics, introduce the physical platforms used for quantum sensors.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

the foundations of quantum metrology and magnetometry, the physical platforms on which quantum calculators and sensors are implemented, the implementation of algorithms and measurements with them.

be able to:

explain the basic processes in quantum metrology and in the way quantum sensors work, estimate quantum sensor performance.

master:

the mathematical apparatus of quantum mechanics, especially related to quantum computing and measurement.

Content of the course (training module), structured by topics (sections):

1. Physical platforms

Physical platforms: cold atoms, cold ions, artificial atoms, photons. Main physical platforms on which optical clocks, atomic interferometers and gravimeters are based. Methods for obtaining

and preparing particles, n.o. laser cooling, pumping and polarization processes. The advantages and disadvantages of various platforms in a specific application.

2. Quantum logic operations

Basic operations performed on atoms (ions, photons) to prepare and read states. The method of quantum logic, which uses a sparing ion to read the internal state of a "clock" ion.

3. Optical clocks

Principles of operation of optical clocks. Existing clocks on single and ensembles of ions, on neutral atoms in lattices, nuclear transitions. Systematic shifts and errors of optical clocks. Stability and accuracy of optical clocks.

4. Atomic interferometers, gravimeters

The principles of operation of atomic interferometers and gravimeters. Atomic ensembles used for gravimetry. Sensitivity to various external fields and methods of their measurement. The achievable performance of interferometers and gravimeters. Limiting factors.

5. Non-classical states in quantum metrology

Examples of using nonclassical states of light or atomic ensembles to improve the characteristics of quantum sensors. Using squeezed states to overcome the standard quantum noise limit.

6. Magnetometry

Color centers in diamond (nitrogen-vacancy, silicon-vacancy), NV center ground state, spin optical polarization and readout. DC magnetometer operation principles, error estimation for NV-based magnetometer. Superconducting quantum interference device(SQUID). DC-SQUID, RF-SQUID magnetometers. Magnetometer error estimation. Rubidium vapor cell magnetometer.

7. Thermometry in nanoscale

Living cell thermometry via color centers in nanodiamonds. Measurement principle and error estimation.

8. Nuclear magnetic resonance gyroscopy

8. Gyroscope based on Xenon nuclear spin ensemble. Operation principle, continuous induced precession regime. Measurement errors and precision limits.

9. Electrometry

9. Electrometry with Rydberg atoms. Electrometry with color centers in diamond. Measurement errors and precision limits.

10. Methods of sensitivity improvement

Methods of sensitivity improvement. Quantum error correction. Non-demolition measurement.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Labs in Quantum Photonics and Cryptography/Лабораторный практикум по квантовой фотонике и криптографии (РКЦ)

Purpose of the course:

To familiarize students with state-of-the-art laboratory instrumentation and standard operating procedures in quantum photonics and cryptography.

Tasks of the course:

- To develop practical skills of use of modern tools and device of quantum data processing based on photonics;

- to reinforce the theoretical knowledge acquired on preceeding lectures.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

Practical aspects of operating with photon emitters and detectors, fiber-optic interferometers, state-of-the-art instrumentation and computer system of the photonic lab.

be able to:

- Use modern instruments and data processing systems of the photonic lab;

- apply theoretical knowledge on quantum data processing to handle practical task.

master:

Basic skills to work in a photonic lab.

Content of the course (training module), structured by topics (sections):

1. Lab #1. Single-photon detector.

Measurements of basic characteristics of a single-photon avalanche diode: quantum efficiency, linearity and maximum count speed, dead time of detection, post-pulses, and jitter.

2. Lab #2. Single-photon interferometry with fiber optics.

Obtaining light interference in a fiber-optic interferometer. Stabilization of the interferometer. Young's experiment (interference pattern from single photons).

3. Lab #3. Single-photon reflectometry and plug-and-play interferometer scheme.

An optical time-domain reflectometer (OTDR) for fiber-optic communication systems. Identification of components and measurement of their characteristics using a reflectogram. Switching to photon counting mode to increase sensitivity.

4. Lab #4. Fiber-optic quantum key distribution system.

Setting up and running a quantum key distribution system using autocompensation fiber-optic circuit. Testing its main characteristics.

5. Lab #5. Quantum-optical random number generator.

Setup and run of a hardware random number generator based on the phase of spontaneous emission of a semiconductor laser diode. Checking the correctness of its operation mode, reception and statistical testing of the resulting output sequence.

6. Lab #6. Bright-light control of a single-photon detector.

Demonstration of the blinding of a single-photon avalanche diode and of its classical control using bright light. Measurement of characteristics of single-photon avalanche diode under attack on the quantum key transfer system. Testing of a possible solution.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Laser Physics/Физика лазеров

Purpose of the course:

to give students knowledge of the basic concepts of laser operation and laser physics.

Tasks of the course:

- Acquiring knowledge about methods of light source characterization
- Acquiring knowledge about the basic methods for describing the interaction of light and matter
- Learning how to describe laser action
- Studying the classification of lasers and their modes of action
- Studying applications of lasers in modern technology

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

1. Methods of describing the basic processes of interaction of light with matter
2. Methods of designing optical resonators
3. Description of laser dynamics via rate equations
4. Characteristics of radiation generated by laser source
5. Applications of laser physics

be able to:

1. Formulate equations of dynamics of lasers
2. Select the correct characteristics of an optical resonator for a particular application
3. Solve a system of coupled equations describing the dynamics of interaction between the active medium and light in the resonator

4. Evaluate the properties, including photon statistics, of radiation generated by a laser

master:

1. Methods of describing laser dynamics
2. Methods of design of laser resonators
3. Methods of describing interaction of light and medium
4. Methods of constructing models of complex physical processes

Content of the course (training module), structured by topics (sections):

1. Introductory session: history of lasers and their development

History of the development of light sources. Major milestones in the development of laser technology and its applications. Review of course materials.

2. Sources of light and their characterization

Basic concepts of light source characterization, concept of coherence (spatial and temporal). Methods of coherence measurement. Significance of laser technology in nitrometry problems.

3. Interaction of light with matter (absorption, spontaneous and stimulated emission)

Introduction of basic concepts of absorption and radiation. Black body model. The concept of spontaneous radiation in the Planck model. Einstein's coefficients. Einstein’s rate equations for description of spectrum of black body radiation.

4. Spectral characteristics of absorption and radiation processes, homogeneous and non-homogeneous line broadening

The concept of line width in spontaneous emission processes. Homogeneous and inhomogeneous line broadening. Spectral line broadening in gas and solid-state emitters.

5. Optical amplifiers, rate equations

Formulation of rate equations for three- and four-level systems. Solving equations in continuous and pulsed pumping modes. Formulation of conditions for population inversion.

6. Laser generation, generation threshold conditions, saturation and other effects

Formulation of rate equations for description of radiation in optical resonators. Coupled equations for description of laser generation. Formulation of conditions of laser generation.

7. Optimal conditions for laser operation

Analysis of transient effects in laser generation. Temporal laser modulation. Introduction of optimal laser generation conditions related to the design of the optical resonator. Fabry-Perot resonator analysis.

8. Single-mode and multi-mode operating lasers

Formulation of laser generation equations assuming one or many modes in the optical resonator. Discussion of homogeneous and inhomogeneous line broadening. Conditions for modal beating.

9. Characterization of laser sources

Continuous and pulsed lasers, Q-switching and modelocking. Analysis of active laser generation media. Overview of semiconductor lasers and nanolasers.

10. Laser radiation statistics, generation threshold transition

Noise of laser sources, Schawlow-Townes line width model. Photon statistics below and above the laser generation threshold.

11. Ray optics, ABCD matrix

Formulation of light propagation in ray optics. ABCD matrix for basic optical elements. Analysis of optical elements using the ABCD matrix.

12. Stability conditions for optical resonators

Stability evaluation of optical resonators using the ABCD matrix. Design of the optical circuits.

13. Gaussian beams, stability of optical resonators

Solution of diffraction problem in the formulation of Gaussian beams. Basic properties of Gaussian beams. Propagation of Gaussian beams in optical circuits in the ABCD matrix formulation. Stability conditions of optical resonators.

14. Summary of material

Review of passed material. Solution of typical problems.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Machine Learning for Quantum and Statistical Physics/Машинное обучение для квантовой и статистической физики (РКЦ)

Purpose of the course:

to give a brief introduction to the methods of modern deep machine learning, to give an overview of the existing approaches of machine learning tools utilization for experimental quantum physics and statistical physics.

Tasks of the course:

provide to students with the necessary knowledge and skills for independent interdisciplinary research at the intersection of machine learning and physics.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

the basic methods of deep machine learning and existing methods of their application for research in the field of modern quantum technologies.

be able to:

select appropriate machine learning tools for experimental and theoretical research in the field of quantum physics and statistical physics, navigate in modern research at the intersection of quantum technology and machine learning.

master:

basic technologies and algorithms of deep machine learning, and methods for using them as tools for research in various fields of quantum physics and statistical physics.

Content of the course (training module), structured by topics (sections):

1. Introduction.

Introductory lecture. Overview of modern methods of machine learning. Course overview.

2. Linear classification and fully-connected neural networks.

Linear classification, optimization objective, gradient descent, deep neural networks, forward and back propagation. Methods of automatic differentiation.

3. Diagnosing quality of trained models.

Diagnosing quality of trained models. Quality metrics of training, diagnosing overfitting and underfitting. Regularization.

4. Convolutional neural networks.

Convolutional neural networks. Examples of convolutions, stride, pooling, padding. Examples of convolutional neural network architectures.

5. Recurrent neural networks.

Recurrent neural networks. Different types of recurrent architectures. Backward propagation. Gradient vanishing and explosion. Gated Recurrent Unit (GRU), Long Short Term Memory (LSTM). Bidirectional recurrent networks.

6. Boltzmann machines for statistical physics.

Boltzmann machines for problems of statistical physics. Description of the Boltzmann machine, definition, problem statement, optimization functional, gradient derivation and gradient descent. Utilization for classification and statistical physics tasks.

7. Boltzmann machines for quantum state tomography.

Boltzmann machines for quantum state tomography. Tomography of pure and mixed quantum states. Maximum Likelihood Method. Utilization of Boltzmann machines for tomography. Comparison of methods.

8. Sampling methods

Two sampling algorithms from an arbitrary distribution are discussed: the Gibbs algorithm and Metropolis algorithm. These algorithms are used to train a Boltzmann machine.

9. Variational autoregressive neural networks for statistical physics.

Variational autoregressive neural networks for statistical physics and many-body physics. Problem statement, optimization objective derivation, method of model training, overview of possible neural network architectures. Possible applications for other tasks.

10. Overwiev of recent advance.

Overwiev of recent advance in machine learning.

11. Final project.

Presentation of the independent research projects of students.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Methods for the Synthesis of Nanomaterials/Методы синтеза наноматериалов

Purpose of the course:

Introduction to basic methods of materials synthesis: deposition of thin films of metals, dielectrics, semiconductors (including analysis of thin film growth mechanisms, deposition methods and influence of various working parameters on film characteristics), synthesis of two-dimensional and quasi-dimensional materials (CVD, etc.), exfoliation of two-dimensional materials, atomic layer deposition, pulsed laser deposition, chemical vapor deposition, etc.

Tasks of the course:

To study:

1. Method of deposition of thin films of metals, dielectrics, semiconductors.
2. Method of synthesis of two-dimensional and quasi-two-dimensional materials (CVD, etc.).
3. Method of exfoliation of two-dimensional materials. 4.
4. Method of atomic layer deposition of thin films.
5. Method of pulsed laser deposition of thin films.
6. Methods of optical and electron-beam lithography.
7. Methods of local analysis, sputtering and etching of materials using a focused ion beam.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

1. Basic methods of synthesis of nanomaterials.
2. Basic methods for creating nanostructures.
3. Basic methods of analysis of nanomaterials and nanostructures.

be able to:

1. Use methods of nanomaterials synthesis to create thin-film structures.

2. Use methods of nanostructuring to create nanodevices.

master:

A set of skills and knowledge necessary for the synthesis of nanomaterials and the creation of nanostructures.

Content of the course (training module), structured by topics (sections):

1. Nanoscale structures

Colloidal synthesis of nanoparticles. Laser ablation. Femtosecond laser ablation.

2. Fabrication of thin film structures

Thermal and electron-beam deposition in high vacuum. Pulsed laser sputtering. Ion-plasma methods of material deposition. Atomic layer deposition.

3. Investigation of nanostructures by scanning probe microscopy methods

Fundamentals of the method of scanning probe microscopy. Atomic force microscopy - working principles and measurement methods. Principles of operation of magnetic force microscopes.

4. Investigation of nanostructures by transmission electron microscopy

Transmission electron microscopy - principle of operation and measurement methods.

5. Synthesis of two-dimensional materials

CVD synthesis of graphene. CVD-synthesis of transition metal dichalcogenides. Growth of layered crystals.

6. Exfoliation of two-dimensional materials

Methods of preparation of crystal two-dimensional structures. Exfoliation of graphene, two-dimensional crystals of hexagonal boron nitride, exfoliation of transition metal dichalcogenides.

7. Manipulation of nano-objects and control of nano-movements

Laser transfer. Optical tweezers. Moving nanoobjects using an atomic force microscope.

8. Processing of structures and fabrication of devices using nanotechnology

Plasma chemical etching of substrate surfaces and nanoscale films. Optical lithography. Electronic lithography. Nanostructure fabrication using focused ion beam.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Nanomaterials Analysis and Research/Физические методы исследований наноматериалов

Purpose of the course:

Training of the students on the experimental methods of researching natural and artificial nanomaterials, including materials such as graphene, other two-dimensional materials, carbon nanotubes, perovskites, as well as various metamaterials. Experimental techniques under study include optical research methods (optical microscopy, spectrophotometry, reflectometry, spectroscopy, including terahertz spectroscopy, spectral ellipsometry, Raman spectroscopy, Surface-enhanced Raman spectroscopy (SERS), scanning near-field optical microscopy, surface resonance spectroscopy and other plasmonic methods), atomic force microscopy, scanning tunneling microscopy, scanning and transmission electron microscopy, as well as X-ray diffractometry, electrophysical measurements and a number of other experimental techniques.

Students will receive basic skills in working with complex scientific equipment and will complete a series of practical exercises on educational experimental stands. It is planned to master the culture of modern experiment, as well as safety precautions when working with optical radiation and careful handling of optical equipment and other high-tech equipment. The consolidation of the lecture course materials is carried out within the framework of a laboratory workshop. All laboratory work is accompanied by lectures, where theoretical and practical aspects of equipment operation and measurements are considered. Within the framework of the lecture course and laboratory workshop, the features of the manufacture of nanostructures and the technique of working with two-dimensional materials (synthesis of materials - exfoliation and chemical vapor deposition, fabrication of nanostructures, including using optical and electron lithography), as well as measuring the main parameters of nanomaterials will be studied by various physical methods. When performing laboratory work, students will learn how to correctly formulate the results of experiments, their subsequent processing, as well as present the results for evaluation by the teacher. The tasks solved within the framework of the lecture course and laboratory workshop can be further adapted to study the properties of new nanostructures and nanomaterials for research activities of students. The laboratory work of the workshop will allow students to develop the skills of experimental work, which in the future will allow them to prepare for the implementation of research projects in scientific laboratories. The course is aimed at developing creative skills for setting promising scientific problems.

Tasks of the course:

Study of the theoretical and practical foundations of various physical methods for investigating nanomaterials: optical microscopy, spectrophotometry, reflectometry, spectroscopy, including

terahertz spectroscopy, spectral ellipsometry, Raman scattering and Surface-enhanced Raman spectroscopy, scanning near-field optical microscopy, surface plasmon resonance spectroscopy, atomic force scanning tunneling microscopy, scanning and transmission electron microscopy, X-ray diffractometry, electrophysical measurements and a number of other experimental techniques.

Experience in the characterization of nanomaterials, practice and study of the culture of working with nanomaterials. Study of safety precautions for working with nanomaterials.

Synthesis and manufacture of nanomaterials. Working with 2D materials - exfoliation and chemical vapor deposition. Transfer of nanomaterials to various substrates.

Determination of the most effective research methods for given nanomaterials and nanostructures.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

- basic principles of spectroscopy and spectrophotometry

- basic principles of spectral ellipsometry

- basic principles of far-field optical microscopy

- basic principles of atomic force microscopy

- the basic principles of scanning tunneling microscopy

- basic principles of scanning near-field optical microscopy

- basic principles of Raman and Surface-enhanced Raman spectroscopy

- basic principles of surface plasmon resonance spectroscopy

- basic principles of scanning electron microscopy

- basic principles of transmission electron microscopy

- basic principles of terahertz spectroscopy

- basic principles of optical reflectometry

- basic principles of X-ray diffractometry

- basic principles of laser nanopolymerization (or two-photon polymerization)

- basic principles of photoluminescence microscopy

-basic principles of making samples (deposition of metal films, optical lithography (photolithography))

- the main objects and phenomena, the study of which is possible by optical methods

- safety precautions and rules for working with scientific equipment

be able to:

- work with a spectrophotometer

- work with an ellipsometer

- work with an atomic force microscope

- work with a scanning tunneling microscope

- work with a scanning near-field optical microscope

- work with a scanning Raman microscope

- work with a scanning electron microscope

- work with a photoluminescent microscope

- work with transmission electron microscopy

- work with a scanning electron microscope

- work with chemical solutions, determine the chemical composition of solutions.

- work with van der Waals materials. Determine the composition, properties, quality, and number of layers.

- to plan an experiment to solve a scientific problem using optical methods.

- collect, process and present the results of the experiment, taking into account possible errors and inaccuracies

master:

- methods of analysis and processing of experimental data.

-Skills in the presentation of experimental data.

- the skills of characterizing the manufactured samples using atomic force microscopy, scanning and transmission electron microscopy.

-the skills of solving scientific problems by experimental optical methods (Raman spectroscopy, Surface-enhanced Raman spectroscopy, spectrophotometry, near-field microscopy, ellipsometry, photoluminescence microscopy)

Content of the course (training module), structured by topics (sections):

1. Artificial nanomaterials. Manufacturing technologies

Metamaterials, metasurfaces, photonic crystals. Hyperbolic metamaterials. Van der Waals heterostructures. Methods for the manufacture of artificial nanomaterials. Methods for the characterization of artificial nanomaterials.

2. Natural nanomaterials. Synthesis and manufacturing technologies

Graphene. Two-dimensional materials. Exfoliation of 2D materials. Synthesis methods using ultrasound and chemical vapor deposition. Transfer of nanomaterials to various substrates.

3. Review of physical methods for studying nanomaterials

Optical and electrophysical methods for studying nanomaterials. A review of methods of optical spectroscopy, atomic force, scanning tunneling, scanning electron and transmission electron microscopy.

4. Optical properties of nanomaterials

Optical properties of bulk substance. Classical theories of optical constants. Lorentz model. Multi-oscillator model. Model of anisotropic oscillators. Drude's model. Optical characteristics of the substance. Optical properties of particles. Extinction, absorption, scattering.

5. Optical microscopy

Modern microscopic technology. Confocal laser scanning microscopy. Multiphoton confocal microscopy. Quantitative fluorescence microscopy. Superresolution methods. Special optical methods.

6. Spectroscopy and spectrophotometry

Optical spectroscopy. Spectral analysis. Spectroscopic methods. Photocolorimetry. Spectrophotometry. Photoluminescence spectroscopy.

7. Terahertz spectroscopy

Continuous terahertz spectroscopy on backward-wave lamps (BWT). Time-resolved pulsed terahertz spectroscopy. Fourier transform infrared spectroscopy.

8. Raman spectroscopy

Raman spectroscopy (Raman effect). Classical theory. Quantum theory. Empirical laws of Raman spectroscopy. Stimulated Raman Scattering. Raman spectroscopy techniques. The structure of the Raman spectrometer. Getting skills in working with a Raman spectrometer.

9. Surface-enhanced Raman spectroscopy

Surface-enhanced Raman spectroscopy (SERS). Experimental techniques for obtaining spectra of SERS. Main characteristics and mechanisms of the effect of SERS. Application of SERS to the study of biological molecules. Possibilities and prospects for the development of the SERS method.

10. Surface plasmon resonance spectroscopy

Surface electromagnetic waves. Surface plasmon resonance. Surface plasmon resonance spectroscopy. Sensitivity methods. Limitations of the method. Compact circuits. Biosensors based on surface plasmon resonance spectroscopy.

11. Spectral ellipsometry

Light polarization. An introduction to spectral ellipsometry. Measurement scheme. Receiving data. Data analysis. Measurement of spectra of optical constants of materials, including thin films. Study of the structural properties of thin films and interphase boundaries. Determination of thicknesses and physical characteristics of multilayer structures.

12. Spectral ellipsometry of anisotropic materials

An introduction to spectral ellipsometry of anisotropic materials. Muller Matrix. Measurement of the spectra of optical constants of anisotropic materials. Analysis of the spectra of optical constants of anisotropic materials.

13. Scanning near-field optical microscopy (aperture)

Diffraction limit. Introduction to scanning near-field optical microscopy. Resolution of scanning near-field optical microscopy. Schematic diagrams of scanning near-field optical microscopy. Practical measurements. Solution of applied problems.

14. Scanning near-field optical microscopy (apertureless)

Introduction to scattering scanning near-field optical microscopy. Resolution of scattering scanning near-field optical microscopy. Scheme. Practical measurements. Applied tasks. Plasmons in two-dimensional materials.

15. Electrophysical methods for the study of nanomaterials

Resistivity measurement methods. Four-probe method for measuring resistivity. Specific resistance and specific surface resistance. Measurement of surface resistance of relatively thin semiconductor wafers and thin conductive (semiconductor and metallic) layers isolated from conductive substrates. Two-layer structures. Self-compensation method for geometric effects. Modern installations for measuring surface resistance.

16. Atomic force microscopy

Principle of operation. Construction of an atomic force microscope. Features of work. Processing of the received information and restoration of the received images. Current state and development of scanning probe microscopy. Practical measurements. Thickness of 2D materials. Roughness of thin metal films.

17. Scanning tunnel microscopy

Principle of operation. Construction of a scanning tunneling microscope. Features of work. Processing of the received information and restoration of the received images. Current state and development of scanning tunneling microscopy. Practical measurements.

18. Scanning electron microscopy

Principle of operation. Construction and main components of a scanning electron microscope. Features of work. Processing of the received information and restoration of the received images. Practical measurements. Surface morphology of ultrathin metal films.

19. Transmission electron microscopy

Principle of operation. Design and main components of a transmission electron microscope. Features of work. Processing of the received information and restoration of the received images. Practical measurements. Transmission electron microscopy of two-dimensional materials.

20. Optical lithography (photolithography)

Principle of operation. Photolithography process. Photopolymers. Manufacturing of microstructures. Cleaning and surface preparation. Photoresist application. Exposure. Manifestation. Surface treatment.

21. Electronic lithography

Principle of operation. Electronic lithography process. Resolution in electronic lithography. Principles of writing a drawing on a sample. Systems for electronic lithography. Writing drawings on a sample.

22. X-ray diffractometry

Theoretical foundations of the method. X-ray structural analysis. X-ray diffractometric method. Phase identification and quantification (phase analysis). Practical measurements for thin metal films.

23. Laser nanopolymerization (or two-photon polymerization)

Theoretical foundations of the method. Two-photon polymerization. Polymers. Manufacturing of two-dimensional and three-dimensional structures. Resolution in typical laser nanopolymerization experiments.

24. Photoluminescence microscopy

Photoluminescence microscopy at room temperature and mapping. Photoluminescence absorption microscopy at room temperature. Low-temperature photoluminescence microscopy.

25. Raman spectroscopy of two-dimensional materials

Raman spectroscopy technique for two-dimensional materials: graphene and transition metal dichalcogenides. Practical measurements and processing of spectra.

26. Spectral ellipsometry of two-dimensional materials

Effective spectral ellipsometry models for the analysis of the optical properties of two-dimensional materials: graphene and transition metal dichalcogenides. Practical measurements and extraction of optical constants.

27. Optical reflectometry

Theoretical foundations of the method. Models for analysis. Modeling. Practical measurements for thin and ultra-thin metal films.

28. Far-field optical microscopy

Scattering of nanoparticles. Dark-field microscopy. Method resolution. Applications. Hybrid nanostructures. Practical measurements.

29. Van der Waals materials

Physics of van der Waals materials. Assembly of van der Waals heterostructures. Methods for studying van der Waals heterostructures. Two-layer structures and moire.

30. Review of synthesis technologies and research methods for nanomaterials

Analysis of synthesis technologies and research methods for nanomaterials. Theoretical and practical foundations.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Open Quantum Systems/Открытые квантовые системы

Purpose of the course:

Introduction to the main theoretical methods of analysis of open quantum systems for the research in a wide range of scientific fields

Tasks of the course:

To study:

1. The Heisenberg-Langevin method.
2. The density matrix method (the Lindblad equation).
3. The cluster expansion approach.
4. Method of nonequilibrium Green's functions (Keldysh technique).

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

1. Basic equations describing the dynamics of an open quantum system.
2. Criteria by which the reservoir can be attributed to the Markov one.
3. Influence of a random phase accumulation on the density matrix.

be able to:

1. Calculate the dynamics of correlators of the operators of creation and annihilation of photons interacting with the heat reservoir.
2. Calculate diffusion coefficients (correlators of Langevin forces) using Einstein's equation.

master:

A set of skills and knowledge necessary to study timely scientific and technical problems.

Content of the course (training module), structured by topics (sections):

1. State of open quantum systems

Density matrix. Occupation number representation. The von Neumann equation. The Gibbs distribution.

2. Density matrix method

Spontaneous emission as interaction with a zero-temperature reservoir. Lindblad's equation for a system interacting with a Markovian reservoir. Random accumulation of phase. Spontaneous emission from an emitter with a phase decoherence with a damped resonator in the weak coupling mode (Purcell effect).

3. The Heisenberg-Langevin method

Heisenberg representation in quantum mechanics. Dynamic equation for operators with Langevin forces. Dynamics of operator correlators of the second and higher orders. Quantum Regression Theorem.

4. Cluster-expansion approach

Bogolyubov's hierarchy. Determination of irreducible singlet, doublet, triplet correlators. Application to a single-mode laser.

5. Fundamentals of nonequilibrium diagrammatic technique

Evolution operator in interaction view. The Keldysh contour. Green's function. Partial summation, self-energy, the Dyson equation. The Kadanoff-Beim equations. Application to spontaneous and stimulated emission in a single-mode laser.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Physics of Quantum Fluids/Физика квантовых жидкостей (РКЦ)

Purpose of the course:

Provide students with the basic knowledge of ultracold quantum systems, which are one of the main topics of research around the world and at RQC.

Tasks of the course:

Provide understanding of the main results obtained in the physics of ultracold quantum systems.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

Primary concepts of the physics of ultracold quantum systems: Bose-Einstein condensation, Superfluidity in Bose and Fermi systems etc.

be able to:

solve a large variety of problems related to the physics of ultracold quantum systems.

master:

mathematical techniques that are necessarily for solving these problems.

Content of the course (training module), structured by topics (sections):

1. Key quantities. Elastic and inelastic interaction between atoms.

Key quantities. Elastic interaction between atoms. Weakly interacting regime. Two-body scattering problem. Inelastic collisions

2. Bose-Einstein condensation in an ideal gas.

Second quantization. Thermodynamics of an ideal Fermi gas. Particle and hole excitations.

3. Weakly interacting Bose gas. Gross-Pitaevskii equation.

Gross-Pitaevskii equation for the condensate wavefunction. Density-phase representation. Collapsing condensates. Stable condensates. Healing length. Bose-Einstein condensation in an external harmonic potential.

4. Dynamics of Bose-Einstein condensates.

Exact scaling approach for a two-dimensional evolution of a trapped condensate. Scaling approach for evolving 3D trapped condensates. Fundamental frequencies of oscillating condensates.

5. Elementary excitations of a Bose-condensed gas.

Bogoliubov transformation. Excitation spectrum of a uniform condensate. Non-condensed fraction. One-body density matrix and long range order. Quantum fluctuations of the density and phase. Quantum fluctuations and ground state energy.

6. Bose-condensed gas at a finite temperature. Superfluidity in Bose systems.

Non-condensed fraction and the one-body density matrix at finite temperatures. Landau criterion of superfluidity. Superfluid and normal density. Beliaev damping of elementary excitations. Landau damping. Small parameter of the theory at finite temperatures.

7. Vortices in Bose-condensed gases.

Vortices in rotating and non-rotating superfluids. Circulation. Gross-Pitaevskii equation for the vortex state. Excitations of the vortex state. Fundamental modes. Kelvin modes and vortex contrast.

8. Ideal Fermi gas. Thermodynamics and excitations.

Second quantization. Thermodynamics of an ideal Fermi gas. Particle and hole excitations

9. Repulsively interacting Fermi gas. Landau's Fermi liquid theory.

Weakly interacting Fermi gas with repulsion between particles. Quasiparticles in Landau's Fermi liquid theory. Hydrodynamic regime. Collisionless regime. Zero sound.

10. Attractively interacting Fermi gas. Superfluid pairing.

Cooper problem. BCS approach. Gapped single-particle excitations. Order parameter and transition temperature.

11. Superfluidity in Fermi gases.

Landau criterion in Fermi gases. Superfluid current. Bogoliubov-Anderson sound. Superfluid and normal density. Thermodynamic quantities near Tc.

12. Ginzburg-Landau approach. Vortices in Fermi gases.

Landau-Ginzburg functional. Critical fluctuations. Vortex state. Vortices near Tc

13. Strongly interacting Fermi gases.

Anomalously large scattering length. Fano-Feshbach resonance. BCS-BEC crossover. Description of the strongly interacting regime. Unitarity limit.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Populism, Fakes, and Post-Truth: Algorithm-Driven Media Consumption and New Social Phenome/Популизм, фейки и постправда: алгоритмизированное медиапотр

Purpose of the course:

To familiarize students with new media and communication environment and its impact on society, especially in field of public sphere (including political public sphere), provide them tools to analyze media and communication field and its role within the society.

Tasks of the course:

- To introduce students into core concepts of media and their connections with social realm;

- to give an overview of the contemporary social media driven media consumption;

- to make students able to use social theories in field of media in order to analyze society and role of new technologies within it;

- to provide both social-deterministic and techno-deterministic vision of the role of media and make students able to apply them;

- to introduce students into the core elements of theory of media effects and make them able to take into consideration the 'effect-driven' approach.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

- Core theories and approaches to the role of media and communication within the society;

- core theories of media effects;

- approaches to new social phenomena;

- criteria for analysis of media complexity;

- role of media in politics.

be able to:

- Distinguish between socially-oriented and techno-deterministic theories;

- criticize contemporary communicative capitalism driven by technological algorithms;

- separate well news sources from bad ones, be able to find a bias in media messages;

- write essays on social topic in English language.

master:

- Tools for news analysis;

- tools for analysis of political speech and declarations;

- tools of critical information thinking.

Content of the course (training module), structured by topics (sections):

1. Media, communication and social institutions

Notion of communication and social communication. Differences in communication between animals and humans. 3 types of interactions in societies and their interconnection. Evolution of interactions and evolution of societies. Role of major media innovations in previous communicative revolutions. Role of printing press and printed book. Media and economic institutions. Media and political institutions. Media and cultural institutions. Soft power and hard power.

2. Media and technological determinism in approaching changes in society and its critic

Media and technological determinist vision vs society-centric vision of changes. Linear and non-linear technological development. Everett Rogers and simplistic vision of innovations. Works about technological impact of media: Lerner and MIT school. Latour and Flichy: toward socio-technical complexity. Overview of techno-determinist theories:

- McLuhan and technical thinking on media

- Information society theories

- Castells and network society theory

- Web 2.0 and prosumerist culture

- Works on new media activism

Critic of technological determinism.

3. Contemporary algorithmic media reality: social media, prosumerism, sharing economy.

Core technological changes in recent decades driving media development: raise of media channels, digitalization, device individualization. Rising speed and storage capacity for content. Video as a core content. Social media as new media reality. Alone together philosophy.

Convergence culture and prosumer (playbour) vision. Sharing economy ideology. Political economy of sharing and prosumerism (as critique):

- General models of accumulation of capital

- Idea of digital exploitation

- Network and convergence-based society as still capitalist

4. Some basic concepts about news and truth.

The concept of truth in the society and its ambivalence. Truth and opinion dialectical relationship. News and views separation in journalism. Ideology of news in journalism. Principles of news. Dependent journalism as political activism and propaganda but one of the core function of journalism – core normative visions of journalism. Normativistic and non-normativistic view.

5. Fake news as a parallel communicative flow

Historical origins of the term “fake news”. How multi-channel media undermines the principles of news. News and views separation in digital reality of prosumerist media. Lowering bargains for creating content.. Fake news, disinformation and misinformation. Fake news as propaganda. Types of fake news. Fake news and strategic disinformation. Regulation of fake news: fake news laws, strategic disinformation dispositive, algorithmic solutions, media literacy as magic pill.

6. Media bias in new communicative environment: why fake news works?

Notion of media bias. 5 filters of Herman and Chomsky. Core approaches to media effects. Cognitive dissonance effect. Confirmation bias and selective exposure. Agenda setting in new media. Two steps flow model and how it combines personal trust with mass information in new media world. Media and viral content distribution in new environment.

7. Political public sphere and new media reality: populism and radicalization

Approaches to media and politics. Different visions of power. Public sphere as core concept about communication and politics. Crisis of rational debate in contemporary media. Rise of alternative media. Core concepts of alternative media. Rise of informational and public in politics. Populism as informational phenomenon. Radicalization of political media outlets. Echo-chambers and echo-bubbles and fragmentation of the debate.

8. Activism and new media

Political activism as a concept. Political participation and how new media are challenging it. Ideology if participatory media. Arab spring and “Twitter revolutions”: concept of participatory digital media for changing political regimes. Role of digital media in Trump elections. Critique of digital revolutions. Concept of connective and collective actions and their differences.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Quantum Information Processing/Обработка квантовой информации (РКЦ)

Purpose of the course:

to acquaint students with the basics of quantum information processing theory, necessary for starting their own research activities.

Tasks of the course:

give a general idea of the formalization of information concept from the view point of the probability theory;

introduce the basic ideas of classical information processing;

introduce the formalism of positive operator-valued measures;

introduce the basic concepts of quantum information transfer;

introduce the basic algorithms of quantum computing, as well as modern algorithms of quantum machine learning.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

the basic concepts of quantum and classical information theory and the fundamental differences between quantum and classical information theory;

principles for constructing quantum algorithms and the functioning of quantum computers;

basic approaches to the transmission of information through quantum channels.

be able to:

calculate the entropy characteristics for classical probability distributions and quantum states;

perform operations on bra- and ket- vectors;

purify mixed quantum states;

calculate quantum states of the qubit register after applying a given set of quantum gates;

construct elementary quantum algorithms;

to design the simplest quantum communication protocols.

master:

the mathematical apparatus of classical and quantum information theory;

formalism of the quantum channels description.

Content of the course (training module), structured by topics (sections):

1. Review of the foundations of quantum mechanics formalism for finite-dimensional spaces

Review of the foundations of quantum mechanics formalism for finite-dimensional spaces. Hilbert spaces, bra and ket vectors, unitary, Hermitian, semi-positive operator. Matrix multiplication, trace, eigen values and eigen vectors. Calculation of mean values of the observables. Pure and mixed states, tensor product and partial trace.

2. Quantum measurement and quantum evolution

Quantum measurement and quantum evolution. Quantum measurements and quantum evolution. Formalism of positive operator-valued measures. Naimark's theorem. Completely positive trace-preserving mappings. Representations of quantum channels in terms of Kraus operators. Stinespring representation.

3. Quantum entanglement

Quantum entanglement. The concept of quantum entanglement of pure and mixed states. Measures of quantum entanglement and witnesses of quantum entanglement. The use of entangled states in the protocol of quantum teleportation and super-dense coding.

4. Quantum information theory

Quantum information theory. Foundations of classical information theory. Generalization of classical information theory to quantum states. Information transmission through quantum channels, Holevo bound.

5. Universal quantum computing

Universal quantum computing. Basic quantum gates, universal set of quantum gates, Solovey-Kitaev theorem. Principles of constructing quantum algorithms. Deutsch’s, Deutsch-Jozsa’s, Simon’s, Shore’s, Grover’s algorithms. Demonstration of “quantum supremacy”.

6. Variational and adiabatic quantum computing

Variational and adiabatic quantum computing. The principle of constructing variational quantum algorithms. Examples of using variational quantum algorithms. Using variational algorithms for quantum simulation. The principle of constructing adiabatic quantum algorithms. The relationship between variational and adiabatic algorithms.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Russian as a Foreign Language/Русский язык как иностранный

Purpose of the course:

The Russian as a foreign language (A2) course is aimed at the formation of intercultural professionally oriented communicative competence from the zero level to the elementary level (according to the European scale of foreign language proficiency levels) for solving social and communicative tasks in various areas of everyday, cultural, professional and scientific activities in the Russian language, as well as for further self-education.

Tasks of the course:

The tasks of the formation of intercultural, professionally oriented communicative competence consist of the gradual mastery by students of a set of competences, the main of which are:

– linguistic competence, i.e. the ability to adequately perceive and correctly use language units based on knowledge of phonological, grammatical, lexical, stylistic features of the studied language;

– sociolinguistic competence, i.e. the ability to adequately use realities, background knowledge, situationally conditioned forms of communication;

– sociocultural competence, i.e. the ability to consider during the communication speech and behavioral models adopted in the relevant culture;

– social competence, i.e. the ability to interact with communication partners, to make contact and maintain it, owning the necessary strategies;

– strategic competence, i.e. the ability to apply different strategies to maintain successful interaction in oral/written communication;

– discursive competence, i.e. the ability to understand and generate foreign language discourse considering cultural differences;

– general competence, including, along with knowledge about the country and the world, about the features of the language system, also the ability to expand and improve their own picture of the world, to be guided by the media sources of information;

– intercultural competence, i.e. the ability to achieve mutual understanding in intercultural contacts, using the entire set of skills to realize the communicative intention;

– compensatory competence, i.e. the ability to avoid misunderstandings, to overcome the communication barrier through the use of well-known speech and metalanguage means.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

– The main facts, realities, names, attractions, traditions of Russia;

– some achievements, discoveries, events in the field of Russian science, culture, politics, social life;

– basic phonetic, lexical-grammatical, stylistic features of the Russian language and its difference from the native language;

– the main differences in writing and speaking.

be able to:

– Generate adequate oral and written texts in a specific communication situation;

– to realize the communicative intention with the purpose of influencing the communication partner;

– adequately understand and interpret the meaning and intention of the author in the perception of oral and written authentic texts;

– identify similarities and differences in the systems of native and foreign languages;

– show tolerance, empathy, openness and friendliness when communicating with representatives of another culture.

master:

– Intercultural professionally oriented communicative competence in different types of speech activity at the level of A2;

– social and cultural competences for successful mutual understanding in terms of communication with representatives of another culture;

– various communication strategies;

– learning strategies for organizing the learning activities;

– strategies of reflection and self-evaluation for self-improvement of personal qualities and achievements;

– different methods of memorization and structuring digestible material;

– Internet technologies to select the optimal mode of obtaining information.

Content of the course (training module), structured by topics (sections):

1. My World

Communicative tasks. To talk about your everyday activity. To tell the time. To make an appointment. To talk about your family. To fill the registration form.

Vocabulary. Verbs describing everyday activity. Time. Parts of the day. Numbers 10-100. Events. Family. Registration form.

Grammar. 1st conjugation of verbs. 1 час, 2-4 часа, 5-20 часов. Consolidate conjugation of verbs. Possessive adjectives: мой/моя, твой/твоя.

Phonetics. Pronunciation of sounds: т, ть. Pronunciation of [ц], unstressed «я», «е». Pronunciation of [ж], [ш]. Devocalization of sound «ж» at the end of words.

2. Our Lesson

Communicative tasks. To understand your teacher's instructions in Russian. To ask people if they have something. To indicate something. To set a meeting. To talk about your plans for a week.

Vocabulary. Verbs describing activities at the lesson. Personal things. Numbers 100-1000. Days of week. Events.

Grammar. Imperative form of verbs - читайте, слушайте etc. Construction "у меня есть". Gender of nouns. Construction "У меня + событие". Nouns in plural. Days of week.

Phonetics. Pronunciation of "о" in unstressed position. [ж], [ш]. Devocalization of sound «ж» at the end of words. Pronunciation of у, г.

3. In the City

Communicative tasks. To talk about your city. To ask where to go. To understand signs of a city. To buy a ticket for metro. To order in a restaurant. To refuse an offer. To say where you were yesterday.

Vocabulary. Places in town (parks, restaurants, museums etc.). Words for ordering in a café or buying a ticket for metro. Russian way to say "last/next week".

Grammar. Endings of adjectives. Possessive pronouns. The prepositional case for locations. The past tense of the verb "to be".

Phonetics. Devocalization "д" at the end of words and in front of voiced consonants. Practicing the phrase "к сожалению". Words where "ч" is pronounced as [ш].

4. My Home

Communicative tasks. To describe your house. To call for a master to fix broken things at home. To explain location of things in the house. To talk about your free time and ways to rest at home.

Vocabulary. Furniture. Rooms. Verbs (to sleep, to want, to see, to watch, to hate). Parts of a house (wall, floor etc.). Outside the house (garden, forest). Verbs describing activities at home.

Grammar. Neuter gender nouns in plural. Masculine gender nouns in plural. Exceptions. The prepositional case, exceptions. The past tense. The accusative case for objects.

Phonetics. Pronunciation of the names of the rooms. Pronunciation of words with a change of stress in the prepositional case (в лесу, на полу, etc.). Pronunciation of [х]. Being surprised by the word "ух ты!"

5. Tasty Food

Communicative tasks. To explain what you need to buy. To talk about food preferences. To order and pay in a restaurant. To talk about recipes. To invite friends for dinner. To express admiration or criticism.

Vocabulary. Phrases for shopping. Phrases for restaurants. Phrases for inviting and accepting invitations.

Grammar. Personal pronouns with “нужно”, “надо”, “нравится”. The instrumental case after the preposition “с”. The future tense.

Phonetics. Pronunciation [ы], [и]. Devocalization of the voiced consonants at the end of words (б, д, в, з, ж, г). Intonation of admiration: “Как хорошо!”

6. Health

Communicative tasks. To talk to a doctor. To talk about health. To give recommendations. To talk about mood (I am sad, happy etc.). To agree/disagree.

Vocabulary. Parts of body. Health. Можно/нельзя. Emotions. Mood.

Grammar. Construction “у меня был”. Personal pronouns of with age, “можно”, “нельзя”. Short forms of adjectives.

Phonetics. Intonation of the interjection "ай!" when expressing pain. Pronunciation of ь, ъ.

7. People

Communicative tasks. To talk about people’s character. To describe appearance. To compare things. To buy clothes. To agree to do something.

Vocabulary. Adjectives. Describing a person. Adjectives. Appearance. Clothes. Colors. Size.

Grammar. Endings of adjectives. The comparative and superlative degree. The genitive case in possessive constructions. Endings of adjectives.

Phonetics. Pronunciation of [ш], [щ]. Combination «дж». Intonation of admiration urprise using the word “так”. Pronunciation of “ё” after the hushing sounds.

8. Transport

Communicative tasks. To talk with a taxi driver (price, address, etc.). To order a taxi. To cancel, reschedule or confirm a meeting. To talk about your trip. To describe cities.

Vocabulary. Transport. Dates. Verbs: перенести, отменить, подтвердить, прийти/приехать, уйти/уехать. The compass. Words for travelling.

Grammar. The prepositional case for transport. Ordinal numbers. The accusative case for directions with prepositions “в”, “на”.

Phonetics. Practicing the difference of pronunciation between "е" and "ё" in the conjugation of the verbs "идти", "ехать". Words where the letter "г" is pronounced as "в" (его, сегодня). Devocalization "з" in the preposition "из".

9. My Family

Communicative tasks. To talk about family. To accept the invitation. To talk about hobbies. To refuse the invitation. To ask and tell about biography.

Vocabulary. Family. Relatives. Activities during the holidays. Verb “уметь”. Verbs: пожениться, родиться, случиться, познакомиться.

Grammar. The genitive case. Possession. Reflexive verbs (the present tense). Заниматься + the instrumental case. Reflexive verbs (the past tense).

Phonetics. Devocalization of sound “ж” at the end of words. Pronunciation of тс, тьс = [ц]. Pronunciation of и = [ы] after ш, ж, ц.

10. Holidays

Communicative tasks. To congratulate with holidays. To tell about traditions. To sign postcards. To say wishes. To suggest the idea of gifts. To express surprise.

Vocabulary. Name of the holidays. Verbs: праздновать, поздравлять, прощаться, гулять. Wishes (happiness, love, luck, etc.). Gifts.

Grammar. Поздравлять + the instrumental case. The genitive case with the verb желать. The genitive case after prepositions.

Phonetics. Words with an unpronounceable "д". Words where г = [в]. Intonation of the phrase "Да ладно?!"

11. Shopping

Communicative tasks. To understand the information on the labels of cosmetic products. To buy groceries. To communicate in the store. To buy clothes.

Vocabulary. Body parts. Cosmetic. Stores. Numbers and time. Fruits and vegetables. Clothes, shoes, accessories. In the store.

Grammar. The genitive case. Plural. The genitive case with numbers. The genitive case.

Phonetics. Devocalization of "в" at the end of words. Devocalization of paired voiced consonants before voiceless consonants. The difference in pronunciation between "большой" and "больше".

12. Countries and Nationalities

Communicative tasks. To ask a person where he he is from. To talk about countries. To talk about the weather. To talk about the season. To talk about traditions and nationalities.

Vocabulary. Countries. Months. Weather. Season. Verbs (to love, to call, to speak). Traditions and nationalities.

Grammar. Months in the prepositional case (when?). 2nd conjugation of verbs. Nationalities.

Phonetics. Pronunciation of р, рь, ю. Pronunciation of the names of nationalities.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Semiconductor Nanoelectronic Devices/Полупроводниковые наноэлектронные устройства

Purpose of the course:

The aim of the discipline is gaining knowledge about physical principles, technology and modeling of concurrent semiconductor nanoelectronic devices, including those based on new materials - various quantum materials, including graphene, other two-dimensional materials and van der Waals heterostructures. Problems solved in the lecture course can be further adapted for further research activities of students. The course is aimed at development of creative skills of setting promising scientific problems in the field of semiconductor nanoelectronic devices and quantum materials.

Tasks of the course:

-Acquiring knowledge of modern semiconductor devices;

-acquiring knowledge about devices based on low-dimensional electronic systems;

-studying the problems of creating optoelectronic devices in the terahertz range;

-Gaining knowledge about the physics of two-dimensional materials;

-Study the problems of creating electronic, optoelectronic and photonic devices based on two-dimensional materials.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

-basic principles of operation of modern semiconductor devices

-basic approaches to development of modern optoelectronic devices

be able to:

-Calculate the distribution of electrostatic potential and charge carrier density in semiconductor structures

master:

-calculate characteristics of semiconductor structures

-Methods for calculating the characteristics of semiconductor nanoelectronic devices

-the basic methods of solving the equations of electrodynamics and electron transport (Boltzmann equation, diffusion-drift and hydrodynamic equations) as applied to semiconductor devices

-methods for estimating the parameters of charge carriers (energy spectrum, mobility, free path) in low-dimensional systems

Content of the course (training module), structured by topics (sections):

1. Tunnel transistors for low-voltage electronics

The problem of power dissipation in field-effect transistors. "Thermionic limit" of the subthreshold steepness of MOS FET. Tunneling in Schottky barriers and Schottky-barrier FET. Interband tunneling in semiconductors, calculation of the tunneling current for direct and phonon-assisted tunneling. Field-effect transistor with gate-controlled tunnel junction, its ultimate subthreshold slope. Interband tunneling in semiconductors in the presence of electric potential fluctuations. Influence of the channel dimensionality on the tunneling characteristic. Density of states effects in interband tunneling.

2. Field-effect transistors based on phase transitions

Ferroelectric phase transition: phenomenological description within the Landau theory. Features of the transition in hafnium dioxide. Negative differential capacitance and its effect on the switching voltage of MOSFETs. Current state of negative capacitance devices. Metal-insulator phase transition with a change in the electron density. The nature of the "metal-insulator" phase transition in vanadium dioxide.

3. Transistors with high electron mobility based on 2d electrons in III-V compounds

Methods for localization of electrons in two dimensions: quantum wells and heterointerfaces. Doping of two-dimensional systems, remote doping. High electron mobility transistor (HEMT) schematic and band diagram. Calculation of electron mobility limited by scattering by distant impurities. Distributed capacitance and inductance effects in high frequency transistors. Cutoff frequency and maximum oscillation frequency.

4. Resonant tunneling devices

Tunneling transport in two-barrier heterostructures, calculation of tunneling transparency and current-voltage characteristic of a resonant tunneling diode (RTD). Negative differential resistance and its applications for high-frequency generation. Excess current mechanisms in resonant tunneling diodes.

5. Graphene and its applications in analog and digital electronics

Effective Hamiltonian and energy spectrum of charge carriers in single- and bi-layer graphene. Influence of charge carrier chirality on transport properties: suppression of backscattering and strong interband tunneling. The problem of the minimum conductivity of graphene, the effect of

potential fluctuations on the concentration of charge carriers and conductivity. Limiting factors for electron mobility in graphene: scattering by impurities, optical and acoustic phonons, grain boundaries, and local lattice stresses. Features of charge carrier scattering in suspended and encapsulated graphene. Field effect in graphene and characteristics of a graphene transistor, ambipolar transport. Maximum switching frequency and off-state current problem. Current saturation mechanisms in graphene field-effect transistors.

6. Derivatives of graphene and their applications in electronics

Graphene-based structures with a finite band gap: bilayer graphene and nanoribbons. Relation between the band gap and the transverse field (bilayer graphene) and the nanoribbon width. Resolution of the off-state current problem in transistors based on graphene derivatives. Edge effects in transistors based on bilayer graphene and nanoribbons: current flow through edge channels and electron scattering at edges. Features of tunnel transport in bilayer graphene.

7. Electronic transport in one-dimensional systems

Calculation of coherent electron transport in a one-dimensional system: calculation of the electron density matrix in the channel upon maintaining constant states' filling in the leads. Level broadening effects caused by the presence of leads (concept of self-energy). Derivation of Landauer formula for conductance.

8. Field-effect transistors based on one-dimensional systems

Electronic spectrum and transport of charge carriers in graphene nanoribbons and nanotubes. Relation between geometric chirality of nanotubes and their band structure. Semiconductor and metal nanotubes. Relationship between the edge structure of nanoribbons and the energy spectrum of charge carriers. Ballistic conductivity of one-dimensional systems. Landauer formula and its application for characteristics of a ballistic FET with 1d channel. Interaction of charge carriers in 1d systems and its manifestations in transport.

9. Optical transitions in semiconductors: general theory

K-p Hamiltonian for bulk semiconductors. Matrix element of electron interaction with an electromagnetic wave. Interband and intraband transitions, their symmetry and conservation-law constraints. Density of states effects in optical absorption spectra. Light absorption by two-dimensional systems. Universal optical conductivity of graphene.

10. Semiconductor lasers

Lasing condition in semiconductors in terms of quasi-Fermi levels. Methods for creating interband population inversion. Laser based on a heavily doped p-n-junction. Heterostructure-based laser: effects of super-injection, optical confinement and carrier confinement. Quantum well lasers, their gain spectra, comparison with heterostructure lasers. Quantum cascade lasers and their principle of operation. The problem of terahertz lasing.

11. Semiconductor photodetectors

Main figures of merit for photodetectors: responsivity, noise equivalent power (NEP), detectivity. A "classical" photodetector based on p-n-junction. Principle of operation, calculation of voltage and current responsivity. Influence of recombination on the characteristics of p-n-junction based detector. Factors limiting the NEP: dark current and p-n junction noise. Thermal (Johnson-Nyquist) and generation-recombination noise. Problems for detection of far infrared radiation.

12. Photodetectors based on two-dimensional materials

Photoresponse mechanisms in graphene: photovoltaic, thermoelectric, bolometric, resistive mixing. Dependences of the current generated by these mechanisms on the charge carrier density, temperature, radiation polarization. Response time of graphene-based photodetectors and its limiting factors. Characteristics of a graphene-based thermoelectric photodetector with induced p-n junctions. Photo-gating effect in two-dimensional systems, origins of photoinduced charge. Formation time of photo-induced charge. Origins of anomalously high current responsivity of detectors based on two-dimensional transition metal chalcogenides.

Annotation

Major: 12.04.03 Фотоника и оптоинформатика

specialization: Photonics, Quantum Technologies & 2D Materials/Фотоника, квантовые технологии и двумерные материалы

Solid-State Quantum Computing/Твердотельные квантовые вычисления

Purpose of the course:

To introduce students to one of the main directions of the development of quantum technologies – quantum computing, in particular, solid-state quantum computing.

Tasks of the course:

teach students to navigate the basic physical platforms and algorithms for processing and transmitting quantum information.

List of the planned results of the course (training module)

As a result of studying the course the student should

know:

the basic concept of quantum information processing;

experimental implementations of qubits;

existing solid-state quantum platforms;

theoretical proposals for as yet unexplored types of qubits, using, for example, electrons on the surface of superfluid helium, impurity spins in fullerenes, and others;

realizations of superconducting quantum circuits.

be able to:

solve a broad spectrum of problems related to physical foundations of solid-state quantum computing.

master:

approaches to create the simplest one- or two-qubit schemes, such as semiconductor quantum dots, diamond vacancies, solid-state impurity spins, and other quantum two-level systems;

basic principles of functioning of various types of superconducting qubits, decoherence mechanisms, and strategies for increasing the coherence of superconducting qubits.

Content of the course (training module), structured by topics (sections):

1. Introduction: Basics of quantum computing

A general introduction to quantum computing. Physical limitations of existing classical computing platforms.

2. Microscopic qubits

Microscopic qubits: Atoms, Ions, Photons.

3. Condensed matter qubits

Solid-state qubits: semiconductor quantum dots, impurity spins, NV centers, impurity spins in fullerenes, electrons on the surface of liquid helium. The simplest one-or two-qubit schemes.

4. Superconductivity and Josephson junctions

The main focus of the course will be on superconductors. Therefore, we will devote a separate lecture to the basics of superconductivity and Josephson transitions..

5. Phase and flux qubits

With this lecture, we will begin to discuss superconducting quantum circuits in detail. Such schemes are currently used in existing quantum computers. In this lecture, we will discuss phase and flow qubits.

6. Charge qubit

The first type of superconducting qubit experimentally demonstrated in 1999 was charge qubits. We will discuss these pioneering experiments and talk about the problem of charge noise limiting the coherence time of such qubits.

7. Qubit readout and circuit QED

Quantum electrodynamics of circuits (circuit QED), the Janes-Cummings model, and qubit readout.

8. Transmon qubit

Transmons are currently the most widely used superconducting qubits in quantum processors. We will discuss the advantages of transmons, as well as their limitations and disadvantages.

9. Fluxonium, superinductance, g-flux qubit

The fluxonium is the result of the evolution of the streaming qubit and opens up new perspectives for the construction of quantum circuits. The most important element in such schemes is superinductivity, the properties of which we will discuss.

10. Qubit manipulation and gates

In this lecture, we will talk about manipulating the quantum states of qubits, about one- and two-qubit gates, and about tools for controlling the interaction between qubits.

11. Decoherence, two-level defects

We will talk about the sources of losses and the causes of dephasing of qubits, various decoherence mechanisms, and strategies for increasing the coherence of superconducting qubits.

12. Qubit readout electronics

Manipulating superconducting qubits requires the generation of short microwave pulses with precisely specified amplitude and phase. Qubit measurement involves amplifying weak microwave signals using parametric and low-noise cryogenic amplifiers. We will discuss the details of how practical schemes work.

13. Quantum processors, simulators, error correction

Quantum processors are divided into devices for executing universal quantum protocols and quantum simulators. We will discuss the advantages and practical limitations of different approaches. The second part of the lecture will be devoted to practical methods of error correction in quantum computing.