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Abstracts of the 17th International Conference AMPL-2025. Digest contains the materials on the fundamental and applied problems of pulsed lasers. May be interesting for researches and engineers working in the sphere of quantum electronics, spectroscopy, plasma physics, medicine, remote sensing and laser technologies.

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AI-1

EFFECT OF $Yb:Y_2O_3$ + 5 mol% ZrO_2 NANOPOWDER DECANTATION IN ETHYL ALCOHOL ON THE OPTICAL QUALITY OF THE CERAMICS SYNTHESIZED FROM IT

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The drying conditions (in vacuum and in air) for sedimented in ethanol $Yb:Y_2O_3$ + 5 mol.% ZrO_2 nanoparticles have an impact on the optical quality of ceramic samples made from them, as it has been investigated. The studies were conducted using methods of absorption spectroscopy, both in the 200–1100 nm and the mid-infrared regions, and Raman scattering. It has been shown that, regardless of the drying process for nanopowders, carbonate radicals as well as fragments of ethanol and water are produced in the ceramics, leading to the formation of complex crystalline defects that contain divalent ytterbium ions. Due to these defects, the transparency of the ceramics decreases and the photoluminescence of trivalent ytterbium is excited by laser radiation with a wavelength of 785 nm. The most significant negative effect of these defects on transparency was observed in ceramics made from nanopowders that were dried in a vacuum.

The research was carried out at the expense of a grant from the Russian Science Foundation N 24-19-20074, https://rscf.ru/project/24-19-20074/, with financial support from the Government of the Sverdlovsk region.

AI-2

RADIATION CHARACTERISTICS INVESTIGATION OF A PULSED INDUCTIVE NEON LASER WITH WAVELENGTHS OF 594.4 AND 614.3 nm

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The experimental studies results of the spectral, temporal, spatial and energy characteristics of neon atoms radiation pumped by a pulsed inductive cylindrical discharge are presented. Laser generation was obtained on the $3p \rightarrow 3s$ transitions of neutral neon atoms at wavelengths of 594.4 nm and 614.3 nm. The intensity ratio between the two lines depended on the neon pressure and varied from $I_{594}:I_{614}$ = (2…3):1 at pressures of 0.2–0.3 Torr to the ratio $I_{594}:I_{614}$ = 1:(3…4) at the optimal neon pressure of close to 0.1 Torr. The maximum generation energy value of 17 μJ was obtained at a charging voltage of 29 kV (limited by the maximum characteristics of the excitation system). Reducing the voltage to below 20 kV resulted in breakdown of laser generation. Studies of the temporal characteristics of radiation showed that laser generation at both wavelengths started

simultaneously, while identical pulse durations reaching an average value of 17 ns (FWHM), corresponding to a peak pulse power of approximately 1 kW.

At a distance of 1 m from the output mirror, the beam shape formed a ring with an outer diameter of 16 mm and a width of 2.2 mm. At a distance of 3 m, the ring-shaped beam persisted, while the outer diameter and ring width increasing to 23.5 and 7.3 mm, respectively. The evaluations carried out showed that the beam divergence reached a value of 1.5 mrad. The intensity distribution in the cross section of the laser beam was non-uniform and had a characteristic «spindle-shaped granular structure». This structure had previously been observed by us in an inductive nitrogen laser (wavelength 337.1 nm) as well as in an inductive neon laser (wavelength 540.1 nm). Such phenomena are commonly observed in lasers operating in the amplified spontaneous emission regime.

Stable operation of the inductive neon laser in a pulsed-periodic mode was maintained at both wavelengths (594.4 nm and 614.3 nm) up to a pulse repetition frequency of 50 Hz. These energy and temporal characteristics make the laser suitable for use in ophthalmology for micro-pulse irradiation of biological tissues.

The study was carried out within the framework of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (topic N 121033100059-5).

AI-3

THE LIMITS OF APPLICABILITY OF THE MARX GENERATOR FOR PUMPING THE ACTIVE MEDIUM OF METAL VAPOR LASERS

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The Marx generator, whose principle of operation is based on electric charging of parallel-connected capacitors, which, after charging, are connected in series using various switching devices such as thyratrons, significantly expands the possibilities for optimizing the parameters of pumping metal vapor lasers.

The report presents the results of a study of the energy characteristics of a copper vapor laser pumped by a Marx generator. The main reasons determining the limits of applicability of the Marx generator for pumping the active medium of metal vapor lasers are considered.

AI-4

MOLECULAR-CRYSTALLINE SOURCES OF NARROWBAND TERAHERTZ RADIATION WITH SPECTRAL CONTROL

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Previously, our group demonstrated the possibility of creating a coherent high-quality source of narrowband terahertz radiation based on a molecular crystal of guanylurea hydrogen phosphite (GUHP), for which spectrally limited femtosecond pulses of near-IR laser radiation were used as pumping radiation. The generation mechanism was described by the use of nonlinear optical processes of the second order due to the presence of simultaneous Raman and IR activity of phonon vibrations in the molecular crystal lattice and the corresponding predominance of nonlinearity enhancement in the spectral region of resonances over dissipative absorption processes.

In the subsequent series of works our group for the first time realized generation of narrowband terahertz radiation in molecular crystals of phthalic acid salts ($C_6H_4COOH\ COOM$, M=Na,K,Rb): NaAP, KAP, RbAP. For the rubidium biphthalate crystal RbAP, a record spectral generation line's width of 2.4 GHz at a central frequency of 1.55 THz was achieved. In terms of power and spectral parameters, the studied sources are comparable with THz quantum cascade lasers.

The resulting series of narrowband sources have several generation lines in the range of 0.2-3.6 THz. In this regard, it was suggested to use a surface metamaterial as a terahertz radiation filter to isolate individual narrow spectral emission lines from those observed in the overall generation spectrum. This approach is also promising due to the possibility of controlling the transmission of such filters by changing their parameters using external excitation.

AI-5

INFLUENCE OF THE LASER-INDUCED GRAPHENE SYNTHESIS CONDITIONS ON THE PHOTOCURRENT UNDER PULSED LASER EXCITATION

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Laser-induced graphene (LIG) is a highly porous electrically conductive carbon material obtained by laser pyrolysis of a carbon-containing precursor. Due to its good electrical conductivity, it is a promising material for use in various fields of modern electronics, power engineering and medical instrumentation.

In this work, we present the results of the study of LIG film samples synthesized on the surface of a polyimide film using a cw CO_2-laser. We have found that in such films, the generation of nanosecond photocurrent pulses is observed when their surface is irradiated with pulsed laser radiation of nanosecond duration. It has been established that the polarity of photocurrent pulses depends on the direction of the exciting radiation wave vector. It was also shown that the efficiency of photocurrent generation is affected by the synthesis conditions: power of the CO_2-laser, the laser beam velocity, the distance between the lines and the direction of the laser beam movement across the surface of the polyimide film. The identified features of the photoreponse of LIG film structures allow them to be used as high-speed laser pulse energy meter, orientation sensors, tracking devices, and various angle-measuring devices. The report discusses these and other features of the discovered effect.

The study was carried out with the support of the Ministry of Science and Higher Education of the Russian Federation (N 1022040600237-3-1.3.2).

AI-6

CARBON DOTS AS LUMINESCENT NANOSENSORS IN THE TASKS OF DETERMINING THE COMPOSITION OF MULTICOMPONENT LIQUID MEDIA

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Carbon dots (CD) are a class of carbon nanomaterials, an important distinctive feature of which is stable intense photoluminescence sensitive to environmental parameters (pH, temperature, presence of various ions, etc.). This property opens up prospects for using CD in various sensorics tasks, which, in turn, is reflected in the emergence of hundreds of patents for the creation of a CD-based nanosensor over the past five years. In the vast majority of works, CD-based nanosensors are developed to determine a single target parameter (for example, the concentration of only one ion). However, in practice, such single-component solutions are rare. More popular are methods that allow simultaneous determination of the concentrations of several components.

This work presents the results of solving the inverse problem of luminescence spectroscopy: the qualitative and quantitative composition of the sample was determined using the excitation-emission matrices of CD photoluminescence in aqueous solutions in the presence of several ions (up to seven) using machine learning methods. CD synthesized by the hydrothermal method from citric acid and ethylenediamine (precursor ratio 1:2, synthesis time – 3 hours, temperature – 200 °C) were used. The concentrations of each of the ions Cu^{2+}, Ni^{2+}, Pb^{2+}, Co^{2+}, Al^{3+}, Cr^{3+}, NO_3^- were determined with an accuracy of, on average, 1 mM. The developed nanosensor based on carbon dots with the help of neural networks opens up broad prospects for application in ecology, technological processes and biomedicine.

The study was supported by the grant of the Russian Science Foundation N 22-12-00138-P, https://rscf.ru/en/project/22-12-00138/.

AI-7

PROBLEMS AND PROSPECTS OF OBTAINING LASER GENERATION AT NV-CENTERS IN DIAMOND

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Due to its unique properties, diamond has been increasingly considered in recent decades as a material for creating electronic and photonic devices. In particular, it has very high thermal conductivity and a low thermal expansion coefficient, which makes it a promising material for the manufacture of active elements of solid-state lasers.

Diamond is an indirect-gap material, which makes it possible to create light-emitting devices using local energy levels created inside the bandgap by impurity-defect centers.

One of these centers is the nitrogen-vacancy center (NV-center). In a negative charge state, when pumped with radiation in the range of 450–637 nm, it exhibits luminescence in the range of 637–850 nm.

In 2021, laser generation on NV-centers in diamond was obtained for the first time. This report provides an overview of the current state of affairs in this area: the achieved pulse energy, temporal and spectral characteristics of lasers on NV-centers, existing problems and possible solutions. The steps required for practical application of this type of laser are discussed.

This research was supported by RSF, project № 25-29-00702.

AI-8

CALCULATING ENERGY SPECTRUM OF NeII IN A TERAHERTZ LASER FIELD

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When atomic gases are excited by laser fields, the ionization process of atoms begins fast enough. The influence of laser fields leads to splitting of ion spectral lines into the Stark components and their shifting. The position of the Stark components considerably depends on the electric field frequency and strength. Positions of many spectral lines of atoms and ions in the absence of electric fields can be found in NIST database. However, databases of the energy spectra of atoms and ions in alternating electric fields do not exist.

Calculating the energy spectra of rare gas ions in alternating electric fields is a topical problem for two reasons. First, rare gases are widely used in plasma physics both in pure form and as buffer gases. Second, lasers emitting in the terahertz frequency range have wide practical applications, so exactly this range is chosen to study excitation of the ion spectrum by a laser field.

This paper presents the results of calculating the dynamic Stark effect for ion NeII excited by a circularly polarized electric field of the HCN laser with a frequency of 2.43 THz. To study of the behavior of the ion energy levels in the electric field, the theoretical approach based on numerical solution of the non-stationary Schrцdinger equation is used. The numerical solution is performed in the basis of unperturbed wave functions of NeII. The total energies of the unperturbed ion NeII needed in such calculations are partly presented in NIST database. Unfortunately, these data are not sufficient to solve the Schrцdinger equation correctly. In this work, the missing total energies of singly ionized neon have been calculated in the formalism of irreducible tensor operators with the simplified spin-orbit interaction operator.

The results obtained are of interest both from a theoretical point of view and for practical applications of the calculation results. These results allow one to reveal regularities in the behavior of the ion spectral lines, as well as to identify correctly the ion energy spectrum in the laser field. In addition, the computation data can be useful for plasma diagnostics and in searching transitions to create new lasers.

AI-9

MODELING OF SPATIO-TEMPORAL CHARACTERISTICS OF ACTIVE MEDIA OF RECOMBINATION METAL VAPOR LASERS

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Ion recombination lasers on strontium and calcium vapor are effective sources of visible and UV radiation ($\lambda = 430.5$ and 416.2 nm SrII; $\lambda = 373.7$ and 370.6 nm CaII). The presence of inhomogeneities of gas-discharge plasma can limit the energy characteristics of recombination lasers. In the present work, using a self-consistent mathematical model, we numerically studied the spatio-temporal evolution of plasma parameters, and calculated the energy characteristics of radiation for a strontium vapor laser under optimal excitation conditions found by us experimentally. Analysis of the modeling results showed that the ratios of the working mixture components necessary to achieve high plasma homogeneity are close to the ratios that ensure the maximum recombination pumping rate. The results obtained in the work allow us to predict the optimal excitation conditions for active media of recombination lasers.

AI-10

NUMERICAL OPTIMIZATION OF THE CHARACTERISTICS OF A LASER ON SELF-TERMINATING TRANSITIONS OF SRII

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A distinctive feature of the ion strontium vapor laser is the ability to efficiently implement two different pumping mechanisms: recombination (in the violet spectrum region at $\lambda = 430.5$ and 416.2 nm SrII) and ionization (in the infrared spectrum region at $\lambda = 1033$ and 1091 nm SrII). The recombination mechanism is implemented in the plasma of a pulse-periodic discharge during the early afterglow, and the ionization mechanism is implemented at the leading edge of the discharge current pulse. In this paper, a numerical multiparameter optimization of the laser characteristics on self-terminating IR transitions of strontium ions ($l = 1033$ and 1091 nm SrII) was performed. In particular, the dependence of the plasma parameters, as well as the time and energy characteristics of the radiation on the excitation conditions of the active medium was investigated. The simulation results show that there is a fairly wide range of excitation conditions under which sufficiently high generation characteristics are achieved. The results obtained in the work make it possible to predict the optimal conditions for the excitation of active media of strontium vapor lasers, including those necessary for the implementation of a multi-wave radiation mode with simultaneous generation on visible and IR transitions of the strontium ion.

AI-11

OPTICAL PROPERTIES OF ALEXANDRITE CRYSTAL NEAR THE GENERATION THRESHOLD

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The paper presents the results of experimental studies of a vibronic narrow-band tunable laser on an alexandrite crystal with lamp pumping near the lasing threshold. An alexandrite crystal – $BeAl_2O_4$+Cr^{3+}, with a rod length of 100 mm and a diameter of 6 mm, was used as an active medium. The concentration of Cr^{3+} was ~ 0.12 at.%.

This crystal has anisotropy and, therefore, a strong dependence of polarization on the spectral composition of absorption and emission. When forming narrow-band radiation, a composite resonator was used, providing additional polarization filtration. In this case, when the laser was operating in the Q-modulation mode, the presence of a film polarizer in the resonator did not play a significant role in the implementation of short-pulse radiation. The formation of the divergence of the output radiation was ensured by installing either a telescope or a small-aperture diaphragm in the resonator.

The work was supported by the Development Program of Tomsk State University (Priority-2030) and within the framework of the state task of the FNI SB RAS (N FWRM-2021-0014).

AI-12

PULSED INDUCTIVE LASER ON KRYPTON NEUTRAL ATOMS TRANSITIONS IN THE IR SPECTRAL RANGE

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This paper reports on the development of an infrared (IR) krypton laser pumped by a pulsed inductive discharge. The well-known LC-inverter circuit was used as the high-voltage electrical pumping system. A glass tube with a length of 750 mm and an inner diameter of 7 mm was used as the inductive emitter. The tube was hermetically sealed using flat-parallel plates mounted in alignment nodes. A dense aluminum mirror and a quartz glass plate with a reflectivity of R ~ 10% formed the optical cavity.

Experimental investigations were carried out to study the spectral, temporal, and spatial characteristics of the radiation of krypton active medium pumped by a pulsed inductive discharge. Lasing regime was achieved at wavelengths of 810, 1442, 1476, and 2525 nm, corresponding to transitions of neutral krypton atoms. The maximum intensity of all spectral components was observed at optimal pressures around 1 Torr. The duration of the radiation pulses was 5…7 ns (FWHM). In the cross section, the laser beam exhibited an oval shape with major and minor axis diameters of 6 ± 0.2 and 5.2 ± 0.2 mm, respectively. The output energy did not exceed 3 μJ, corresponding to a peak pulse power of up to 600 W.

The obtained results confirm the potential of inductive discharge using for the creation of compact laser systems based on an inert gas krypton active medium, with possible applications in medicine, particularly in low-level laser therapy.

The study was carried out within the framework of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (topic N 121033100059-5).

AI-13

THE NATURE OF ELECTRON BEAM INDUCED COLOR CENTERS IN TRANSPARENT $Yb:Y_2O_3$ CERAMICS

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Irradiation of transparent colorless ceramics $Yb:Y_2O_3$ + 5 mol.% of ZrO_2, intended for active laser elements, by nanosecond (2 ns) electron beams with an average energy of 170 keV causes it to turn pink. The intensity of staining increases with the number of irradiation pulses. At the same time, an absorption band appears and increases in the transmission spectra of ceramics at 490 nm. The color center spontaneously disintegrates after irradiation with a time constant of about 50 hours. Its effect on the lifetime of the upper laser level of ytterbium has not been detected.

The research was carried out at the expense of a grant from the Russian Science Foundation N 24-19-20074, https://rscf.ru/project/24-19-20074/, with financial support from the Government of the Sverdlovsk region.

AI-14

MEASUREMENT OF THE DYNAMICS OF THE EMISSION OF Yb^{3+} UPPER LASER LEVEL IN OPTICAL CERAMICS OF DIFFERENT THICKNESSES BASED ON Y_2O_3

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The report presents the results of experimental and theoretical studies the of radiation attenuation kinetics of the Yb^{3+} ion laser transition in a matrix of ceramic Y_2O_3 samples of various thicknesses. The purpose of such studies was to determine the true lifetime of the upper laser level of the Yb^{3+} ion, that is, to get rid of the influence of the well-known “radiation trapping” effect. Ceramic samples were made from a synthesized nanopowder of yttrium oxide doped with ytterbium. We have presented the sample manufacturing technology at previous conferences. The experimental setup included a semiconductor laser diode at a wavelength of 970 nm, the radiation of which was directed to the sample area. To ensure smooth adjustment of the thickness, a sample with a wedge-shaped edge with a length of 4.44 mm was made. The Yb^{3+} radiation was recorded by a photodetector, the signal from which was transmitted via an amplifier to an AKIP-4115/1A digital storage oscilloscope. The saturation effect of the increase in photoluminescence attenuation time has been experimentally detected depending on the thickness. For a sample of 5% $Yb:Y_2O_3$ with the addition of ZrO_2, this thickness was 1180 microns. To explain this effect, a mathematical model based on the Biberman-Holstein integro-differential equation, solved numerically, was developed. The calculation results are in good agreement with the experimental data.

The work was carried out with the support of the Russian Science Foundation and the Government of the Sverdlovsk region (grant N 24-19-20074).

AI-15

STUDY OF THE EMISSION KINETICS OF Yb^{3+} ION IN OPTICAL CERAMICS FROM YTTRIUM OXIDE

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The paper presents theoretical and experimental studies of the kinetics of decay of radiation on the laser transition of the Yb^{3+} ion in the matrix of ceramic samples made of yttrium oxide. The ceramic samples were made of yttrium oxide nanopowder doped with ytterbium that we synthesized. We presented the technology of sample fabrication at previous conferences. The experimental setup contained a semiconductor laser diode at a wavelength of 970 nm, the radiation of which was directed to a section of the sample. The radiation of Yb^{3+} was received by a photodiode FD-24K, the signal from which was given through an amplifier to a storage digital oscilloscope AKIP-4115/1A. The radiation power of the semiconductor laser was regulated using an LDD-10 power source. To analyze the results obtained, a kinetic model was developed and implemented in the MathCad software environment. The calculation results showed that in the ceramic sample there is a source of pumping of the upper level of Yb^{3+}, presumably in the form of defects with a nearby lower energy level. Without it, it is impossible to explain the longer "tail" of the oscillograms than follows from a purely exponential decay. During pumping, the levels of these defects are saturated with energy, and after the pumping stops, they give it to ytterbium ion, transferring it to the upper level of . At the same time, the energy exchange is quite weak and, most likely, will have an insignificant effect on the energy of the laser radiation of the samples.

The work was carried out with the support of the Russian Science Foundation and the Government of the Sverdlovsk region (grant N 24-19-20074).

AI-16

STUDY OF RADIATION CHARACTERISTICS OF UV INDUCTIVE N_2 LASER IN MIXTURES OF NITROGEN WITH HYDROCARBONS

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The report presents the results of experimental studies of the effect of hydrocarbon additives (propylene C_3H_6 and methane CH_4) on the energy, temporal and spectral characteristics of the radiation of a UV nitrogen laser pumped by a pulsed inductive cylindrical discharge. A chemically unprepared ceramic tube with an active length of 630 mm with external and internal diameters equal to 50 and 42 mm, respectively, was used as an inductive laser emitter. An inductor consisting of a set of solenoids connected in parallel was placed on it. Laser generation was obtained on the transitions (0–0) and (0–1) $C^3\Pi_u \rightarrow B^3\Pi_g$ of the second positive system of nitrogen molecule bands with wavelengths of 337.1 and 357.7 nm, respectively, with an intensity ratio of 100:1. The radiation energy in pure nitrogen reached 1.8 mJ, with a radiation pulse duration of 18 ± 1 ns (FWHM), which corresponds to a pulse power of 100 kW. The use of gaseous hydrocarbons (propylene and methane) as additives to nitrogen in concentrations of less than 2% did not lead to a significant change in the generation energy, the duration of optical radiation pulses and the spectral structure. An increase in the additive concentration above 2% led to a visually observable deterioration in discharge combustion and a decrease in the radiation energy (the duration and spectrum of generation did not undergo noticeable changes). When operating an inductive nitrogen laser in a pulsed-periodic mode, the use of propylene as an additive (at a concentration of 2%) allowed the operating time per filling to be increased by more than two times.

The report discusses various mechanisms of the influence of hydrocarbons on the energy characteristics of the radiation of an inductive UV nitrogen laser.

The study was carried out within the framework of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (topic N 121033100059-5).

AI-17

METAL ATOMIC TRANSITION-BASED MEDIA FOR SIGNAL GENERATION IN THE VISIBLE AND NEAR-INFRARED SPECTRAL RANGES

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The development of methods for imaging of fast transient processes hidden by background radiation using narrowband laser amplification is closely tied to the design and optimization of signal (images) amplifiers. Among the most widely used gain media for these applications are those based on copper atom transitions. Their popularity is attributed to the favorable spectral range of operation, advantageous spectral and energetic characteristics, and the relatively simple construction of active elements using copper halide vapors (CuBr, CuCl).

It is noteworthy that brightness amplifiers based on copper atom transitions have enabled record-setting performance in laser imaging systems, including filtering efficiency, spatial resolution, and temporal resolution of imaging. With the rapid advancement of imaging technologies in the near-infrared (NIR) spectral range – driven primarily by progress in short-wave infrared (SWIR) cameras – the development of brightness amplifiers capable of generating and amplifying signals and images at wavelengths up to 2 μm becomes increasingly important.

In this context, media based on self-terminating transitions of manganese, barium, and europium atoms are considered promising ones. Their selection is based both on the presence of suitable emission lines and the anticipated spectral, energetic, and amplification properties.

Active elements (gas discharge tubes) were fabricated using manganese bromide and chloride vapors (with an active zone diameter of 2 cm), barium (1.5 cm), and europium (2 cm). Using conventional thyratron-based excitation systems, high output power levels were achieved in generator mode with a plane-parallel resonator: 5 W for europium vapor radiation at 1.76 μm, for barium at 1.13 and 1.5 μm, and for manganese at both visible (534.1, 542, 547.1, 551.7, 553.8 nm) and near-infrared wavelengths (1.289, 1.329, 1.332, 1.362, 1.386, 1.399 μm).

Amplification studies confirmed the potential of these media for use as brightness amplifiers in laser monitoring systems. They demonstrated high single-pass gain, ASE power and the capability to form images in monostatic laser monitors.

AI-18

INVESTIGATION OF THE PROCESS OF SERS RADIATION WITH λ = 355 nm IN BARIUM VAPOR

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In the presented work, barium vapors were irradiated with radiation with λ_P = 355 nm. Such radiation with a pulse duration of about 10 ns and an energy of 18 mJ was generated by a solid-state YAG:Nd^{+3} laser LS-2147. The pump spectrum of this laser is represented by only one line with a fixed wavelength value, unlike excimer lasers.

The experiment was conducted to study the energy characteristics of the SERS process involving the initial Ba($6s6s^1S_0$) intermediate Ba($5d6p^1P^0{}_1$) and final Ba($6s5d^1D_2$) levels of the barium atom. The detuning of the pump quantum energy from the excitation energy of the Ba($5d6p^1P^0{}_1$) was Δ = 362 cm^{-1}. The pumping photon energy magnitude (λ_P = 355 nm) and the barium excitation energy Ba($6s5d^1D_2$) level in this case determine the wavelength of the SERS as λ_{SERS} = 595.4 nm.

The next goal was to establish the presence in the spectrum of the transformed radiation of the ASE lines belonging to the barium atom and ion. The paper considers a possible scheme for creating an inversion at barium atom transitions when pumped with radiation with λ_P = 355 nm. This scheme involves the generation of a number of possible IR transitions in a barium atom.

SERS in barium vapor at a pulsed pump energy of 18 mJ (λ_P = 355 nm), excluding losses on optical elements, had a maximum pulsed energy of 5.6 mJ. Which corresponds to the value of efficiency n = 32%. At the same time, the efficiency of the EUCR process in terms of the photons number was n_{PHOT} = 53%.

A study of the spectrum of converted radiation in the visible and IR (up to 3500 nm) regions has shown that, in addition to the EUCR line with EUCR = 595.4 nm, it does not contain any other forced lines.

The absence of a barium resonance line with λ = 553.6 nm in the spectrum of the transformed radiation indicates that the line with a similar wavelength that we observed when irradiating samarium vapor is generated as a result of the interaction of pumping (λ_P = 355 nm) with samarium vapor.

The results of optical pumping of barium vapor YAG:Nd^{+3} laser LS-2147 $\lambda_P = 355$ nm are compared with the results obtained by other authors when exciting barium vapor with excimer lasers and a picoseconds laser on phosphate glass.

AI-19

INVESTIGATION OF THE SPECTRUM OF TRANSFORMED RADIATION OBSERVED DURING OPTICAL PUMPING OF A MIXTURE OF SAMARIUM AND HELIUM VAPORS BY UV RADIATION WITH λ = 355 nm

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The paper presents an optical pumping of a mixture of samarium and helium vapors by total frequency radiation at a wavelength of λ = 355 nm of an LS-2147 solid-state laser. In this case, the pump radiation spectrum is represented by one rather narrow line. According to the LS-2147 datasheet, the pump radiation has a linear vertical polarization.

As the cuvette was heated at a temperature of 840 °C, stimulated radiation at a wavelength of λ = 593.6 nm was the first to appear. A further increase in cell temperature was accompanied by the appearance of stimulated radiation at wavelengths λ = 652.8, 618.8, 709.3, 598.6, 553.5 nm. The report presents recordings of the converted radiation spectrum obtained using the Avesta ASP-75m survey spectrometer and the Avesta ASP-150T tunable spectrometer.

Measurements of the total power of all forced lines by the Ophir Vega device showed that at a temperature of 1100 °C and a pulse repetition rate of 10 Hz, it reached a maximum value of 1.2 mW.

During the experiment, the following features of the transformed radiation were discovered:The stimulated radiation of the line with λ = 593.6 nm propagated both in the direction of the pump and against it. While all other observed lines propagated mainly in the direction of the pump radiation; All lines, except of lines with λ = 709.3 and 618.8 nm, had vertical polarization. The lines with λ = 709.3 and 618.8 nm show horizontal polarization.

To identify the observed lines, we used well-known reference literature and relevant Internet resources.

AI-20

PHOTODISSOCIATION LASERS ON THE FIRST RESONANCE TRANSITIONS OF Na($3P^2P^0_{1/2,3/2} \rightarrow 3S^2S_{1/2}$) AND K($4P^2P^0_{1/2,3/2} \rightarrow 4S^2S_{1/2}$) ATOMS

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For a number of practical applications, laser radiation realized in the process of photodissociation of alkali metal halides, i.e. photodissociation lasers, is of undoubted interest. The radiation of these lasers is tied to the resonance spectral lines of metal atoms and, first of all, can be used to analyze a number of metals in gaseous media by the absorption and resonance fluorescence method.

To study the photodissociation method of generating stimulated emission on the first resonance transitions of Na and K atoms, the salts NaJ, NaBr, KJ and KBr were chosen. UV radiation at the sum frequency of the second and third harmonics of the YAG:Nd^{3+} laser with a wavelength of λ = 212.8 nm was used as a pump source.

Analysis of the NaJ salt spectra showed that starting from a cuvette temperature of 450 °C, the pump radiation excited spontaneous emission on the known sodium resonance lines $\lambda_1 = 589.6$ nm and $\lambda_2 = 589.0$ nm. As the cuvette was heated to a temperature of 600 °C, the long-wavelength sodium line with $\lambda_1 = 589.6$ nm switched to the enhanced spontaneous emission (ASE) mode. The spectrum of KBr salt showed that spontaneous emission on potassium resonance transitions with wavelengths λ_1 = 770.0 nm, λ_2 = 766.5 nm appeared at a cuvette temperature of 560 °C. A further increase in the cuvette temperature led to the transition of the short-wavelength component of the potassium resonance doublet with λ_1 = 766.5 nm to the ASE mode. Optical pumping of NaBr and KJ vapors was accompanied only by the appearance of spontaneous emission on resonance lines. In the first case, this is explained by the fact that the pump wavelength λ = 212.8 nm is insufficient to overcome the threshold values. In the second case, the observed spectrum demonstrated the presence of dips due to self-reversal of lines, which is a consequence of the appearance of potassium atoms in the ground state in the active medium.

According to the analysis, the threshold values of pump wavelengths for KBr (λ_P = 223 nm), KJ (λ_P = 250 nm) and NaJ (λ_P = 235 nm) vapors are longer-wavelength than radiation with λ = 212.8 nm. Therefore, there is reason to hope that an excimer laser on the KrCl* molecule (223 nm) can be used to implement PDL on these salts.

AI-21

ENERGY CHARACTERISTICS OF $MnBr_2$ AND $MnCl_2$ LASERS

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Recently, laser monitors based on image brightness amplifiers have been actively used for visualization of fast processes screened by background illumination. This is mainly carried out in the visible spectrum range by using an active medium of the copper atom transitions. Along with this, the IR region of the spectrum is also of interest. For solving these problems, the manganese atom medium is also interest. Generation on self-limited transitions of this element is realized at several wavelengths in the visible (534.1–553.8 nm) and near IR regions of the spectrum (1.29–1.40 μm).

The issue of increasing the energy characteristics of manganese halide vapor lasers by optimizing excitation conditions and selecting a manganese salt remains relevant. In this paper, a comparative study of the characteristics of $MnBr_2$ and $MnCl_2$ lasers with an active zone volume of 157 cm^3, associated with obtaining high output parameters, is carried out.

The results showed that under the same excitation conditions they demonstrate identical characteristics with the buffer gases helium and neon. The optimal pressure of the buffer gas (He, Ne) is 15–20 Torr, the operating range of pulse repetition rates is 14–17 kHz and the wall temperature of the gas discharge tube is ~ 780 °C. A linear increase in the output power was established with an increase in the pump power to 2 kW. A positive effect of hydrogen halide impurities (HBr, HCl) with a pressure of 0.1–0.15 Torr to the buffer gas on the energy characteristics of these lasers was shown. The maximum radiation power of 5 W was realized at a pump power of 2 kW and a repetition rate of 14 kHz. The specific generation power of 32 mW/cm^3 is a record value for manganese halide vapor lasers.

Taking into account the obtained results and the fact that the gain of these media is about 0.2 cm^{-1}, it can be concluded that manganese halide lasers can be used in high-speed laser monitors in the visible and IR spectral ranges.

AI-22

SPECTRAL AND TEMPORAL CHARACTERISTICS OF THE PULSE METAL VAPOR LASERS PUMPED IN BINARY BUFFER GAS

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A number of applications require laser sources emitting at multiple wavelengths in the required spectral bands. Suitable for this purpose are ion metal vapor lasers, with pumping of laser transitions in the plasma of pulsed or stationary hollow cathode discharge by charge transfer (CT) – inelastic collisions of the second kind between buffer gas ions and metal atoms. Previously, we proposed using in such lasers a binary buffer gas, i.e. mixture of helium and neon, each of which pumped a separate group of ion metal laser lines by CT, which led to a larger number of ion laser emission lines. The report summarizes the results of these studies. So, with binary buffer gas, simultaneous pumping occurs by CT the ion laser transitions of following metals at following wavelengths: thallium at 473.8, 498.9, 508, 515.2, 595, 695 and 707 nm Tl^+; copper at 248.6, 259.9, 260, 780 nm Cu^+; silver at 224.3, 408.6, 478.8 and 502.7 nm Ag^+; tellurium at 484.3; 570.8; 593.6 and 635 nm Te^+; arsenic at 455.1; 459.3; 507.8 and 602.5 nm As^+, and gold at 282.2 and 569.6 nm Au^+. The mutual influence of binary buffer gas components on the laser output power on individual lines was studied, as well as on their temporal characteristics.

Session B
DISCHARGES FOR LASERS AND NON-COHERENT RADIATION SOURCES
Session E
NON-COHERENT RADIATION SOURCES

BE-1

NANOSECOND DISCHARGES IN AIR AND DISTILLED WATER IN A SHARPLY INHOMOGENEOUS ELECTRIC FIELD

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This report is dedicated to studies of nanosecond discharges developing in air and distilled water in highly non-uniform electric fields. Such discharges enable the generation of non-equilibrium low-temperature plasma containing various radicals, excited atoms and molecules, as well as ions. Such plasma is of interest for its application in plasma chemistry. Fundamental aspects of electrical breakdown physics in highly non-uniform electric fields are still a subject of ongoing research. These include studies of streamer initiation mechanisms, ionization processes of molecules and atoms under conditions of high electric field strength and high medium density, and the formation and evolution of plasma channels. All this occurs on sub-millimeter and micron spatial scales at picosecond timescales. A detailed study of such processes requires the application of diagnostic methods with high temporal and spatial resolution, in particular, the use of ICCD cameras and streak cameras equipped with a spectrometer. The report will present the results of experimental studies on the dynamics of streamer and plasma channel development, as well as the dynamics of the emission spectra. The emergence and evolution of streamers in air and distilled water will be demonstrated, along with data on their propagation velocities and their dependence on applied voltage and medium properties. Particular emphasis will be placed on the spatial and temporal dynamics of the emission spectra, as well as parameters of plasma.

The studies were performed in the framework of the State Task for IHCE SB RAS, project N WRM-2021-0014.

BE-2

UV CONTINUUM- AND HYDROGEN LINE-EMISSION IN HARD IONIZED, HIGH PRESSURE NEON

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Hard ionized (e.g. electron-beam excitation, pre-ionized discharge), high pressure (> 0.5 bar) neon often show a distinct UV continuum emission in the 200–500 nm spectral range.

The intensity of this continuum clearly scales with neon pressure squared, and thus can directly be attributed to a molecular neon precursor. Tentatively, this continuum had previously been attributed to some so called "third continuum" (ionic molecular continuum) emission.

Concurrently, hydrogen line emission, mostly H-alpha (656.3 nm) and (486.1 nm) can be observed, and is often used for plasma analysis. Furthermore, strong hydrogen Lyman-alpha (121.6 nm) line emission can be observed under similar excitation conditions.

Here it will be shown that no hydrogen line emission and particularly no UV-continuum emission, at all, can be observed in highly purified, hydrogen-free neon. Furthermore, the intensity dependence on hydrogen partial pressure of all structures – the UV-continuum, the hydrogen H-alpha- and H-beta-, as well as the Lyman-alpha line – essentially coincide and show a distinct maximum at about 0.7 Pa, largely independent of the absolute neon base-pressure. It should be noted that the H-alpha line shows a second, relatively broad, intensity maximum at about 5Pa hydrogen partial pressure.

The UV-continuum thus clearly originates from excited hydrogen species, and is here attributed to the $a^3\Sigma_g^+ \rightarrow b^3\Sigma_u^+$ hydrogen excimer transition. Excitation of the upper $a^3\Sigma_g^+$ level is proposed as stemming from neon excimer molecules: While part of the Ne_2^* - energy is sufficient to split hydrogen molecules and excite one of the hydrogen atoms into the $n = 2$ level, leading to successive Lyman-alpha radiation, Ne_2-excimer molecules close to the so called "classical left turning point" lack some of the necessary energy, but would readily excite hydrogen molecules directly from the $X^1\Sigma_g^+$ into the excited $a^3\Sigma_g^+$ state.

BE-3

EFFICIENT LASING IN HIGH PRESSURE NANOSECOND DIFFUSE DISCHARGES FORMED BY RUNAWAY ELECTRONS

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A study of the parameters of stimulated emission of diffuse discharges in gaps with a sharply inhomogeneous electric field, initiated by runaway electrons, was carried out. Efficient lasing was obtained in various spectral ranges from the IR to the VUV region. New operating modes of nitrogen and non-chain HF(DF) lasers based on mixtures of N_2–SF_6 and $H_2(D_2)$–SF_6 have been found, and the maximum lasing efficiency of the above lasers has been achieved. The maximum energy at 337 nm was 4.1 mJ, with the N_2 laser efficiency of up to 0.25%. The maximum lasing energy on HF molecules is as high as ≈ 110 mJ, which corresponds to the limiting internal lasing efficiency of non-chain chemical lasers of ≈ 10%.

It is shown that the duration of radiation pulses and the efficiency of lasing on molecules of fluorides of inert gases XeF*, KrF*, ArF* and the VUV transition of molecular fluorine at 157 nm in diffuse discharges are close to the parameters of laser radiation realized upon pumping by transverse discharges with additional preionization.

New operation modes of H_2 laser were obtained for the first time.

The work was performed within the framework of the State assignment of the HCEI SB RAS, project N FWRM-2021-0014.

BE-4

EXPERIMENTAL STUDY ON THE PROPERTIES OF PLASMA ACTIVATED WATER PREPARED BASED ON BUBBLING-DBD CONFIGURATION AND ITS PERFORMANCE IN THE DECOMPOSITION OF UREA SOLUTION

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Atmospheric pressure low-temperature plasma as a novel advanced oxidation technology, which has received extensive discussion and research. Plasma-activated water (PAW) refers to a highly oxidative aqueous solution generated through the interaction of plasma produced by high voltage gas discharge with water. This water treatment technology has been widely studied for applications in sterilization, wastewater treatment, and biomedical fields. To overcome the limitations of conventional discharge plasma reactors caused by poor gas-liquid phase mass transfer efficiency, this study developed a method combining bubble generation with a coaxial dielectric barrier discharge (DBD) reactor to investigate reactive species in PAW and their concentration evolution. By adjusting the related parameters of bubbles including the hole sizes, number of holes and different gas flow rates, the correlation between bubble characteristics and PAW efficacy was systematically explored. Urea is an important compound, which is used in agriculture, industry and other fields, and also causes certain pollution to the environment. This research validated the pollutant degradation capability of this discharge configuration through bubbling-DBD treatment of urea solutions. An innovative coaxial DBD structure integrated with bubble discharge was designed, powered by a high-frequency AC supply with argon as the working gas. Results revealed that argon discharge still generated reactive nitrogen species due to residual dissolved air in water. The bubble-enhanced discharge configuration significantly improved PAW performance, achieving 17.32, 34.68, and 37.81% increases in H_2O_2, and concentrations respectively after 60 min treatment. The modification of bubble parameters significantly impacts the properties of PAW. Key factors such as bubble quantity, size, and residence time in the liquid phase collectively govern the production efficiency of reactive species. Optimal PAW characteristics were obtained with the hole size of 0.75 mm, the number of 4–8, under 1200 sccm gas flow rate. Under identical treatment durations, lower concentration and smaller volume of urea solutions exhibited enhanced degradation efficiency. The experimental results show that the designed coaxial DBD device can effectively degrade urea, and the degradation efficiency will be improved with the increase of voltage.

BE-5

EXPERIMENTAL MODELING OF THE ”GLOW” AND ”BEADS” REGIONS WHEN FORMING ANALOGS OF RED COLUMNAR SPRITES

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When studying red columnar sprites, discharges in the Earth’s atmosphere at an altitude of 40–100 km above sea level, a number of features in their glow are recorded. In the lower part of the primary ”sprite column”, formed by a positive streamer spreading from the halo region downwards, a dark area appears, followed by bright luminous dots ”beads”. In a number of cases, the glow of the main part of the ”column” intensifies, and negative streamers start upwards from its upper part. Part of the columnar red sprites with the greatest radiation brightness is called ”glow”. At the same time, the color of the ”glow” area in photographs taken from the surface of the Earth, aircraft and satellites does not differ significantly from the glow color of columnar sprites that do not have a ”glow” area and from the color of negative streamers.

In this work, during the formation of plasma diffuse jets (PDJs) in low-pressure air, conditions are realized under which it is possible to obtain glow areas similar to those observed in the ”glow” region, as well as individual bright points. During the initial breakdown due to a positive streamer, the increase in the glow intensity in its trace was obtained due to an additional quasi-stationary discharge. Conditions are established under which an intense ”glow” glow is observed during a single breakdown of air. Analogues of bright glowing points ”beads” in red columnar sprites, during the formation of PDS, were obtained in the pulse-periodic capacitive discharge mode with external electrodes. In this case, the plasma initiating the PDS had no contact with the metal electrodes.

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BE-6

HIGH-FREQUENCY SUBNANOSECOND SLIT-DISCHARGE BASED SWITCHES FOR PUMPING RM-LASERS

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The results of experimental studies on high-voltage switches based on slit discharge (eptrons) and their application for pumping lasers operating on resonance-metastable (RM) transitions of metal atoms and ions are presented. The key features of the investigated switches include ultrafast switching (< 1 ns) and short dielectric recovery time (< 10 μs), enabling efficient generation of excitation pulses for RM-lasers pumping at high repetition frequencies *f*, while minimizing the adverse effects of pre-pulse electron density in the laser active medium.

The study examined the effects of slit discharge channel geometry, operating gas composition and pressure (He, Ar, H_2 at 1–20 Torr), and electrical circuit configuration on switch performance. The eptron cathode assembly consisted of a hollow stainless steel cylinder with 2.2 cm inner diameter and 10.2 cm length. A rectangular hole (60 × 6 mm) was milled in the side surface for insertion of various slit structures. Stable operation was demonstrated in burst mode with repetition frequency up to 500 kHz.

For investigating frequency-energy characteristics, gas discharge tubes with copper vapor and mercury vapor were used. The copper vapor tube had 2 cm diameter and 50 cm electrode spacing, while the mercury vapor tube measured 0.8 cm in diameter with 30 cm electrode spacing. For the copper vapor laser (510.5 and 578.2 nm), increased average output power was observed when pumped by pulse trains at repetition rates above 40 kHz, with significant dependence on pump pulse polarity. The mercury vapor laser (398.4 nm) maintained power increase up to repetition rates exceeding 100 kHz.

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BE-7

TRANSITION FROM DIFFUSE TO MICROCHANNEL FORM OF HIGH-VOLTAGE NANOSECOND DISCHARGE IN DENSE GASES

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Pulsed discharges of various types are one of the most effective and technologically advanced methods of generating low-temperature plasma, and technologies based on gas-discharge plasma have taken an important place in many production processes. One of the main areas of practical application of low-temperature pulsed discharge plasma is modification of the surface of various materials. It was previously established that when a grounded electrode is exposed to discharge plasma, traces of erosion are observed on its surface. In this case, the microstructure of erosion in the impact zone correlated with the structure of current microchannels arising near the pointed potential cathode at the initial stage of discharge development. Nevertheless, the question of the mechanisms of formation of anode and cathode spots in spark discharges in air at atmospheric pressure, as well as the structure of current microchannels, still remains open.

High-voltage nanosecond discharges initiated by runaway electrons are very promising for uniform action of gas-discharge plasma on the surface of a material. The problems of forming high-voltage pulse discharges with a duration from units to tens of nanoseconds are being intensively studied. In this paper it is shown that during a pulsed nanosecond discharge between a potential needle and a flat grounded electrode, a diffuse form of discharge can be realized during the first voltage pulse. Anode spots and a microchannel structure of current channels are formed later - during the second and subsequent voltage pulses caused by reflections of voltage pulses from an unmatched load.

BE-8

APOKAMP DISCHARGE IN THE SIMULATION OF LIGHT PHENOMENA IN THE MIDDLE ATMOSPHERE

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Discharge phenomena in the Earth's mesosphere are the source of the corresponding transient luminous events (TLE): the so-called starters, blue and giant "jets". There are no direct methods for measuring the parameters of these TLE, therefore, remote sensing methods, theoretical modeling and experimental measurements of laboratory discharge parameters are applied.

This review presents data from laboratory modeling of TLE in conditions of apokamp discharge obtained since 2020. The energy threshold for launching TLE has been experimentally identified: the maximum energy release and electroluminescence in the UVB spectrum range in an apokamp discharge in air are reached in the pressure range from 70 to 100 Torr, which approximately corresponds to the heights of formation of TS of the Earth's mesosphere (12–18 km). A similar criterion obtained by igniting an apokamp discharge in carbon dioxide predicts the heights at which mesospheric TLE should be searched for in Venus mesosphere – 70–75 km. Recording the propagation dynamics of apokamp discharge plasma plumes with hc resolution confirms these conclusions, and, moreover, allowed us to formulate a new hypothesis: the type of mesospheric transient starting from the thundercloud dome depends on the intra-cloud discharges and the ratio of the positive charge of the dome tip and the negative charge of the outer layer.

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BE-9

THE INSIGHT INTO THE SURFACE CHARGE ACCUMULATION UNDER NEGATIVE DISCHARGE OF DIFFERENT HUMIDITIES AND PRESSURES

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The surface discharge phenomenon of polymers severely limits their applications in electrical and electronic devices, especially in complex environments. In this study, a drift-diffusion model based on hydrodynamic approach was developed to investigate the influence of humidity and gas pressure on the negative surface discharge. The results indicate that the discharge pattern did not change under different humidity conditions. The increased humidity accelerated the formation of discharges and increased the discharge pulse current. In particular, as the humidity increased, tiny pulses occurred at the tail of the first pulse and the number of tiny pulses increased. The appearance of these tiny pulses changed the surface charge distribution from a ”ring-like” distribution to a ”spot-like” distribution. Meanwhile, the accumulation of surface charges significantly distorted the spatial electric field distribution and suppressed the electron multiplication stage of the subsequent discharges, thus reducing the current in the Trichel pulse discharge stage. It is precisely because the discharge is stronger under high humidity, resulting in more surface charges accumulating on the surface which is in keeping with the experimental results. The measured charges at different humidities show a similar distinct “spot-like” distribution, illustrating a constant pattern of discharge. All these results demonstrated the correctness and applicability of the simulation. The surface discharge under different pressures exhibited some similarities with the case of different humidity levels. As the pressure increased, the number of discharge current pulses and the pulse amplitude decreased, resulting in a decrease in the surface charge density.

BE-10

SPATIAL NON-UNIFORMITY OF A POSITIVE COLUMN OPTICAL EMISSION IN A GLOW DISCHARGE IN AN ARGON FLOW AT ATMOSPHERIC PRESSURE

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Spatial non-uniformities in gas discharge plasma are usually caused by the occurrence of various instabilities. Most often, such phenomena are a consequence of the so-called ionization waves – spatially periodic axial changes in the electron concentration, reduced electric field strength, electron temperature, and glow intensity in the discharge gap. In this work, we observed the formation of a stationary spatially periodic structure in the positive column of a low-current pulsed glow discharge (50–70 kHz) in an argon flow at atmospheric pressure with a threshold current (60 mA), below which the discharge died out. Visually, the structure consisted of a sequence of alternating areas of moderate and brighter glow, like beads strung on a thread.

The dynamics of the plasma discharge channel was studied using optical diagnostics with time resolution synchronously with voltage and current waveforms. It is shown that the spatially periodic structure appears during the discharge current decay and continues to exist in the intervals between active phases of the pulse period, and also during the discharge current growth in the next pulse, but is blurred to a homogeneous state when the current reaches its peak value. Reasoning is given about the physical mechanism of the observed phenomenon, which is obviously caused by gas-dynamic instability resulting from periodic oscillations of the argon concentration in the discharge channel, as well as heat exchange processes at the interface between the gas heated in the current channel and the flow of colder gas surrounding it. A conclusion is made that when studying gas discharges with stratified plasma, the possible non-electrical nature of the observed radiation inhomogeneity should be taken into account.

BE-11

EFFECTIVE EMISSION COEFFICIENT IN GLOW DISCHARGE IN NOBLE GASES

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High-voltage subnanosecond plasma switching devices ’kivotron’ and ’eptron’ allowed to expand the frequency-energy range of gas lasers, however, their operating medium requires “physically clean” conditions, i.e. conditions of minimizing the presence and influence of uncontrolled impurities of the working medium, cathode material and structural elements of the discharge cell on the processes of formation of the discharge current. The development of these devices in the field of laser technology is driven by the study of the processes leading to current development and including emission processes. The purpose of the present work is to determine the dependence of the effective emission coefficient in noble gases γ_{eff}. To determine γeff, the breakdown characteristics of discharges in the voltage range of 100–10000 V and pressures from 0.1 to 100 Torr were measured in a discharge cell of planar geometry with an interelectrode distance of 30 mm. The dependences of γ_{eff} on the electric field value from the breakdown characteristics using the dependences of the Townsend electron multiplication factor from the breakdown criterion known in the literature were determined. It is shown that, depending on the adopted values of the Townsend coefficient – function $\alpha(E/N)$, the effective secondary electron emission coefficient takes a wide range of values. At large electric fields E/N > 100 Td, the scatter of γ_{eff} can reach up to two orders of magnitude.

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BE-12

HIGH-FREQUENCY EXCITATION OF ACTIVE MEDIA BASED ON TUNABLE TRANSISTOR RF GENERATORS IN THE RANGE OF (1÷3) MHz IN A PULSE-PERIODIC MODE

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One of the urgent problems of gas discharge physics is the search for new ways to excite active media.

Most researchers use industrial RF oscillators (13.56 MHz) of continuous operation. In other works, a pulsed induction excitation method is used. A feature of the ignition of a pulsed induction transverse discharge in inert gases is that the oscillatory process is attenuating, and the use of a spark gap is required.

In this work, studies of the processes of occurrence and development of gas discharge processes using transistor high-frequency tunable frequency generators operating in a pulse-periodic mode with an adjustable duration and frequency of repetition of a burst of pulses in a wide range are carried out. The experimental setup consists of a transistor high-frequency sinusoidal oscillator operating in a pulse-periodic mode, which, due to its low output resistance, is directly connected to a series oscillatory circuit consisting of inductance and capacitance, so there is no need for a matching device between the generator and the load. The generator operates in a pulse-periodic mode, the pulse repetition rate is adjusted within (1–12) Hz, and the pulse burst duration is within (25–1000) microseconds. The flash lamp turns on parallel to the oscillating circuit capacity.

The paper investigates the processes of occurrence and development of gas discharge processes using tunable transistor RF generators in the pulse-periodic mode in the range of (1÷3) MHz for both induction and capacitive pumping, as well as for combined pumping consisting of high-frequency ignition, then a high-frequency ignition-pumping unit, as well as discharge a capacitor with an adjustable discharge voltage. With high-frequency ignition of a flash lamp, the possibility of obtaining both a single-dimensional discharge channel and a multi-dimensional discharge channel is demonstrated.

BE-13

VUV RADIATION OF HYDROGEN, DEUTERIUM AND NITROGEN IN PULSED SELF-SUSTAINED DISCHARGES

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The creation of powerful VUV and UV sources of spontaneous and stimulated radiation is an important task, which is associated with the use of such sources in scientific research and various industrial processes. In this report, the results of studies of VUV and UV radiation of self-sustained discharges, including diffuse discharges formed by short voltage pulses in high-pressure gases, are presented. A comparison of VUV radiation of hydrogen and deuterium in a diffuse discharge is carried out, which confirmed the assumption of a cascade transfer of energy to the upper level of the transition of the Lyman band of molecular H_2, which leads to an increase in the laser pulse duration on this band.

Intense radiation on VUV lines of atomic nitrogen in self-sustained discharges was detected. The conditions under which the intensity of this radiation is maximal are determined.

During a discharge in a gas stream, the radiation power at 149.3 and 174.3 nm reached 6.8 mW/cm^2.

The work was performed within the framework of the State assignment of the HCEI SB RAS, project N FWRM-2021-0014.

BE-14

ATMOSPHERIC PRESSURE GLOW DISCHARGE IN PULSED BIPOLAR MODE: OPTICAL AND ELECTRICAL CHARACTERISTICS

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The repetitively pulsed bipolar power supply of the atmospheric pressure discharge provides the possibility to observe the ignition and operation of the discharge in the presence of afterglow in the discharge gap and at uniform thermal load on the electrodes. Using this feature, the dynamics and spatial distribution of the optical emission of the plasma of the atmospheric pressure glow discharge in the argon flow operating in the mode of generation of metal atoms were studied. It was shown that the optical emission of the working gas atoms is observed in the time intervals between the active phases of the discharge current, and the highest values of the spectral power density of argon atoms are observed in the positive column and near the anode. In the close proximity of the emission surface of the cathode, the optical emission of argon atoms is observed during the entire duration of the discharge current pulse. The most intense spectral power density of ions and metal atoms is observed near the electrode, which in a given half-period of the pulse is the cathode of the glow discharge. A key effect of the dynamic processes in the positive column on self-sustaining the discharge in a repetitively pulsed mode was shown.

BE-15

EXPERIMENTAL AND THEORETICAL MODELING OF THE EMISSION SPECTRA OF COLUMNAR RED SPRITES AT AIR PRESSURE OF 0.02–2 Torr

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Over the last three decades, much attention has been paid to the study of pulse discharges that are observed in the Earth's atmosphere at an altitude of over 40 km. These discharges have various forms. The greatest attention has been paid to the study of red sprites, in particular, columnar ones. It has now been established that the emission spectra of sprites change with changes in their altitude above sea level and their shape. However, the available data are contradictory and further research is required into the spectral characteristics of the emission of red sprites, as well as their miniature analogues, and the physical processes that lead to changes in the emission spectra.

The aim of this work is to study the influence of air and nitrogen pressure, as well as the excitation mode, on the emission spectra of miniature analogues of columnar red sprites.

For experimental studies, two installations based on discharge chambers made of quartz tubes with internal diameters of 5 and 8 cm with different pulse generators were used. The radiation spectra were measured in the range of 250–1000 nm at air and nitrogen pressures of 0.02–2 Torr. The parameters of the discharge current and voltage on the gap were also recorded. The studies were carried out for discharge modes in which plasma diffuse jets consisting of streamers (ionization waves) were formed.

Theoretical modeling of the sprite properties was performed using the model of electron kinetics of molecular nitrogen for altitudes of 40–90 km of the Earth's atmosphere under conditions of an electric discharge with a pulse duration of several microseconds. The model includes the kinetics of triplet ($A^3\Sigma_u^+$, $B^3\Pi_g$, $W^3\Delta_u$, $B'^3\Sigma_u^-$, $C_3\Pi_u$) electronically excited states of N_2 taking into account the excitation energy transfer during inelastic molecular collisions and spontaneous radiative transitions. In this case, the processes of both intramolecular and intermolecular transfers of electron excitation energy between triplet states during inelastic molecular interactions are taken into account. The model allows calculating the luminescence intensities of the bands of the first (radiative transitions $B^3\Pi g \rightarrow A^3\Sigma_u^+$) and second (radiative transitions $C^3\Pi_u \rightarrow B^3\Pi_g$) positive systems of N_2. The results of modeling the emission spectra of nitrogen in the bands of the first and second positive systems are compared with the results of experimental measurements at pressures corresponding to altitudes above sea level of 40–90 km.

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BE-16

ANALYSIS OF PLASMA PARAMETERS AND OTHER PROPERTIES OF RED COLUMNAR SPRITES AND PLASMA DIFFUSE JETS

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The aim of this work is to study the plasma parameters of plasma diffuse jets (PDJs) initiated by a pulse-periodic capacitive discharge. Other characteristics PDJs also were investigated and to compare the properties of PDJs with the properties of red columnar sprites.

Three setups based on discharge chambers made of transparent tubes with an internal diameter of 5, 8 and 14 cm and generators with different pulse parameters were used for experimental studies. The emission spectra were measured in the range of 250–900 nm at air and nitrogen pressures of 0.02–3 Torr. The parameters of the discharge current and voltage across the gap were also recorded. The studies were conducted for various discharge modes, including those in which PDSs consisting of streamers (ionization waves) and a quasi-stationary discharge were formed. Experiments with various electrode designs and tube diameters have shown that some properties of columnar sprites can be modeled during the formation of the PDS. It was found that bright regions can arise during streamer collisions. The studies also showed that during the formation of the PDS by a pulse-periodic capacitive discharge, a runaway electron beam (REB) is generated in the absence of contact between the initiating plasma and the metal cathode. It was found that under these conditions the REB precedes the PDS front and is recorded by the collector before its arrival.

The results obtained show the possibility of generating runaway electron beams from columnar red sprites during the formation of negative streamers directed upward from the Earth's surface.

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BE-17

UV-, VIS- AND NIR-EMISSON OF 10keV ELECTRON BEAM EXCITED AIR AT VARIOUS PRESSURES

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Various atmospheric events, such as lightnings, so called air-showers, sprites, blue-jets, and elves, as well as polar lights, are concomitant with light emission from excited air species. Differences in spectral features can indicate different excitation schemes, like discharges, high energy particle excitation, or e.g. runaway electron "beam" excitation. Here, a 12 keV electron beam, generated in a "cathode ray tube" is sent through a 300nm thick SiN-membrane into the target chamber, resulting in a 10keV beam used to excite air at various pressures. Emission spectra in the wavelength range from 200nm to 1000nm will be presented.

BE-18

COMBUSTION OF CARBON INITIATED BY A HIGH-VOLTAGE NANOSECOND DISCHARGE IN ATMOSPHERIC PRESSURE AIR

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At present, considerable attention is paid to the study and application of low-temperature gas-discharge plasma. One of the practical applications of low-temperature gas-discharge plasma is the initiation of combustion and plasma-stimulated combustion. A characteristic feature of high-voltage nanosecond discharges initiated by runaway electrons in dense gases is a breakdown at high overvoltage, which leads to the formation of spherical or conical streamers with transverse dimensions comparable to the interelectrode distance. Under excitation conditions of this type of discharge, ignition of a soot layer deposited on the surface of a grounded electrode was observed.

The aim of this work was to study the dynamics of plasma-stimulated ignition and combustion of a soot layer deposited on the surface of a grounded electrode. The work shows that during a discharge in air at atmospheric pressure, the formation of anode bright spots in the presence of a soot layer on the surface of a grounded electrode occurs within no more than 10 ns after the arrival of a voltage pulse. The speed of movement of the plasma glow front formed from anode spots reaches several hundred meters in the first microsecond after applying a voltage pulse during discharge in air.

The study was carried out within the framework of the state assignment of the IHCE SB RAS, project N FWRM-2021-0014.

BE-19

ELECTRIC-DISCHARGE XENON CHLORIDE LASER WITH A MODULAR EXCITATION SYSTEM

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The paper presents the results of development and study of the characteristics of an electric-discharge excimer laser on xenon chloride with a modular excitation system. Attention is paid to the development and optimization of the laser design, providing an output radiation energy of up to 1.8 J per pulse with high stability of pulse parameters. The laser emitter is made according to the classical scheme. Discharge electrodes made of stainless steel are located inside the dielectric discharge chamber at a distance of 35 mm from each other. The all-metal anode had a hemispherical profile. The cathode had a flat profile with a perforated working area with a light transmittance of 50%. Preionization of the working medium in the interelectrode gap was carried out by the radiation of a barrier discharge from under a perforated electrode. To increase the power of energy input into the active medium of the laser, it was proposed to use a parallel connection of discharge modules. The discharge excitation system consisted of six modules synchronously operating on a common load. The synchronicity of the switches was no worse than 5 ns. The results of an experimental study of the energy, time and spectral characteristics of laser radiation depending on the composition and pressure of the working mixture, charging voltage, and parameters of the discharge excitation circuit are presented. It is shown that the optimal working medium is the composition of HCl:Xe:Ne – 1:17:2000 at a total pressure of 4 atmospheres. The duration of the generation pulse was 60–150 ns depending on the parameters of the excitation system modules. The obtained results allow us to state that this laser source can be successfully used in scientific research, microprocessing of materials, synthesis of nanoparticles, etc.

BE-20

VUV AND UV RADIATION OF HALOGEN-RARE GAS MIXTURES IN DIFFUSE DISCHARGES FORMED BY RUN-AWAY ELECTRONS

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Powerful VUV and UV spontaneous radiation sources are widely used in scientific research and various industrial processes. Therefore, expanding the range of emission spectra of these sources is an important scientific and practical task. This report presents the results of studies of VUV and UV radiation of diffuse discharges formed by short voltage pulses in pressured gas mixtures of rare gases with halogens.

In this report, the results of studies of VUV and UV radiation of diffuse discharges formed by short voltage pulses in high-pressure gas mixtures of rare gases with halogens are presented. In ternary mixtures of rare gases with $F_2(NF_3)$–$Cl_2(HCl)$, intense radiation of Cl_2 molecules with a maximum at 258 nm and ClF molecules with a maximum at 284 nm is obtained. It is shown that the choice of the type (Ar, Ne, He) and the pressure of the rare gas changes intensity of these bands. Therewith in helium based mixtures, a band of F_2 molecules at 157 nm appears in the radiation spectrum, while in Ar based mixtures with a band of ArF molecules with a maximum at 193 nm was evident. Emission of interhalogen molecules IF and ICl in blue spectrum region was obtained in mixtures of $F_2(NF_3)$ or Cl_2 with iodine.

The conditions providing peak radiation intensity on VUV lines of atomic iodine in mixtures with helium, neon and argon are determined. The possibility of changing in a wide range intensities of the I* lines at 160–187 nm and UV line at 206.2 nm is shown.

The work was performed within the framework of the State assignment of the HCEI SB RAS, project No. FWRM-2021-0014.

BE-21

EXPERIMENTAL STUDY OF A CuBr-LASER WITH A SUBNANOSECOND EXCITATION EDGE PULSES UP TO A REPETITION FREQUENCY OF 100 kHz

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Due to the rapid development of semiconductor and solid-state diode-pumped lasers, copper vapor lasers have been displaced from most applications. However, there remain a few areas where their use is in demand, particularly in high-speed projection systems. For these applications, copper halide lasers capable of operating at pulse repetition frequencies of hundreds of kilohertz are most suitable. To further improve these applications, compact lasers with high average power are required. Significant improvements in the output characteristics of lasers on self-terminating transitions can be achieved by shortening the leading edge of the excitation pulse to ~ 1 ns. For CuBr-lasers such studies have not been performed previously, and presented research fills this gap.

The experiments were carried out using a CuBr + Ne vapor-gas mixture. In a laser tube with external heating (length 25 cm, diameter 1.1 cm, volume 24 cm^3), the medium was excited by a burst of 40 pulses formed with an eptron, which is switch based on capillary discharge with plasma cathode.

As the tube heats up, lasing appears at the 15th pulse and reaches a peak at ~ 25 and disappears after the 30th pulse. As the temperature increases, the area of laser radiation in the burst expands in both directions. Under optimal conditions, the lasing starts at the 6–8th pulse and reaches a plateau by the 20th pulse and then remains constant until the end of the burst. At a voltage of ~ 20 kV, the typical duration of the voltage pulse edge (at the level of 0.2–0.8) was 0.6 ns.

Shortening the pump pulse leading edge significantly changed the laser output characteristics. In particular, starting from 30 kHz up to the maximum $f \approx 100$ kHz with the pumping system used, a proportional growth of the lasing power is observed, reaching 16 W at $f \approx 100$ kHz with an efficiency of 0.6% calculated from the energy stored in the operating capacitance.

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BE-22

SUBNANOSECOND SWITCHING OF EPTRON: INVESTIGATION OF CURRENT DEVELOPMENT AND OPTIMIZATION FOR LASER PUMPING

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Recent studies have demonstrated an improvement in the output characteristics of lasers on self-terminating transitions when the leading edge of the excitation pulse is shortened to ~ 1 ns using eptron, a switching device based on capillary discharge with a plasma cathode. The peculiarity of eptron is the two-stage current development, which increases the switching time and decreases its efficiency.

In this study, the initial stages of current development in options with subnanosecond time resolution are investigated. An eptron with a meandering capillary channel with a slit cross-section of 1 × 15 mm and length of 50 mm was investigated. Excitation by a burst of 20 pulses and switching to an ohmic load with resistance of 0.1–5000 Ω were carried out. The operating gases were helium, neon, hydrogen, and their mixtures. Computer modeling of the initial stage of breakdown was performed for a helium.

Both theoretical and experimental studies have shown that the development of discharge begins with the formation of an ionization wave near the anode. At low concentration of charges in the plasma cathode ($n_e < 10^{11}$ cm^{-3}), the ionization wave is reflected and after a sharp increase in the current within 1 ns, its fall occurs due to the slow development of emission processes in the cathode.

This leads to a two-stage switching process with a time gap between stages of up to 10 ns. At an artificial increase in n_e by increasing the repetition rate or organization of auxiliary discharge, the two-stage nature disappears and realization of current rise rate up to 10^3 A/ns is possible. In this case, subnanosecond switching times are achieved, which is favorable for pumping lasers on self-terminating transitions at $U > 10$ kV.

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BE-23

COMPUTER MODELING OF XeCl LASERS ON THE BASIS OF LC-CIRCUIT

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Model of electro-discharge XeCl lasers on the basis of LC-circuit is developed. The computer model includes the following modules.

The module of the solving of Boltzmann equation (Bolsig+) for the electron energy distribution function (EEDF). This module on composition of a mixture, on value of a degree of ionization and set E/N (E – intensity of an electric field in an interelectrode gap; N – full concentration of particles) allows to find EEDF and to define rates of plasma-chemical reactions with participation of electrons. Rate coefficients are determined as tables in which their dependence on mixture of the active medium, electron concentration n_e, the resulted strength of electric field U/Pd.

The module of the solving of system of the equations of plasma-chemical reactions. Two channels of formation of XeCl*-molecules were taken into account: harpoon reaction and three-body recombination.

The module of the solving of the equations of an electric circuit. This module describes work of system of excitation of the volume discharge in active medium.

A database on dependence of cross-sections of reactions with participation of electrons from their energy (file Siglo.sec from Bolsig+).

On the basis of model, the emission characteristics of a XeCl laser (the volume of the discharge plasma ~ 15 cm^3) were calculated, taking into account the operation of the excitation system, active medium, and resonator. Correspondence with experimental results is obtained.

BE-24

PROBE DIAGNOSTICS OF STATIONARY ABNORMAL GLOW DISCHARGE IN HELIUM

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Glow discharges are sources of low-temperature plasma, electron beams, sources of radiation in various spectral ranges and are characterized by simplicity of achieving the required parameters. This determines their diverse applications in science and technological processes of modern production. Current-voltage characteristics (I–V curves) of abnormal glow and "open" discharge depend to a large extent on experimental conditions. In particular, at careful degassing of the discharge volume and conditioning of the cathode ("clean" conditions), the I-V curves acquire an unusual S-shaped form (in the coordinates voltage U – current I). To explain the effects leading to this type of I–V curves, probe diagnostics of discharge under pure conditions in a "flat cathode"–"flat anode" discharge structure with an interelectrode distance of 3 cm in helium (99.9999% purity) was carried out. Electric field distributions in the region of cathode sheath at pressures up to 9 Torr and voltages up to 2 kV were measured. Spatial dependences of the Townsend electron multiplication coefficient under different discharge conditions have been determined and correlated with I-V curves of the discharge. Influence of temperature effects on the I-V curves of the discharge was demonstrated.

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BE-25

FORMATION DYNAMICS AND STRUCTURE OF A STREAMER OF THE APOKAMP DISCHARGE

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This paper presents the results of an experimental study on the dynamics of formation and spatio-temporal structure of apocampic discharge streamers in air. Apocampic discharge is an extended plasma jet initiated from the bend of the positive column of a pulse-periodic (tens of kHz) discharge between the main circuit electrodes. The studies were conducted using time-resolved optical and spectral methods. The sequence of discharge development in the steady-state regime was established: during the voltage rise stage, a plasma channel forms between the electrodes, followed by the detachment of the plasma front from the bend of the positive column, forming a streamer. A key result is the discovery of two zones in the streamer head: a main brightly luminous zone and a preceding faintly luminous zone, named the precursor. It was shown that the temporal lag between these zones is several nanoseconds. It is suggested that the luminescence of the precursor is attributed to a region of uncompensated positive ion charge in close proximity to the streamer front, where the electric field strength reaches maximum values, whereas the main brightly luminous zone corresponds to the streamer body. The obtained data are of significant importance for refining and supplementing existing models of cathode-directed streamers.

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BE-26

FILAMENT FORMATION DURING NANOSECOND DISCHARGE IN AIR IN A SHARPLY INHOMOGENEOUS ELECTRIC FIELD

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This report presents the results of a study on the formation dynamics and spectral composition of filament emission in a nanosecond discharge in air at atmospheric pressure in a point-to-plane geometry. Voltage pulses with an amplitude of +25 kV, a full width at half maximum (FWHM) of 13 ns, and a rise time of 2.2 ns were applied to the point electrode. Time-resolved optical and spectral methods, utilizing a streak camera coupled with a spectrometer, were employed for diagnostics. The following discharge development sequence was established: during the initial stage (hundreds of picoseconds), a rapid breakdown of the gap occurs via a large-diameter streamer, which forms a diffuse plasma channel. At this stage, with a current of approximately 0.1 kA, the N_2(C–B) band emission dominates in the emission spectra. Several nanoseconds after breakdown, a bright spot forms near the point electrode, from which thin channels (filaments) begin to grow slowly towards the plane electrode. Time-resolved plasma emission spectra in the filament nucleation region demonstrate drastic changes: intense broadband emission (250–1000 nm) appears, decaying within

10 ns after the current fall, along with emission lines of nitrogen and oxygen atoms, which persist for up to 300 ns and beyond. Notably, N_2(C–B) band emission is completely absent at this stage. The obtained results suggest that the primary mechanism for filament formation is the dissociation of air molecules in regions of locally high current density.

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BE-27

LASER ON RAREFIED ATMOSPHERIC AIR WITH LONGITUDINAL DISCHARGE PUMPING

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The continuing interest of researchers in the N_2 laser is primarily due to its low cost, small size, and safety of the gas medium used, unlike, for example, excimer lasers. The laser can operate at repetition rates of tens and hundreds of Hz, providing generation pulses of 3–5 ns duration with energy of units of mJ.

The paper presents the results of an experimental study of a nitrogen laser pumped by a longitudinal discharge in which nitrogen is replaced by air. The creation of an experimental sample of such a laser is reported. Excitation of the laser is carried out by a pulse generator that charges the discharge capacitance connected to a two-section discharge tube with an inner diameter of 6.7–17 mm and a section length of 100–217 mm. It is shown that at air pressure of 7–9 mm Hg and its pumping through the discharge tube the laser can operate at a frequency of up to 100 Hz, provide at a wavelength of 337.1 nm the energy of the radiation pulse of 0.27–1.9 mJ at a duration from 4 to 13.5 ns.

The optimum characteristics of the laser are as follows: air pressure in the discharge tube 6–10 mm Hg; reduced voltage on the tube sections E/P = 0.1–0.2 kV/cm·mm Hg; current density in the discharge ring – up to 6 kA/cm^2; specific pumping power up to 5–7 MW/cm^3; efficiency of conversion of stored energy into radiation 0.025%.

BE-28

INJECTION OF LOW-CURRENT ATMOSPHERIC PRESSURE DISCHARGE PLASMA IN AN ARGON FLOW INTO THE FOREVACUUM PRESSURE REGION

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Non-self-sustaining gas discharges are effective plasma generators used as spontaneous emission sources, as plasma sources for initiating breakdowns in high-power microwave beams, and in technological processes of ion-plasma surface modification. Of considerable interest are discharge systems operating in the pressure range from medium vacuum to forevacuum of 0.5–500 Pa ($3 \cdot 10^{-3}$–3 Torr), and up to atmospheric pressure. To generate plasma under such conditions, a two-electrode discharge system was used based on a glow discharge of atmospheric pressure in an argon flow, the anode of which was a diaphragm with an opening of 200–300 μm in diameter. This ensured a pressure difference between the discharge system of the plasma generator and the vacuum chamber. With the flow of working gas, plasma from the anode region was injected into the region of reduced pressure, where it was in the state of a diffuse plume localized in a small volume of 1 cm^3. The characteristics of the optical emission of this plasma jet were studied depending on the pressure and parameters of the glow discharge at atmospheric pressure. The prospects for using such a plasma source as an alternative to systems based on inductively coupled plasma and microwave discharges were considered.

BE-29

OPTICAL CHARACTERISTICS AND MASS-CHARGE COMPOSITION OF VACUUM ARC DISCHARGE PLASMA: SIMULTANEOUS DIAGNOSTICS AND COMPARISON OF RESULTS

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To study the mass-charge composition of the vacuum arc cathode spot plasma, the methods of time-of-flight, magnetic and quadrupole mass spectrometry (MS) are widely used. In each of these methods, the results are the dependences of the ion beam current amplitude Ii on the mass-to-charge ratio Mi/Q, which are determined by the operating conditions of the vacuum arc: cathode material, operating pressure, discharge current amplitude. Analysis of these dependences allows us to determine the elemental composition and ionization multiplicity of charged particles - ions of metals and gases with high accuracy. However, using mass-charge spectrometry it is impossible to determine the presence and state of electrically neutral particles in the plasma of a vacuum arc. For this purpose, the methods of emission optical spectroscopy (OS) are successfully used. Nevertheless, many studies have shown that the results of determining the elemental composition of ions based on MS and OS are far from coinciding. As a rule, the spectral density of optical radiation of the lines of triply and more ionized metal atoms (Me IV or Me^{3+}) has a fairly low intensity. This feature may lead to incorrect interpretation of the results of the study. In the present work, complementary MS and OS were used simultaneously, which allowed us to study the elemental neutral and charge composition of the plasma of a vacuum arc discharge with cathodes made of different materials in a single experimental cycle.

BE-30

CONVERSION OF CO_2 TO CO IN A PULSE DISCHARGE WITH LIMITED ENERGY STORAGE

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The paper verifies the assumption that limiting the energy input into the plasma of a spark discharge ensures the conversion of carbon dioxide into CO. Two options were used for this: 1) a spark gap circuit in which one electrode was high-voltage and the other had a capacitive decoupling with grounding (~ 2–3 pF); 2) a capacitive decoupling circuit in which several discharge gaps served as a load, which provided a distributed mode of energy input from a single power source. In both variants, the supply of carbon dioxide at atmospheric pressure to the discharge gaps provided partial conversion of $CO_2 \rightarrow CO$, which was recorded on the FTIR spectra of the mixtures obtained. A qualitative conclusion has been made that the first processing option provides a more efficient conversion.

The studies were performed in the framework of the State Task for IHCE SB RAS, project N FWRM-2021-0014.

BE-31

EFFECT OF THE EXCITATION PULSE DURATION ON ENERGY CHARACTERISTICS OF BARRIER DISCHARGE XeCl-EXCILAMPS

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Excilamps are gas-discharge sources of spontaneous ultraviolet radiation based on exciplex and excimer molecules. One of their most important parameters determining the power and efficiency of the excilamp radiation, along with the composition and partial pressure of the working mixture, the size of the gas discharge gap, are the characteristics of the excilamp excitation pulse: shape and amplitude. It was previously shown that the optimal form of the excitation pulse for excilamps of a barrier discharge on exciplex molecules is a unipolar voltage pulse, similar in shape to a meander, with a front and fall duration of tens to hundreds of ns. However, the effect of the excitation pulse duration on the energy characteristics of the excilamps has not been specifically investigated.

In this study of barrier discharge XeCl-excilamp, it is shown that reducing the excitation pulse duration of the XeCl-excilamp from 1.5 to 0.7 microseconds increases the energy luminosity of the excilamp by 14%. At the same time, the power consumption of the excilamp increases to 7%. During each time step the luminescence pulses occurs at the leading and trailing edges of the voltage pulses. The delay between the first and second pulses of radiation can be varied. Possible applications of this effect are discussed.

The studies were performed in the framework of the State Task for IHCE SB RAS, project N FWRM-2021-0014.

BE-32

CHARACTERISTIC EVOLUTION OF SURFACE DIELECTRIC BARRIER DISCHARGE UNDER DIFFERENT PULSE REPETITION FREQUENCIES

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Abstract: The pulse repetition frequency (PRF) was demonstrated to significantly affect the discharge physics in nanosecond-pulse surface dielectric barrier discharge (NS-SDBD), showing nonlinear evolution characteristics and modulation effects. Previous research was mainly limited to frequencies below 5 kHz, leaving higher PRF regimes insufficiently explored. In this study, the experimental range was extended to 5–50 kHz. A clear frequency dependence of secondary ionization waves was observed, corresponding to three distinct discharge modes: 1) a discrete-channel mode dominated by surface ionization waves (SIWs) at 5–16 kHz, 2) a transitional mode at 20–30 kHz, 3) a filamentary mode with streamer dominance (Streamer > SIW) at 35–50 kHz. These findings were verified through ICCD and high-speed imaging, which captured the propagation behavior of SIWs and streamers during the initial nanoseconds of discharge. In addition, The deposited energy was found to correlate strongly with both PRF and pulse number. In the discrete-channel mode (5–16 kHz), rapid energy saturation was observed. The transitional region (20–30 kHz) exhibited dual-mode energy characteristics, while the filamentary mode (35–50 kHz) showed fast energy peaking followed by rapid decay, occasionally leading to thermal runaway. This work provides important theoretical guidance and design principles for high-PRF ns-SDBD applications in engineering fields.

BE-33

BEHAVIOR OF A NEGATIVE CORONA DISCHARGE NEAR THE TRICHEL PULSE GENERATION THRESHOLD

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The work is devoted to the study of the behavior of a negative corona discharge in atmospheric pressure air near the threshold of Trichel pulse generation. A system of electrodes "tip (cathode) – plane (anode)" with an interelectrode gap of 10–20 mm and a radius of curvature of the tip of ≈ 20 μm was used. For the first time, it was found that in a certain voltage range, the Trichel pulse mode becomes unstable after its initiation and is periodically replaced by a pulse-free discharge mode with a current of ≲ 1 μmA. This phenomenon occurs quite rarely and lasts for a limited time. To clarify the physical mechanism of this phenomenon, we use physical modeling using a bipolar corona discharge (a system of "tip–tip" electrodes), which facilitates the conditions for the flow of quasi-stationary current before and in the presence of Trichel pulses. It is suggested that the low-current pulseless phase of corona combustion is a dark Townsend discharge.

BE-34

APPEARANCE OF RUNAWAY ELECTRONS IN PHYSICAL MODELING OF RED SPRITES USING CAPACITIVE DISCHARGE

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When studying such a rare phenomenon in the Earth's atmosphere as red sprites, its physical modeling is of invaluable help. In this study, red columnar sprites are modeled using a capacitive discharge.

A beam of runaway electrons was detected during the generation of plasma formations modeling red sprites in low-pressure air. It was found that the beam outpaces the front of the ionization wave. It was shown that the amplitude of the beam current in the pulse-periodic mode increases with increasing pulse repetition frequency.

BE-35

NUMERICAL ANALYSIS OF THE FORMATION OF AN ACTIVE MEDIUM ON $3p \to 3s$ TRANSITIONS OF THE NE ATOM DURING EXCITATION OF A Ne/H_2 MIXTURE BY AN INDUCTIVE DISCHARGE

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Interest in laser radiation in the yellow region of the spectrum (550–590 nm), which continues to this day, is associated with the development of methods for treating a wide range of diseases in ophthalmology and dermatology. One of the known lasers in this region of the spectrum is a laser with generation on the $3p \to 3s$ transition of Ne I atoms (585.3 nm). The active medium of a neon laser was intensively studied at the end of the 20th century, but traditional methods were used to excite it – an electric discharge and an electron beam. Earlier, the possibility of obtaining laser generation when pumping a Ne/H_2 mixture with a pulsed inductive discharge was demonstrated. The practical prospects without electrode excitation of the active medium, as well as the poor study of the behavior of low-pressure inductive discharges, aroused interest for their further research.

The report presents a model of the active medium that was formed when the Ne/H_2 mixture is excited by an inductive discharge. When calculating the excitation, the pump discharge current turn was considered as a secondary winding of an air transformer, whose primary winding is loaded on a pulse current generator. An equivalent circuit was used in which electromagnetic connections were replaced by electrical ones. In addition to the equations for currents and voltages on the excitation circuit elements, a system of kinetic equations for the plasma particle concentration and the Boltzmann equation for determining the EEDF were solved. A comparison of the obtained numerical results with experimental ones showed good agreement.

Based on the presented model, an analysis of the effect of partial pressure of hydrogen on the magnitude of the gain was performed. It was shown, that the optimum for the mixture composition is determined by two opposite trends that arise with an increase in the hydrogen content in it. An increase in the unloading of the lower laser level in the processes of Penning reactions with Ne($3s$) and H_2. A decrease in the average electron energy due to a large cross section of elastic collisions for the H_2 molecule. In addition, it was shown that the shape of the EEDF in such discharges differs significantly from the Maxwell one both at the stage of their formation and at the stage of their recombination decay. This fact must be taken into account when creating their models.

Session C
ULTRASHORT LASER PULSES

C-1

EFFECT OF FEMTOSECOND LASER STRUCTURING ON THE OPTICAL AND PHOTOLUMINESCENT PROPERTIES OF THIN CHALCOGENIDE GLASSY SEMICONDUCTOR FILMS

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Chalcogenide vitreous semiconductors (ChVS) have potential for telecommunications and infrared (IR) polarization optics, being transparent with high refractive index in the near IR range, and possessing possibilities of photostructural transformations and laser-induced periodic surface structures (LIPSS) formation with optical anisotropy on their surface.

In this work, femtosecond laser pulses (515 nm, 300 fs, fluence 8–270 mJ/cm^2, frequency up to 2 kHz) were used to produce various LIPSS types on the surface of 1-µm-thick ChVS (As_2S_3, As_2Se_3 and $As_{50}Se_{50}$) films. The obtained LIPSS were in the form of one-dimensional gratings with a period from 500 to 170 nm and a depth of up to 100 nm, or hierarchical structures containing two mutually orthogonal gratings with different periods. The possibility to control the optical anisotropy of LIPSS formed on the ChVS by changing the number and fluence of the laser pulses is demonstrated: the optical retardance value in the LIPSS varies from 0 to 30 nm for one layer of ChVS film. The possibility of increasing the optical retardance using layer-by-layer deposition of ChVS with subsequent LIPSS formation on each layer is presented. A correlation is demonstrated between the photoluminescence intensity of laser-modified As_2S_3 films and the concentration of defects in the form of homopolar bonds in them, while paramagnetic defects in the form of dangling sulfur bonds are shown to not contribute to the luminescence.

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C-2

GENERATION OF HIGH-ORDER HARMONICS IN LASER PLASMA BY PICOSECOND RADIATION

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High-order harmonic generation (HHG) opens up possibilities for creating powerful sources of ultrashort coherent radiation in the VUV and soft X-ray ranges, which are important for a wide range of fundamental and applied research. The most commonly used method for HHG is generation in gases. In this work, another method is developed for initiation of HHG, using laser-induced plasma, which is promising for increasing the HHG efficiency.

The report discusses the results of experiments on the formation of laser plasma near the surface of a copper target, the features of the optical scheme for generating and recording the parameters of the high harmonic radiation, and the experimental implementation of the scheme for separating laser radiation and high harmonics radiation propagating collinearly.

The description of an experimental setup for HHG in laser-induced plasma created on the surface of a copper target using the second harmonic radiation of a Nd:YAG laser (532 nm, 90 ps, 300 mJ) operating at a pulse repetition rate of 10 Hz is presented. The pulsed radiation is divided into two beams, one of which creates laser plasma (excitation beam, intensity on the target surface ~ 10^{11} W/cm^2), the second beam initiates HHG in the laser plasma (generating beam with maximum intensity of ~ $5 \cdot 10^{13}$ W/cm^2 in the region of the laser plasma excitation). The peak voltmeter based on a photodiode with a very high sensitivity of about 200 femtojoules is used to register parameters of the high-order harmonic radiation. These also open up the possibility of measuring the structure of the HHG spectra in a wide spectral range.

The dependences of the HHG radiation parameters on the pulse energy, both exciting the plasma and generating harmonics, were measured experimentally for different operating modes and compared with the calculation data.

The study was carried out with financial support of the Ministry of Education and Science of the Russian Federation, the scientific project FWGU-2021-0005.

C-3

SATURATION OF SUPERCONTINUUM RADIATION DURING LASER FILAMENTATION IN COMPRESSED GASES

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We present the results of our experimental measurements of the spectral composition of a high-power femtosecond titanium-sapphire laser with different initial energy during its filamentation in optical cuvette filled with different gases (nitrogen, argon, helium, carbon dioxide) at a stepwise change of their pressure from 1 to 50 atm. We show that after nonlinear propagation in a cuvette with compressed gas, the spectral width of the optical pulse first exhibits growth and then saturation with increasing gas pressure. At the same time, the limiting broadening of the spectrum of femtosecond radiation is about 8 times relative to its initial value regardless of the type of gas (except helium) and is achieved at a pressure in the optical cuvette of about 20 atm. Worthwhile noting, a further increase in pressure leads only to intraspectral transformations of the pulse, but not to a broadening of its spectrum. Moreover, at very high pressures (> 30 atm), the spectral width of the pulse even begins to decrease, which we attribute to the increase of radiation absorption in the self-created plasma in the filamentation region.

C-4

GENERATION OF COHERENT WHITE BEAMS IN NITROGEN

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The report presents the results of experimental study of the conditions for formation of a highly directed supercontinuum (HDSC) in gaseous nitrogen pumped by a radiation pulse with wavelength of 950 nm, duration of 70 fs, and energy of 3–6 mJ. The pump radiation was focused into a gas chamber by spherical mirror with $F = 75$ cm under aberration conditions (the angle of incidence of radiation on the mirror was 150). It is shown that there is the optimal pump energy of 4.5 mJ and gas pressure of 3 atm. The spectral composition of the HDSC covers the range from 350 to 1000 nm. The HDSC divergence is diffraction and its largest value (the diameter of the white spot in the far field) corresponds to a wavelength of 780 nm.

The maximum energy of the HDSC was 17 μJ.

The work was carried out within the framework of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (FWRM-2021-0014).

C-5

THE EFFECT OF LOCAL HETEROGENEITIES OF THE MEDIUM ALONG THE PROPAGATION PATH OF HIGH POWER FEMTOSECOND LASER PULSES ON THE GENERATION OF ELECTROMAGNETIC RADIATION AT SHIFTED WAVELENGTHS

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The report presents the results of studies of filamentation of femtosecond laser pulses in the presence at the beginning of the propagation path of a layer with a randomly inhomogeneous refractive index formed by a stream of hot air directed perpendicular to the direction of radiation propagation. It is shown that this technique of forced initiation of inhomogeneities in the transverse energy structure of a laser beam leads to the formation of high-intensity light sub-beams, which, unlike low-intensity narrow beams, are not blurring at short distances due to the large diffraction divergence, while maintaining a small diameter and, consequently, intensity over long distances due to the implementation of Kerr nonlinearity in the medium. Such preliminary segmentation of high-power laser radiation leads to a multiple increase in the number of high-intensity slightly divergent light channels, the characteristic intensity of which is sufficient to realize two-photon absorption in the volume of aerosol particles, which in turn significantly increases the magnitude of the fluorescence signal detected by the lidar circuit. In addition, it is shown that the turbulent layer formed at the beginning of the optical path makes it possible to increase the efficiency of THz radiation generation from the filamentation region by up to 1.5 times due to the formation of a multitude of randomly arranged filaments resulting from random perturbations of the energy profile of the optical beam.

C-6

CARRIER-ENVELOPE PHASE STABILIZATION OF PULSES OF THE FEMTOSECOND LASER SYSTEM

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Recently, laser sources of short wavelength radiation have become widespread, which are in demand for experimental research in the field of physics, chemistry and biology. The short wavelength radiation is obtained from high order optical harmonics generation. The effective generation of high order harmonics requires extremely short pulses with stabilization of the carrier frequency phase relative to the pulse envelope (CEP).

The work is devoted to the study of the influence of pulses amplitude noise on the CEP stabilization system of a solid-state kilohertz Ti:Sa femtosecond laser. The stabilization system is based on an f-2f interferometer with a resolution of the spectral interference pattern. To obtain an interference pattern in the spectral region, a part of the broadband radiation (supercontinuum) is used to generate second harmonic radiation.

The influence of radiation parameters and noise on the accuracy of CEP determination was analyzed using numerical simulation methods. Numerical simulation was carried out using the generalized nonlinear Schrцdinger equation taking into account the radiation divergence, dispersion of the refractive index of the medium, absorption in the medium, self-phase modulation, and stimulated Raman scattering. The fourth-order Runge–Kutta in the Interaction Picture method (RK4IP) was used for numerical calculations. A 1 mm thick sapphire plate was used as a nonlinear medium for generating supercontinuum radiation. Pulses have the energy of about 20 μJ, a duration of 50 fs, and a central wavelength of 800 nm. It was shown that the error in determining CEP from supercontinuum radiation increases with increasing noise of the original pulse and reaches about 100 mrad at a noise level of 1%.

The obtained results can be used to develop systems for measuring the carrier phase relative to the envelope of femtosecond pulses with a low repetition rate.

The study was carried out with the financial support of the Ministry of Education and Science of the Russian Federation within the framework of the scientific project FWGU-2021-0005.

C-7

TERAHERTZ EMISSION FROM SINGLE-COLOR LASER FILAMENT PLASMA

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The plasma generated by femtosecond laser filaments is a promising source of terahertz radiation. The study presents experimental results on the spatial and energy characteristics of terahertz emission during single-color filamentation. The influence of various laser pulse parameters — such as energy, pulse duration, numerical aperture, and wavelength — has been explored. It has been found that the angular distribution of terahertz radiation is primarily determined by its frequency and is independent of both laser pulse energy and beam numerical aperture. The spectral maximum of this radiation is in the gigahertz range. The efficiency of terahertz generation increases with the laser wavelength. Additionally, a specific numerical aperture of the laser beam has been identified, at which terahertz generation is maximized across all frequencies. However, for tight focusing, there is an optimal pulse duration for each terahertz frequency that ensures the most efficient generation. Thus, the study allows to control the terahertz emission characteristics over a wide range for practical applications by selecting the appropriate laser pulse parameters.

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C-8

CHARACTERISTICS OF THE SECOND HARMONIC GENERATED DURING LASER PULSE FILAMENTATION IN AIR

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The work presents both experimental and numerical investigations of the second harmonic generated in the plasma formed during the laser pulse filamentation in air. The dependence of second harmonic energy on various experimental parameters is explored, including laser pulse energy (for different polarizations), focusing conditions, and the gas pressure in which filamentation occurs. It is shown that the spatial distribution of the second harmonic consists of two maxima along the laser pulse polarization. The influence of the initial laser pulse parameters on the polarization of the second harmonic is also examined. Numerical analysis of the physical processes reveals the second-order currents in the filament plasma to be the dominant mechanism for the second harmonic generation.

C-9

PLASMA-MIRROR-BASED LASER PULSE CONTRAST ENHANCEMENT SYSTEM FOR MULTITERAWATT LASER FACILITY

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State of the art laser systems with ultrashort pulse duration and high peak power are based on the chirped pulse amplification technology. One of the disadvantages of the technology is the presence of prepulses, which change the surface of the target before the arrival on the main laser pulse. Reducing the intensity of prepulses and increasing the temporal contrast is an important technical challenge, especially in a view of continuing growth of research laser facilities peak power. One of the most effective ways to solve this problem is the use of plasma mirror technology.

We have developed a laser pulse contrast enhancement system (CeS) on the base of double plasma mirror for a 200TW femtosecond laser (λ = 0.8 μm). The CeS is installed in the vacuum chamber between the laser pulse compressor and the target chamber. The design of the system allows the adjustment of the main laser pulse energy density on plasma mirrors in the range from 10 J/cm^2 to 1000 J/cm^2. The alignment of the CeS optical elements and the precise positioning of the target at the focus of the laser pulse inside target chamber is carried out by using an optical system of our own design with a CW laser (λ = 0.53 μm).

We report the optical schemes of the CeS and of the optical alignment system. We present the results of the first experiments on the interaction of the high-contrast laser pulses with solid targets at intensities of up to 10^{20} W/cm^2.

C-10

AMPLIFICATION OF SOLITON MOLECULES IN AN ALL-FIBER ERBIUM-DOPED TWO-CASCADE AMPLIFIER

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This work is devoted to the experimental study of the amplification process of groups of bound pulses (soliton molecules) in an all-fiber erbium-doped amplifier. The amplification of a 10-pulse regime (with a pulse duration of 509 femtoseconds and temporal separation between pulses of 2.64 picoseconds), generated by a ring fiber laser with passive mode locking based on nonlinear polarization evolution (NPE), up to an average power of 152 mW, is demonstrated. The amplification process did not disrupt the order of the bound state but resulted in significant spectral broadening, leading to the generation of a coherent supercontinuum. A comb-like spectrum in the range from 1400 to 1700 nm was obtained without altering key characteristics of the soliton molecules, such as the number of pulses (while increasing the pulse duration within the molecule to 1.13 ps) and without changing the temporal separation between the pulses. This work also demonstrates the potential of using an all-fiber laser with soliton molecule amplification as a source of pulsed radiation with high average power while maintaining low peak power due to the energy distribution across a group of pulses.

C-11

MEASURING THE PARAMETERS OF RELATIVISTIC ELECTRON BEAMS ACCELERATED FROM THIN SOLID TARGETS BY FEMTOSECOND LASER PULSES OF 100 TW POWER

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A series of experiments on the generation of relativistic electrons beams from thin solid targets carried out using a femtosecond high-intensity laser system. Metal (W, Ta, Al) foils with a thickness of 15÷500 microns, as well as mylar of 175 microns thickness were used as targets in experiments. Spectra, angular distribution and total charge of the relativistic electron bunches accelerated in the laser field and transmitted to the back of the target were characterized.

All measured relativistic electrons spectra follow the relativistic Maxwell distribution $dNe/dE/d\Omega = A \cdot E^2 \cdot \exp(-E/T)$, where A is a constant, E is the electron energy, and T is the characteristic temperature of the distribution ranging from 1 to 3 MeV in experiments. The maximum electron energy in experiments was about ~ 40 MeV. The divergence angle (FWHM) of electron beams was about 20°÷45° and the total charge of tens of nC/pulse were obtained. The smallest angular dimensions of electron beams were observed for aluminum targets and amounted to 20–30° (FWHM). With improved stability of laser pulses, such targets are promising from the point of view of generating beams with high charge and directionality.

C-12

TRANSFORMATION OF THE CHARACTERISTICS OF THE LASER RADIATION FILAMENTING IN A GAS AT THE INCREASED PRESSURE

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The report presents the results of our experimental studies of the effect of the pressure of a gaseous medium (nitrogen) in an optical cell on the characteristics of femtosecond laser radiation propagating in the filamentation mode. It is shown that under conditions of high pressure and acute geometric focusing of radiation, its Kerr self-focusing is realized, which, with increasing gas pressure, switches from the mode of single filamentation to the mode of formation of a multitude of intense filamentous filaments. It has been established for the first time that with an increase in the sharpness of the initial beam focusing, the broadening of the pulse spectrum acquires an asymmetry and is realized mainly in the long-wavelength region. In addition, as the gas pressure in the optical cell increases, the average size of the intense light postfilaments formed inside the beam decreases and may be fractions of a millimeter.

C-13

DYNAMICS OF THE SPECTRUM CHANGE OF SECOND HARMONIC DURING CONVERSION AND AMPLIFICATION OF CHIRPED PULSE

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The results of experimental and theoretical studies of the behavior of spectral contour of second harmonic radiation with central wavelength of 475 – 477 nm during its formation in KDP nonlinear crystal and amplification in gas XeF(C-A) amplifier are presented. It is shown that depending on the chirp sign and radiation intensity the spectrum deformation is observed. With negative chirp the shift of spectrum to the short-wavelength side (blue shift) is observed and with positive chirp the long-wavelength side (red shift) is realized. The only difference is that when the second harmonic is formed in nonlinear crystal, the magnitude of the spectrum deformation is practically independent of the radiation intensity on the crystal and when the radiation is amplified the deformation magnitude increases with increasing input intensity to the amplifier.

The work was carried out within the framework of state assignment of Ministry of Science and Higher Education of the Russian Federation (FWRM-2021-0014).

C-14

NUMERICAL SIMULATION OF EVOLUTION SPACE-TIME-FREQUENCY DISTRIBUTION OF RADIATION ENERGY IN LASER SYSTEMS

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Based on the Cohen distribution function and concept of physical spectrum, an algorithm for numerical modeling of the space-time-frequency distribution of the radiation energy density in gas XeF(C-A) amplifier of the THL-100 laser system has been developed. This made it possible to use the photon transport equation to simulation the evolution of not only spatial and energy, but also spectral characteristics of radiation in high-power laser systems. This approach allows one to solve the problem of "negative probability" that arises when using the Wigner distribution function for non-Gaussian laser beams.

Comparison of experimental data with the results of numerical simulation of chirped laser beam amplification in the XeF(C-A) amplifier of the THL-100 laser system confirmed the applicability of the proposed model. Simulation results of study of the influence of input radiation characteristics on the evolution of radiation intensity and spectra at different points of the output window are presented.

C-15

THE REABSORPTION MODEL FOR TERAHERTZ RADIATION GENERATION FROM AN ARRAY OF THE INCOHERENT OPTICAL FILAMENTS

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The generation of terahertz radiation from an array of the incoherent optical filaments formed after a powerful laser pulse passes through an atmospheric turbulent layer is numerically studied. A theoretical model is proposed that allows to reduce the solution of the problem to the study of a reduced stationary version of the nonlinear Schrцdinger equation with phenomenological consideration of the effects of radiation reabsorption in plasma.

Session D
LASER APPLICATIONS, LASER SYSTEMS, LASER-OPTICAL TECHNOLOGIES

D-1

QUASI-TWO-DIMENSIONAL SEMICONDUCTORS FOR USE IN HIGH-POWER LASERS (NLO)

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An overview is given of the experimental and theoretical results of studies on the structural-, optical-, and nonlinear-optical (NLO) properties of pure and doped highly anisotropic AIIIBVI semiconductors (where A – is for Ga, In and B – is for Se, S, Te) and some solid solutions (GaSe–GaS, GaSe–InSe). First results on the NLO properties of GaSe have been reported in 1972 by the Azerbaijanian (Institute of Physics Azerbaijan National Academy of Sciences, Baku, Azerbaijan) and Russian (Lebedev Institute of Physics USSR Academy of Sciences, Moscow, Russia) teams. GaSe has been recognized by the world scientific community as a crystal with an outstanding NLO properties. The properties of this material may be summarized as follows: high birefringence $\Delta n \sim 0.3$ at 700 nm, wide optical transparency range of (0.65÷18) um with quite law absorption coefficient in this range ($\alpha \leq 0.3$ cm^{-1}); one of the highest second-order NLO coefficient ($d_{22} = 86 \pm 17$ pm/V); high power optical damage threshold, possibility to perform frequency conversion under phase-matching conditions in the near-, to mid-IR and THz range of spectra. Solid solutions of GaSe (GaSe–GaS and GaSe–InSe) increases the possible ranges of NLO of this class of highly anisotropic materials. An analysis of the literature data and the results of the present work allows us to conclude that this class of materials is very promising for use as converters of high-power laser radiation. Present paper does not pretend to be one reflecting all existing papers on above mentioned subjects.

D-2

STUDY OF THE INFLUENCE OF OPTICAL FIBER DISPERSION ON THE SYSTEM OF INCOHERENT LASER BEAM COMBINING

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The system of synchronous incoherent beam laser beam combining on several N fiber-optic delay lines developed by the authors is considered in report. The system provides an increase in the energy and peak power of laser pulses due to the redistribution of the energy of a series of N pulses and its concentration in the N-th pulse by means of their synchronous incoherent combining by means of a time delay introduced between them. The influence of the optical fiber dispersion used as time delay lines on the operation of the system is studied, it is characterized by the values η of the magnification factor η and the ultimate magnification factor η_U of the laser pulses amplitude. The computational experiment is carried out, in result graphs of the dependencies are plotted: the dependence of the magnification factor η on the number of combined pulses in a series N or the number of delay lines N $\eta(N)$ and the dependence of the ultimate magnification factor η_U on the laser pulse repetition rate f $\eta_U(f)$ for different values of the dispersion in fiber optics τ 0, 10^{-16}, 10^{-15}, 10^{-14}, 10^{-13}, 10^{-12}, 10^{-11},

10^{-10} s/km and the dependence of the ultimate coefficient η_U on the dispersion τ η_U (τ) for different values of the pulse repetition rate f 10^3, 10^4, 10^5, 10^6, 10^7, 10^8, 10^9 Hz.

D-3

CRYOGENIC COOLING SYSTEM WITH FLEXIBLE THERMAL BRIDGE FOR ACTIVE ELEMENTS OF LASER AMPLIFIER

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Currently, laser systems based on active elements doped with Yb^{3+} ions with simultaneously high pulse repetition rates and high peak power are in demand. In high-power solid-state laser systems, thermal effects are an important limiting factor that constrains the average power. The application of cryogenic coolers with a closed-loop cycle increases, due to good temperature stability of active elements and effective heat removal. However, such cryocoolers introduce mechanical disturbances to the cooling system elements during helium expansion-compression cycles, which leads to the need to ensure the immobility of the active element relative to the amplified radiation.

Numerical modeling of a multicomponent cryogenic cooling system for a multidisk multipass amplifier with subkilowatt power level of diode pumping was carried out. Based on the modeling results, modified composite holders with a flexible thermal bridge of various modifications were developed and manufactured. Dependencies of the equilibrium temperature of active elements on the average radiation power of diode pumping up to 200 W for various modifications of crystal holders were experimentally studied. It has been experimentally shown that a closed-loop helium cryogenic cooling system provides adequate cooling of active elements, and the use of coolers with a flexible copper thermal bridge significantly reduces the influence of mechanical effects of cryogenic coolers on angular deviations of amplified radiation. Optimization of a closed-loop helium circulation cryogenic cooling system used for active elements of a multi-disk multi-pass diode-pumped amplifier of subkilowatt power level has been performed.

The study was carried out with the financial support of the Ministry of Education and Science of the Russian Federation within the framework of the scientific projects FWGU-2021-0005 and FSUN-2023-0007.

D-4

THE CHANGE IN PHASE PROFILE OF RADIATION IN THE ACTIVE ELEMENTS OF A LASER AMPLIFIER

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Currently, significant efforts in laser physics are devoted to the development of laser systems generating radiation with both high peak power and pulse repetition rate. In such systems, the amplified radiation has a change in the phase profile of the radiation when passing through the active elements. This leads to a number of negative consequences that deteriorate the spatial and power characteristics of the generated radiation.

A method is proposed for the simultaneous study of the electronic and thermal contributions to the change in the phase profile and depolarization of radiation based on the measurement of the gain distribution and temperature distribution in an active element. A series of studies of the change in the phase profile of the amplified radiation in a laser amplifier with cryogenic cooling of active elements made of Yb:YAG crystals was carried out. Pump pulse repetition rate was 1000 Hz, the average radiation power was 110 W. The results of the study of the change in the phase profile are confirmed by the results of experimental measurement of the radiation depolarization and the focal length of the lens in the active element induced by the pump radiation.

The reported study was carried out with the financial support of the RF Ministry of Science and Higher Education (FWGU-2021-0005, FSUN-2023-0007).

D-5

EFFECTIVE PICOSECOND PULSE AMPLIFICATION AT SATURATION CONDITIONS

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Neodymium-doped crystalline and glass laser media are widely used to produce picosecond and short nanosecond pulses of high peak power. Most often, laser generation occurs between the Stark sublevels of the transition $^7F_{3/2} \rightarrow {}^4I_{11/2}$, which is often addressed as a classic 4-level scheme.

For the most efficient conversion of pump energy into output radiation of a laser amplifier, it must operate near the saturation condition, which tends to equalize the upper and lower laser levels populations and make the medium more transparent. A sufficiently rapid relaxation of the lower laser level population, in turn, contributes to the partial recovery of the population difference and the amplification properties of the medium. Thus, the generation and amplification of short pulses, comparable in duration or shorter than the lifetime of the lower laser level, is a substantially non-stationary problem.

Based on the available data on the lifetime values of the lower laser level in various neodymium-doped crystalline and glass matrices, one can conclude that the values differ very significantly (for example, in the cases of popular media as Nd:YAG, Nd:YLF, Nd:glass, etc.). Thus, the value of the lifetime of the lower laser level should be adequately taken into account when creating efficient, especially two-pass, schemes for amplifying picosecond and short nanosecond pulses.

Previously, we proposed and experimentally implemented an approach for direct measurement of the lifetime of the lower laser level in Nd:YAG, based on recording the dynamics of partial gain recovery of a probe pulse following with a variable delay after a saturating pulse.

In the present work, we develop an approach to detailed modeling of efficient amplification schemes based on neodymium-doped crystalline and glass media operating under saturation conditions. In the framework of theoretical modeling, we modify the well-known model of laser pulse amplification taking into account finite relaxation rate value of the lower laser level. Based on the experimental data and calculations, we obtained a more accurate estimation 60 ± 20 ps of the lower level relaxation time in Nd:YAG and then analyzed the operation of a picosecond pulse amplifier scheme based on sequential two-pass diode-pumped amplifiers. This provides on the output 25 ps pulses with an energy of 5 mJ at a fundamental wavelength with a repetition rate of 1 kHz.

D-6

THE DEVELOPMENT OF PHOTO-ACOUSTIC DETECTORS FOR LASER SPECTROSCOPY AND GAS ANALYSIS IN IAO SB RAS

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The photo-acoustic method is widely used to study spectra of linear and nonlinear absorption of the laser radiation by molecular gases and laser gas analysis.

In this report the results of the long-term program of the development of the photo-acoustic detectors (PAD) family started in IAO SB RAS in 1972 year are presented for the different types of laser spectrometers and gas- analyzers like: PAD with gas continuum pumping, PAD with Helmgolz and ring resonator, PAD with temporal and space resolution.

The summary of specifications of the developing high sensitive PADs and the PA spectrometers and gas – analyzers is presented together with the review of the experimental results.

D-7

HIGH-POWER 1083nm PULSED LASER-BASED METASTABLE HELIUM DETECTION LIDAR SYSTEM AND ITS APPLICATIONS IN SPACE ENVIRONMENT MONITORING

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This study has successfully developed a ground-based lidar system for detecting metastable helium He(2^3S) density in the thermosphere and lower exosphere (200-1000 km), which demonstrates significant application value in space environment monitoring. The core of the system consists of three 1083 nm high-power pulsed lasers (single pulse energy 200 mJ @ 50 Hz), a 1-meter beam expander, six 1-meter receiving telescopes, and superconducting nanowire single-photon detectors (SNSPD). The system has innovatively achieved the following technological breakthroughs: 1) Adoption of an OPG/OPA hybrid amplification architecture, achieving high-quality laser output with 8–9 ns pulse width and 33 μrad divergence angle through KTP crystal parametric conversion and polarization beam combining techniques; 2) Development of an active beam control system (real-time CCD monitoring) ensuring sub-milliradian parallelism among the three laser beams; 3) First realization of continuous dusk-dawn detection of metastable helium variations with 50 km vertical resolution. During actual observations, the system successfully captured rapid changes in metastable helium density over several hours at dawn, providing a novel observational means for studying neutral-ionospheric coupling mechanisms.

D-8

DOMAIN SEPARATION NETWORKS FOR RIVER WATER IONIC COMPOSITION DIAGNOSTICS BY RAMAN SPECTROSCOPY

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The development of effective methods for monitoring metal ion concentrations in natural waters is one of the pressing issues of modern ecology. Raman spectroscopy allows for non-destructive analysis of multicomponent aqueous media. However, the interpretation of Raman spectra of aqueous media is complicated by their complex composition and the influence of various environmental factors, which requires the use of modern data processing methods. In this work, artificial neural networks (ANN) are used for this purpose.

It is important to note that the use of spectra for training adaptive models requires obtaining a representative set of data from real media (thousands of spectra). Quite often, it is technically impossible to obtain a representative spectral database for real media. Therefore, model solutions prepared in laboratory conditions are used. Obviously, ANNs trained on the spectra of model solutions (source domain) do not provide good accuracy in determining the desired environmental parameters when applied to the spectra of real waters (target domain).

In this work, when solving the problem of determining the ionic composition of the aquatic environment (Zn^{2+}, Cu^{2+}, Li^{+}, Fe^{3+}, Ni^{2+}, NH^{4+}, SO_4^{2-}, NO^{3-}), it is proposed not only to solve the problem of transferring ANN training from a large database of Raman spectra of model solutions in distilled water (3744 spectra) to a small database of real rivers (Moskva River – 400 spectra; Yauza, Bitsa, Setun – 200 spectra each), but also to interpret the obtained result in order to identify relevant common features for the two presented domains. For this purpose, an approach using Domain Separation Networks was implemented. The ability to combine disparate databases increased the versatility of the neural network approach for testing in real conditions.

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D-9

DEVELOPMENT OF A SUB-PICOSECOND LASER SYSTEM WITH A TUNABLE PULSE REPETITION RATE FOR THE ATRAUMATIC SKIN REMODELING

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Today, the presence of skin pathologies and defects of varying degrees of intensity is considered as a source of serious psychological problems and social consequences for people. Lasers have proven to be an effective tool for the treatment of atrophic and hypertrophic scars, as well as for the correction of other aesthetic imperfections, improving skin turgor, density, texture and pigmentation. One of the most effective laser sources for these purposes today is a non-ablative millisecond laser, which produces radiation at a wavelength of 1550 nm. Its action allows intensive skin remodelling by accelerating the regeneration of characteristic biological markers such as matrix metalloproteinases and interleukins. A major disadvantage of such a source is the thermal damage to the treated tissue, which leads to visual complications (erythema, oedema, etc.) and increased rehabilitation time. The use of laser pulses with a duration shorter than all the characteristic relaxation times in tissues (> 20 ps) makes it possible to eliminate the thermal effects on the tissue and, at the same time, to stimulate the growth of biological markers of remodeling. Therefore, the aim of this work was to study methods of obtaining a compact laser source of simple configuration with a pulse duration not exceeding 20 ps, a radiation spectrum in the range from 1530 to 1580 nm with a variable pulse repetition rate in the range from hundreds of kHz to units of MHz (so as to exceed the ablation threshold) and an average power of not less than 500 mW.

The reference oscillator was designed based on a 15.66 m long circular erbium fiber resonator with a total group velocity dispersion (GVD) of 0.005 ps^2, producing a stable sequence of pulses in the similariton mode at a repetition rate of 13.3 MHz. The output pulse duration was 2.5 ps, the emission spectrum was 42 nm wide at –5 dB level with $\lambda_{\_center}$ = 1541 nm, and the average emission power was 8.1 mW. The pulses were then stretched in a 48 m passive fiber loop with positive GVD (D = –72 ps/(nm · km) at a wavelength of 1550 nm to a duration of 30 ps, which was necessary to control the peak radiation power in the fibers.

The radiation was then amplified in the first stage of the preamplifier, which consisted of 5 m of active erbium-doped I-25 single-mode fiber with an absorption coefficient of 40 dB/m. This fiber was pumped by continuous emission from a pump diode at a wavelength of 980 nm with a power of 650 mW. The amplified pulse sequence was then thinned by an acousto-optic modulator (AOM) with a division factor ranging from 2 to 20 The second preamplifier stage, consisting of 3 m of I-25 active fiber pumped by continuous emission from a pump diode at a wavelength of 980 nm with a power of 350 mW, compensated for the losses caused by the AOM. The pulse sequence was then amplified in a 7 m loop of a large mode area erbium-doped active fiber ($d_{\text{mod.area}}$ = 25 μm) pumped by continuous emission from a pump diode at a wavelength of 980 nm with a power of 30 W. As a result, a sequence of pulses with a duration of 20 ps was obtained at a repetition rate of 0.67…13.3 MHz, and the average radiant power reached 512 mW.

D-10

DENSITY OF THE HYBRID PLASMA MAINTAINED BY MICROWAVE RADIATION AND CO_2 LASER

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In this paper, we study the number density of electrons in a hybrid atmospheric-pressure plasma supported by microwave radiation (2.47 GHz) and a CO_2 laser (10.6 μm) in the chamber of an experimental plasma-chemical reactor designed to study the synthesis of diamond-like and other coatings. The reactor is based on a quasi-cylindrical TM_{012}-mode microwave resonator into which focused radiation from the CO_2 laser is introduced simultaneously with microwave radiation; both radiations are presented in a pulse-periodic mode. The products of the hybrid plasma are transported through a supersonic nozzle to the substrate on which the coating is synthesized.The gas mixture in the chamber is at a pressure slightly higher than atmospheric.

It is known that the density of charged particles in the plasma of an atmospheric pressure microwave discharge exceeds 10^{13} cm^{-3}. When powerful radiation from the pulsed-periodic CO_2 laser is supplied to such a plasma, the density of charged particles will increase, since the typical density of charged particles for a laser plasma is 10^{15}–10^{17} cm^{-3} and higher. At such densities of charged particles, the spectral lines of atomic hydrogen experience significant Stark broadening, which we used to measure density of electrons in the hybrid plasma. The shapes of the atomic hydrogen H_α line emitted by atmospheric-pressure plasma in H_2:Ar:CH_4 mixtures were studied. The shapes of the H_α line in the spectra of the hybrid plasma, in contrast to the shapes of this line emitted by microwave plasma approximated by the Lorentz function, have broad wings and are described by a Lorentz function with a two-contour approximation, which indicates significant spatio-temporal inhomogeneity of the hybrid plasma. The half-widths of the two Lorentzian contours of the approximation differ significantly. The densities of electrons in atmospheric-pressure microwave plasma measured from the Stark broadening of the H_α lines lie in the range of $5 \cdot 10^{14}$–10^{16} cm^{-3}. In hybrid plasma, the density of electrons corresponding to the shape with a smaller half-width slightly exceeds the density of electrons in microwave plasma and lies in the range of 10^{15}–$5 \cdot 10^{16}$ cm^{-3}. In the case of focusing the laser radiation in the region of a microwave plasma clot, the density of electrons measured from the shape with a larger half-width is ~ 10^{17} cm^{-3}.

The study was carried out with financial support of the Russian Science Foundation, the scientific project N 25-29-00816.

D-11

GENERATION OF THz RADIATION IN $ZnGeP_2$ CRYSTALS AT THE DIFFERENCE FREQUENCY OF THE SPECTRAL COMPONENTS OF THE FS PUMP PULSE IN THE REGION OF MAXIMUM TRANSMISSION OF THE CRYSTAL

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For efficient generation of the difference frequency, it is necessary to match the phase velocities of the waves interacting in the nonlinear medium, i.e., to satisfy the phase matching (PS) conditions. In the case where two waves are spectrally contained in one pump pulse, the possibility of achieving the PS conditions is even more limited; however, a shorter duration of the pump pulses softens these limitations (due to spectrum broadening), which in principle allows generating higher-frequency radiation.

As a result of mathematical modeling, it was found that the PS conditions for pumping a $ZnGeP_2$ crystal with pulses of 70 fs duration and a central wavelength of 2200 nm are achievable for e–o = o and e–o = e interaction types, which allows generating THz radiation from 100 to 900 μm with a crystal rotation of 14 degrees. The use of comparatively long-wavelength pumping, coinciding with the region of maximum transmission of the crystal, allows a significant reduction in absorption losses.

The obtained results contribute to solving the fundamental problem of creating powerful, frequency-tunable THz radiation sources.

D-12

ENERGY CHARACTERISTICS OF A COPPER VAPOR LASER WITH AN ACTIVE MEDIUM PUMPING BY A MARX GENERATOR

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The active medium of the copper vapor laser (CVL) is pumped during the discharge of the storage capacitor through a gas discharge tube (GDT). One of the factors limiting the energy characteristics of the CVL is the need to maintain the input power to the GDT at a certain level when changing the pumping parameters so as not to disrupt the thermal operation of the laser. This makes it necessary to reduce the capacity of the storage capacitor with an increase in the voltage at the anode of the thyratron or the pulse repetition rate (PRR) of the excitation. With a decrease in the capacity of the storage capacitor, the quality factor of the discharge circuit of the laser increases, which leads to an increase in the reverse voltage at the thyratron anode and is a significant factor in limiting the efficiency of the CVL, since thyratrons have a fairly narrow range of stable operation. As the analysis showed, the Marx generator, whose principle of operation is based on charging parallel-connected capacitors with electric current, which, after charging, are connected in series using various switching devices such as thyratrons, significantly expands the possibilities for optimizing the pumping parameters of the LPM.

The report presents the results of a study of the energy characteristics of a copper vapor laser pumped by a Marx generator. The experiments used gas discharge tubes – LT-10Cu, UL-102, GL-201 (NPP «Istok», Fryazino).

D-13

MODELING OF THE IR-TO-VISIBLE RADIATION CONVERSION ON COMPETITIVE OPTICAL TRANSITIONS IN MANGANESE VAPORS

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Active media on self-terminating transitions in vapor of metal and their halides have an advantage of high gain and high quality of the radiation beam that allows to use them as brightness amplifiers for active optical systems. Moreover, active media on vapors of manganese and its halides show high gain on lines in both the visible and infrared (IR) ranges. Combined with the fact that they can operates at relatively high frequencies (over 100 kHz), this makes them a promising candidate for use as a selective converter of signals from the IR to the optical range, since the emission lines of the IR and optical ranges share common lower operating levels.

However, no experimental results on the implementation of such an operating mode for active media on manganese vapor have been obtained previously, that raises the question of the possibility of such optical conversion. Advancement in this matter can be made by mathematical modeling that take into account the competition between different spectral lines of amplification/radiation. The presented work uses an approach to modeling based on solving a system of kinetic partial differential equations consistent with the equations describing the electric pumping circuit. The model is an adaptation of a similar model developed previously for active media on copper vapors. The results of calculating the integral characteristics of radiation conversion from IR to the visible range for various pulse repetition rates and energy characteristics of the active medium pumping are presented. We made an evaluation of the feasibility of such operation mode with respect to the obtaining a contrast image in the visible range is carried out.

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D-14

FEATURES OF THE SMALL LENGTH GDT HIGH-FREQUENCY EXCITATION

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Metal vapor lasers are effective devices for visual-optical diagnostics of fast processes shielded by strong background radiation. Usually, such radiation occurs during the interaction of high-intensity energy flows with a matter (laser ablation, laser welding) and is expressed in the glow of plasma, which shields the area of interaction, preventing observation of the process, and, consequently, makes it difficult to study the interaction process itself. Metal vapor lasers and metal vapor halide lasers, in particular copper bromide laser can suppress this radiation when used as brightness amplifiers in laser monitor schemes or in laser illumination schemes. One of the key parameter in imaging issue is the pulse repetition frequency (PRF), which defines the temporal resolution of laser monitors. It should also be emphasized that the overall system features play a significant role in ensuring operational convenience, mobility and efficiency of system using.

In this study, the amplification features of copper bromide active media are investigated at pulse repetition frequencies (PRFs) of 15 and 150 kHz.

The mean excitation power remained constant in all experiments and was equal to 715 W. The gas discharge tube (GDT) with active length of 20 cm and inner diameter of 1.2 cm was used. The excitation power supply with direct discharge of the storage capacitor on the GDT by a thyratron was used to pump medium at PRF of 15 kHz. The capacitance of the storage capacitor in this case was 750 pF. The semiconductor excitation power supply based on LTD (linear transformer driver) concept was used to pump medium at the PRF of 150 kHz. The storage capacity was 45 nF.

The mean radiation power was 1100 mW for PRF of 15 kHz. Single-pass radiation and superradiance (amplified spontaneous emission – ASE) was 645 mW and 189 mW respectively. ASE value is satisfactory for image formation in the laser monitor. The single-pass radiation power is about 59% from radiation power formed by the plane-parallel resonator.

The radiation power was 830 mW when PRF was 150 kHz. Single-pass and ASE power was too low to measure it by optical power meter. It has been experimentally shown that the use of the the LTD excitation source with a specific energy input of 31.6 kW/L under high-frequency excitation (above 100 kHz), does not provide needed ASE power and single-pass amplification level in a short-length gas discharge tube (GDT) for image formation in the laser monitor schemes. This imposes significant limitations on the applicability of such a configuration (short GDT + LTD power supply) for the development of brightness amplifiers in high-frequency laser monitor systems.

The work was made within the framework of the base budget of IAO SB RAS (FWRU-2021-0006).

D-15

AUTOMATIC BEAM STABILIZATION SYSTEM OF METASTABLE HELIUM LIDAR BASED ON CCD CAMERA

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The metastable helium lidar is a novel ground-based resonance fluorescence radar designed to detect the number density of metastable helium atoms in the thermosphere and exosphere (200-1000 km altitude) by employing a pulsed laser tuned to the 1083.0 nm transition. This technique offers unique advantages for studying upper atmospheric dynamics and space weather. However, factors such as mechanical jitter, thermal change, and atmospheric turbulence often degrade the coupling efficiency of atmospheric backscattered light into the receiving telescope, leading to reduced signal strength and measurement accuracy. Traditional manual alignment methods are insufficient for real-time correction, necessitating an automated beam stabilization system to optimize optical performance and ensure long-term stability.

To overcome this challenge, we propose an automatic beam stabilization system utilizing a CCD (Charge-Coupled Diode) camera for real-time laser spot monitoring. The system captures the beam position and transmits the data to a control center, where algorithms process the information and generate corrective signals. These signals drive a piezoelectric steering mirror at the transmitter to actively compensate for beam misalignment. The proposed design is expected to significantly enhance optical coupling efficiency and signal intensity by maintaining precise beam-telescope alignment throughout observations. This stabilization approach addresses a critical limitation in metastable helium lidar systems and could potentially improve the reliability of high-altitude atmospheric measurements. Theoretical analysis suggests the system architecture should effectively mitigate beam wander caused by both mechanical vibrations and atmospheric effects.

D-16

OPTICAL COMMUNICATION SYSTEM BASED ON VORTEX BESSEL-GAUSSIAN BEAMS

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Vortex Bessel-Gaussian laser beams are one of the promising types of vortex beams, since they have the property of invariance to a certain extent. This paper presents an optical communication system using vortex Bessel-Gaussian laser beams. The detection strategy of this optical communication system is based on the orthogonality of vortex Bessel-Gaussian laser beams. The transmitter encodes the message symbols into the values of the topological charges of vortex Bessel-Gaussian laser beams. At the receiver, a multichannel correlation detector determines the value of the topological charge, i.e. the message symbol, by the value of the correlation metrics of the mutual coherence of the fields of vortex Bessel-Gaussian beams.

The results of a theoretical study of correlation metrics of mutual coherence at the receiving aperture of fields of vortex Bessel-Gaussian beams with various topological charges in a turbulent atmosphere are presented. The expression for the second-order mutual coherence function of vortex Bessel-Gaussian beams in a turbulent atmosphere with different topological charges is obtained in the paraxial approximation using the extended Huygens – Fresnel principle. When constructing the solution, a quadratic approximation of the function describing the distorting influence of random inhomogeneities of the environment was used.

The correlation metrics of mutual coherence at the receiving aperture of fields of Bessel-Gaussian beams with different topological charges are analyzed depending on the optical thickness of atmospheric turbulence. It is shown that the possibility of an optical communication system using

Bessel-Gaussian beams based on topological charge coding of a beam with a multichannel correlation detector at the receiver is not significantly limited by the distorting effect of atmospheric turbulence.

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D-17

MEASUREMENT OF THERMOPAUSE ATMOSPHERIC TEMPERATURE USING A METASTABLE HELIUM RESONANCE FLUORESCENCE LIDAR

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Accurately measuring temperature in the challenging thermopause region (500–650 km altitude) presents significant difficulties due to the extremely low atmospheric density. This work presents a groundbreaking solution utilizing a novel, high-performance 1083 nm lidar system deployed in Fuke Village, Hainan (19.3 °N, 109.0 °E) to target metastable helium atoms (He(2^3S)), which are abundant at these altitudes.

The core enabling technology is a sophisticated, high-energy, narrow-linewidth 1083 nm pulsed laser transmitter. Pumped by 532 nm light, it employs a continuous-wave (CW) 1083 nm seed laser followed by optical parametric generation (OPG) and two stages of optical parametric amplification (OPA). This architecture produces 140 mJ pulses with exceptional 62 MHz linewidth at a 50 Hz repetition rate. A key innovation is the rapid, precise wavelength control of the seed laser. To resolve the complex temperature-dependent absorption lineshape of metastable helium around 1083.32 nm, the seed wavelength is cycled between three specific wavelengths (1083.329, 1083.318, and 1083.337 nm) every 30 seconds. This is achieved using real-time wavelength monitoring and a PID control loop, enabling wavelength switching in under 2 seconds with frequency jitter below 4 MHz – performance critical for accurate spectral discrimination.

By analyzing the resonance fluorescence backscatter intensity at these precisely controlled wavelengths and employing multi-variable inversion techniques, the system simultaneously retrieves metastable helium density and, for the first time globally, the atmospheric temperature profile within the thermopause. This achievement demonstrates the vital role of advanced, spectrally agile high-power lasers in probing the most tenuous regions of our atmosphere.

D-18

CuBr + Ne + HBr LASER WITH SEMICONDUCTOR EXCITATION SOURCE

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The described laser system is designed for the use in an imaging complex for monitoring fast processes accompanied by broadband intense radiation. Such systems are commonly referred to as ”laser monitors”. They are characterized by several key parameters: field of view and temporal resolution. To increase the field of view, it is necessary to enlarge the geometric dimensions of the active element and, consequently, the exciting pump power. Improving the temporal resolution, i.e., the frame repetition rate of the imaging system, requires increasing the excitation pulse repetition rate. This is largely limited by the capabilities of the pump pulse-forming unit. The LTD (Linear Transformer Driver) concept enables the generation of pulses with high energy, a high energy transfer rate to the load, and a high repetition rate, all while maintaining compact dimensions and reduced cost compared to sources based on plasma switches (such as thyratrons and tacitrons). The implemented excitation source, with an average power of 0.9 kW, generates excitation pulses with a voltage amplitude of up to 12 kV and a current of up to 120 A at a repetition rate of 50 kHz. A gas-discharge tube with a volume of 0.115 liters (active length: 45 cm, diameter: 1.8 cm) was used. In stable operation, the output power was 6.0–6.5 W, with 3.0 W of single-pass radiation and 0.6 W of superradiance. The pumping efficiency ranged from 0.66 to 0.72%. The external dimensions of the excitation source are 100 × 20 × 30 cm (L × W × H).

D-19

PHASE TRANSITIONS IN TWO-DIMENSIONAL $TlGaSe_2$ CRYSTALS: STUDIES OF HIGH-RESOLUTION OPTICAL SPECTROSCOPY IN A WIDE TEMPERATURE RANGE

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Infrared and terahertz spectroscopy of $TlGaSe_2$ crystals has been studied over a wide temperature range (3,325 K). The appearance of new phonon modes in the $TlGaSe_2$ spectra below a temperature of T = 120 K was detected, due to a structural phase transition; the phonon parameters of the crystal under study revealed features at temperatures of 30, 60, and 92.5 K. The observed anomalies may be related to the reaction of phonons to the formation of an antisegnetoelectric structure and a change in the latter with temperature. Splitting of some phonon modes at 60 K may occur due to symmetry breaking due to increased interaction between two polar sublattices.

Session F
PHOTONICS IN REMOTE STUDIES OF ENVIRONMENT

F-1

PROGRESS IN EXPERIMENTAL AND THEORETICAL RESEARCH ON THE BACKSCATTER CHARACTERISTICS OF CIRRUS CLOUDS

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Cirrus clouds consisting mainly of ice crystals are important components of the atmosphere which essentially modulate the radiative budget of the Earth. Until now, the microphysical properties of the ice crystals as well as their number density are poorly known because of their great variability in time and space and difficulties of field measurements. The lidar and radar soundings are promising device providing active remote sensing of the cirrus clouds. By combining the backscatter signals of lidar and radar, it was found that the lidar-radar ratio is sensitive to ice crystal size and the depolarization ratio is sensitive to shape.

We have established a dynamic empirical relationship between the hollow degree and length of ice crystals, breaking through the limitations of traditional fixed hollow degree and more accurately describing the scattering characteristics of hollow ice crystals. Propose a modal hollow ice crystal model suitable for the analysis of cirrus hollow particles, which can distinguish the mixing ratio of solid/hollow ice crystals based on lidar ratio, color ratio, and depolarization ratio.

The research results significantly improve the inversion accuracy of microphysical parameters of cirrus clouds (ice crystal shape, size, hollow ratio), providing key support for climate model radiation budget calculation and remote sensing algorithm optimization.

F-2

PROGRESS IN THE DEVELOPMENT OF Fe RESONANCE FLUORESCENCE DOPPLER LIDAR

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Temperature and wind profiling in the middle and upper atmosphere with high accuracy precision and resolution is crucial in the validation and improvement of global atmosphere models. Resonance fluorescence Doppler lidar is a powerful tool for temperature and wind measurements with high-resolution in the mesopause region. Because of the state-of-the-art laser technology and high Fe abundance, Fe resonance fluorescence Doppler lidar is considered to be an ideal candidate for the next-generation lidar. As the complexity of the Fe lidar, only few Fe lidars have been operated in few locations. Therefore, considering the importance of temperature and wind measurement and the superiority of Fe lidar, it is very meaningful to make some contributions to the development of high-performance Fe lidar.

The generation of pulsed laser at 372 nm wavelength and frequency stabilization of pulsed laser are key technologies for the development of high-performance Fe lidar. For the generation of pulsed laser at 372 nm wavelength, the method we use is directly through the third harmonic generation of a Nd:YAG laser operating at 1116nm wavelength. The Nd: YAG crystal have an emission line with a linewidth of about 1.3 nm near 1116 nm wavelength, which is within a few GHz of the tripled wavelength of the iron absorption line at 372 nm wavelength. A specific laser frequency can be obtained by injection-seeded technique in combination with an active cavity control technique. For the frequency stabilization of pulsed laser, the saturation absorption spectrum of iodine near 558 nm wavelength is carried out, and the frequency difference between the lock point and the needed frequency (the tripled wavelength of the iron absorption line at 372 nm wavelength) is corrected by the beat and lock frequency modules. The progress and some test results about frequency stabilization will be presented in the extended paper.

F-3

NEW ROBUST LIGHT SCATTERING DATABASE FOR ICE CRYSTALS OF CIRRUS CLOUDS

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Cirrus clouds significantly impact the planet's climate by altering the radiative balance. However, their optical properties remain poorly understood due to unresolved challenges in light scattering by large non-spherical particles. This complicates the interpretation of experimental data from remote sensing instruments and impedes the development of accurate optical models for cloud assimilation into radiative transfer models. Until recently, light scattering by large non-spherical particles could not be solved rigorously due to computational limitations. While the geometrical optics approximation provides solutions for ice crystal particles, it has an unavoidable singularity in the backscattering direction. Only with the recent development of the physical optics method has it become possible to address light scattering for large non-spherical particles, taking into account particle orientation as commonly found in cirrus clouds.

This report presents the robust database of light backscattering matrices computed for all typical ice crystal shapes in cirrus clouds (excluding particle aggregates). Unlike existing databases, this one covers the full particle size range (0.1 to 10,000 μm) for the three most common lidar wavelengths: 0.355, 0.532, and 1.064 μm. Such a database is essential for developing algorithms to interpret lidar data from both ground-based and space-borne systems. To ensure broad accessibility, the database is openly available in a simple text format.

The work was supported by the RSF (25-17-00087).

F-4

APPLICATION OF MACHINE LEARNING METHODS TO ANALYZE THE PRESENCE OF HARMFUL IMPURITIES IN THE ATMOSPHERE BASED ON SPECTRAL DATA

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One of the most important problems of humanity's existence in the industrial age is the problem of maintaining its comfortable living environment. Environmental monitoring is a component of the safety management system. The development of pulsed terahertz and submillimeter spectroscopy methods makes it possible to monitor the state of the environment by measuring and analyzing the absorption spectra of the atmosphere.

The proposed analytical approach integrates machine learning methods with high-precision spectroscopic measurements. A ResNet neural network with self-awareness mechanisms has been created, which identifies gases in a multicomponent atmospheric mixture and determines their concentrations through the analysis of absorption spectra in the terahertz range. The network architecture includes convolutional blocks with residual connections and a specialized Focal Loss function.

Experimental studies on model sets of spectra demonstrate the potential of the technique in identifying six gas components with an accuracy of 0.01 ppm. The neural network has achieved 90-95% accuracy in detecting gas concentrations. A series of experiments based on real experimental data were conducted to refine the architecture of the model and improve its characteristics

The scientific significance of the study lies in a new methodological approach that expands the possibilities of spectroscopic analysis. Research is in an active stage: noise models are being refined, data augmentation is underway, and prediction mechanisms are being adjusted. The prospect is to create a universal gas analysis platform with high sensitivity to microconcentrations of atmospheric gases.

F-5

BACKSCATTERING PROPERTIES OF QUASI-HORIZONTALLY ORIENTED ICE CRYSTALS FOR SCANNING LIDARS WITH SMALL TILT ANGLE

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Cirrus clouds cover approximately 30% of the global area and have a significant impact on the radiation balance of the Earth system. Given the pressing challenge of global climate change, it's imperative to consider the radiative forcing of cirrus clouds, which is primarily influenced by the shape, size, and orientation of non-spherical ice crystals within them. For a more precise assessment of cirrus clouds' climatic characteristics, comprehensive observational investigations are essential. These studies require the establishment of a physically consistent forward model of ice crystals rigorously validated against observational datasets. Quasi-horizontal orientations of ice crystals were conventionally described using a Gaussian distribution. However, recent researches have shown that the exponential distribution provides a more accurate representation of them. The backscattering properties of plate-like and column-like ice crystals with the exponential distribution for lidar with tilt angles ranging from 0 to 15° off-zenith is investigated by using the Beam-Splitting physical optical approximation method for the first time in this study. It reveals that using the realistic distribution law significantly impact on the scanning lidar's retrieval algorithms especially in case of plate-like ice crystals. It is found that the color ratio is also sensitive to the plate's flutter, while the linear depolarization ratio sensitive to the orientation of the columns. These new results are very crucial for adjustment the Micro-Pulse Lidar Network (MPLNET) retrieval algorithms.

F-6

LIGHT SCATTERING BY LARGE NON-SPHERICAL PARTICLES OF DUST AEROSOL FOR PROBLEMS OF EXPERIMENTAL DATA INTERPRETATION

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Space exploration expands our knowledge of nature and fundamental laws of physics. Currently, remote sensing is a key method for studying space and obtaining information about space objects. Over the past decades, a large number of both ground-based and space-based instruments have been developed and put into operation worldwide, the main task of which is space polarimetry. Within the framework of international scientific projects, large-scale studies of the microphysical properties of small and large space objects have been conducted based on the results of polarimetric observations. At the same time, the main difficulty in interpreting the obtained experimental data lies in the lack of a solution to the direct problem of light scattering by submillimeter-range cosmic dust particles, since for particles less than 30 um in size, accurate numerical methods (for example, the discrete dipole method) are successfully used, and for large particles larger than a millimeter, the geometric optics approximation works effectively. This state of affairs is due to the absence, until recently, of an effective method for solving the problem of light scattering by such objects. However, the method of physical optics, developed with the direct participation of the authors of the report to solve the problem of light scattering by large particles, can be successfully applied to solve this problem. This report is devoted to solving the problem of light scattering on cosmic dust particles of submillimeter and millimeter ranges for the interpretation of remote sensing data.

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F-7

INVESTIGATION OF SATURATION EFFECTS ON METASTABLE HELIUM LIDAR PERFORMANCE

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As an emerging method for upper atmospheric detection, the metastable helium fluorescence lidar typically relies on high-power laser systems to generate sufficient return signals due to the low density of metastable helium atoms in the atmosphere. However, when the laser energy density exceeds a certain threshold, the backscattered signal exhibits pronounced nonlinear behaviour and may even enter a saturation regime, thereby limiting signal enhancement and adversely affecting the quantitative retrieval capability of the system. Currently, research on fluorescence saturation effects is primarily focused on theoretical modelling and numerical simulations, with a notable lack of systematic experimental validation and model calibration. Moreover, the interaction between the target energy levels of metastable helium atoms also influences the evolution of saturation behaviour, necessitating experimental verification and correction.

To address these issues, this study first conducts steady-state saturated absorption spectroscopy experiments to demonstrate that metastable helium atoms can be approximated as a closed two-level system, wherein the transition dynamics are dominated by Einstein processes between the target levels, with negligible influence from other levels. Based on this foundation, the study further investigates the dynamic response under non-steady-state pulsed laser excitation, systematically analyzing and quantitatively evaluating the effects of key parameters, such as laser energy density and Gaussian pulse width, on the saturation effect. A corresponding mathematical model for the nonlinear response is established. The results provide not only a theoretical basis for optimising lidar system parameters but also technical support for improving the accuracy of atmospheric density and temperature retrievals, thereby contributing to the practical advancement of high-performance lidar systems.

F-8

ESTIMATION OF TIME PARAMETERS OF LASER RADIATION SOURCES FOR TWO-PULSE LASER DIAGNOSTICS

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The paper describes a test bench for studying the dynamics of photofragments during two-pulse excitation of molecules by laser fragmentation/laser-induced fluorescence (LF/LIF). A synchronization scheme for two solid-state lasers and a photodetector using the two-pulse LF/LIF method is presented. Experimental results of the time jitter of laser pulses of two solid-state lasers depending on their external firing scheme are presented. The experimentally measured jitter of the LX329A titanium-sapphire laser turned out to be 35 ns and did not depend on the external firing scheme. While the jitter Nd:The Q-Smart 850 YAG laser turned out to be 1 and 150 ns, depending on the external trigger with two synchronization channels and one channel, respectively.

Two firing schemes are possible for the external firing of a solid-state laser with an electro-optical shutter. The first starting scheme consisted of applying an external pulse to start the laser pump lamp, and the electro-optical shutter is started using an internal laser generator. And the second trigger scheme, in which two external pulses are applied to the laser, one to start the pump lamp, and the second, delayed in time, to start the electro-optical shutter. The time jitter estimation was investigated for both laser firing schemes. In addition, the tunable Titanium-sapphire laser system was studied both as a whole and separately as a pump laser (model LQ929B).

The information obtained on the time jitters of laser pulses will make it possible to take into account their temporal inaccuracy when conducting future experiments to study the dynamics of two-pulse excitation of molecules by the LF/LIF method. Experiments conducted to estimate the time jitter of two solid-state lasers using the two-pulse LF/LIF method have shown the need to use at least three independent synchronization channels for more accurate positioning of laser pulses in time.

F-9

INSTALLATION FOR DIAGNOSTICS OF METABOLIC DISORDERS OF PLANT COVER BASED ON IR SPECTRA OF ATMOSPHERIC RADIATION

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Measures to protect plants from various pathogens should be carried out over a certain period of time to avoid possible economic losses. Complex mobile systems are needed to monitor the susceptibility or resistance of various plant crops. The report presents a setup that allows recording signs of metabolic disorders in agricultural crops at the early development stage using direct atmospheric absorption in the IR range. The characteristics of the equipment used are provided. The methodology of the approach to processing primary experimental data is described.

A series of experiments were conducted on a standard FT-801 Fourier spectrometer. A greenhouse measuring 50 cm wide and 200 cm long was used as a working volume. A representative sample of plants consisted of 35 pieces.

It is shown that the spectroscopic approach allows recording the presence of infection 5 days before the appearance of the corresponding morphological features in plants.

F-10

RUSSIAN SEGMENT OF GLOBAL AEROSOL-CLOUD-PRECIPITATION OBSERVATION NETWORK (GAONet) IN TOMSK

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To advance our understanding of atmospheric phenomena, it is essential to carry out observations in various regions of the world. This requires the development of global monitoring networks. The GAONet network is an example of the expansion of global infrastructure for studying climate change and the environment. The V.E. Zuev Institute of Atmospheric Optics has has joined GAONet and is actively developing an atmospheric observation site in Tomsk.

The scientific and technical equipment of the Russian segment of the international GAONet network in Tomsk includes instruments designed to study atmospheric processes, including continuous observations of key parameters such as cloud profiles, cloud fractions, and precipitation. Atmospheric and cloud profiler determines the height of the lower and upper boundaries of clouds and atmospheric aerosols. It provides real-time data on cloud cover, a critical parameter for climate studies. Optical monitor of cloud fraction measures cloud fraction and cloud cover. It allows continuous monitoring of cloud cover and cloudiness during daylight hours. The obtained data is essential for developing new methods and algorithms for climate modeling. Optical precipitation monitor measures both liquid and solid precipitation. This instrument enables continuous observation of precipitation levels in both warm and cold seasons.

These three instruments work together to deliver comprehensive atmospheric data necessary for scientific research within of the China-Russia Research Center for Atmospheric Optics. Such efforts are fundamental for addressing local and global environmental challenges, from regional weather forecasting to long-term climate modeling. This report presents the first experimental results.

Session G
BIOPHOTONICS

G-1

VIBRATIONAL SPECTROSCOPY OF BLOOD FOR GLIOMA DIAGNOSIS

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Glioma diagnosis by analysis of serum or blood plasma by vibrational spectroscopy has of considerable interest for early tumor detection and timely treatment. Using the U87 human glioblastoma model, we performed a comparative analysis of mouse serum in the dynamics of tumor development by terahertz (THz), infrared (IR) and Raman spectroscopy. A machine learning pipeline was proposed to analyze the spectral data, which included the main steps: 1) smoothing by Savitzky-Golei filter (THz and IR), background subtraction (Raman), and data normalization; 2) informative features extraction by principal component analysis; 3) construction of predictive models using support vector machines, random forests, and stochastic gradient boosting methods; and 4) selection of informative spectral features. The proposed approaches were applied to analyze blood plasma of patients with glioma of various degrees of malignancy, trauma and healthy individuals. It is shown that the sensitivity, specificity and accuracy of the constructed predictive models for diagnostics of patients with glioma based on Raman and THz spectroscopy data exceed 90%.

The work was partially carried out within the state assignment of IA&E SB RAS, NRC “Kurchatov Institute” (in part of THz measurements) and IAO SB RAS (analysis of spectral data).

G-2

SPECTRAL CHARACTERISTICS OF CDOM IN NATURAL WATER: FEATURES OF MEASUREMENT AND INTERPRETATION BASED ON THE RESULTS OF LONG-TERM STUDIES

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The color of natural water and its optical properties are determined by the colored part of dissolved organic matter, CDOM (Chromophoric Dissolved Organic Matter): humic substances, represented by high-molecular aromatic oxycarboxylic acids. Most often, in laboratory studies, CDOM is defined as the chromophoric fraction of organic matter in natural water passing through filters with a pore size of 0.22 or 0.45 micrometers. However, in remote sensing CDOM is distinguished from other marine components by its optical properties. Due to the presence of humic substances, CDOM of natural origin absorbs well the UV light and emit fluorescence, therefore, optical methods, primarily fluorescence and absorption spectroscopy, are widely used to study the origin and dynamics of CDOM.

The absorption spectrum of CDOM usually represents a monotonically decreasing dependence of optical density on wavelength without clearly defined peaks. At 260–270 nm a ”shoulder” may appear caused by the absorption of phenolic compounds or protein molecules. A typical fluorescence spectrum of CDOM upon excitation at a wavelength of 270 nm or shorter consists of two broad overlapping bands: a ”protein-like” band with an emission maximum in the range of 300-350 nm, caused by the fluorescence of proteins, aromatic amino acids and phenolic compounds, and a much more intense humic-type fluorescence in the blue region. In unfiltered samples, an intense UV emission band arises due to the fluorescence of microorganism cell proteins, but its intensity is significantly reduced upon water filtration. In filtered water ”protein-like” fluorescence is usually negligible. However, “protein-like” fluorescence in filtered samples becomes noticeable in layers of water with massive development of microorganisms, such as in the chemocline zone of meromictic reservoirs.

Important spectral characteristics of CDOM are the wavelength of the emission maximum and the quantum yield of CDOM fluorescence. The composition and ratio of CDOM components are individual for each water area and for different water layers, therefore ”optical markers” are successfully used to identify natural waters, study water mixing processes, and investigate the transformation and degradation of organic matter. The report provides an overview of the spectral and optical characteristics of CDOM, including the dependence of the fluorescence quantum yield and the position of the emission maximum on the excitation wavelength in a wide range of its alteration, from 240 to 500 nm. The know-how of measurement the spectral characteristics and features of their interpretation are described, based on the results of long-term studies from 1995 to 2025. The study of CDOM is of great importance for understanding environmental processes in aquatic systems and developing environmental protection techniques.

G-3

THE CAPABILITIES OF OPTICAL COHERENCE TOMOGRAPHY FOR EVALUATING THE POROSITY OF TITANIUM NICKELIDE (NiTi)

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Titanium nickelide (NiTi) has established itself the best biomaterials for implantation. Due to its unique properties, NiTi ensures optimal biocompatibility with human body tissues. Porous NiTi implants closely resemble the bone tissue of the human body. One of the most important parameters of biocompatibility is porosity, which has a direct positive impact on cell morphology, proliferation, and adhesion. Porosity is defined by the presence of voids within the material and is characterized by the relationships between these pores and the walls of the medium, forming a three-dimensional structure. Currently, methods such as optical microscopy and scanning electron microscopy are used to study porosity. However, these methods have disadvantages: limited depth of focus and difficulties in focusing on three-dimensional porous structures. Optical coherence tomography (OCT) is an optical method that provides spatial resolution at the micrometer scale, allowing for control over the spatial position of the area of interest and enabling the study of pores both on the surface and at depth. OCT allows for the determination of the number of pores on a sample, the average pore size, and the percentage ratio of pore area to sample area. This study presents the results of applying OCT to investigate the porosity of NiTi samples fabricated using self-propagating high-temperature synthesis (SHS) and selective laser melting (SLM) methods.

This research was funded by the Ministry of Science and Higher Education of the Russian Federation grant N 075-15-2024-557 dated 04.25.2024.

G-4

FACTORS AFFECTING HORMESIS IN MICROORGANISMS UNDER THE INFLUENCE OF VUV RADIATION

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The work investigated the phenomenon of hormesis (stimulation of biological processes) in microscopic fungi of various species under the influence of small doses ($W < 1$ mJ/cm^2) of vacuum ultraviolet (VUV) radiation ($\lambda = 166–182$ nm).

It is known that irradiation of microscopic fungi with small doses of both ionizing radiation and vacuum ultraviolet (VUV) one can lead to stimulation of colony formation.

The aim of this work was to determine the factors influencing the manifestation of hormesis under VUV irradiation. In the course of the work, it was found that the growth of hormesis is facilitated by:

– the presence of the pigment melanin in microorganisms (Cladosporium herbarum, Exophiala xenobiotica). This resulted in an increase in colony forming by up to 200%, which can be explained by the formation of active radicals due to photodecomposition of melanin,

– a decrease in the concentration of water decomposition products ($\cdot OH$, $HO_2\cdot$, H_2O_2). Thus, a decrease in the concentration of these products by 3 times resulted in an increase in colony forming by 50%,

– a decrease in the radiation wavelength. With an increase in the radiation wavelength up to $\lambda = 300$ nm within doses $W < 1$ mJ/cm^2, hormesis was not detected

G-5

POROUS MEMBRANES FOR PHOTOACTIVATED OLIGONUCLEOTIDE SYNTHESIS

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Synthesis of oligonucleotide libraries (DNA/RNA) is in demand in modern methods of genetics and molecular biology. In technologies for solid-phase synthesis of oligonucleotides, granules with controlled pore size (CPG), smooth glasses, perforated silicon, as well as organic polymers functionalized with starting groups on which the synthesis takes place are used as carriers. The disadvantage of non-porous carriers is a small specific surface area, which does not allow achieving large quantities of substances, and materials such as CPG are not suitable for printing and photolithographic synthesis technologies.

In our studies, it was shown that modified porous anodized aluminum oxide can be used as a solid-phase carrier, whose specific surface area is 2–3 orders of magnitude greater than that of smooth glass and silicon surfaces. In addition, aluminum oxide can be formed with a modulated pore diameter in the form of a one-dimensional photonic crystal. This makes it possible to control the effective refractive index of the material and reduce light scattering from the porous structure. Since the size of the light spot can be significantly smaller than the size of the droplet formed by the jet dosing system, the density of spots can be significantly increased (more than 27,000 pcs/cm^2).

This work was performed within the framework of the State Assignment of the Ministry of Education and Science of the Russian Federation (Project N FEWM-2024-0001).

G-6

USING AN APOKAMP DISCHARGE TO INCREASE POTATO YIELDS (SOLANUM TUBEROSUM L.)

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The specificity of apokamp discharge at atmospheric pressure air is that there is a predominant formation of nitrogen oxides (NO, NO_2 and N_2O). This is due to the achievement of a critical concentration of NO_x oxides, at which oxygen atoms react with nitrogen oxides faster than in reactions with O_2 and O_3. Therefore, the apokamp discharge in the air produces a gaseous medium with a predominance of nitrogen oxides over the rest of the active particles. In 2022 we have experimentally shown that the treatment of potato tubers of two varieties "Gala" and "Queen Anna" with such a gas medium improves the biometric parameters of potatoes as plants develop, and also increases crop yields.

This paper summarizes the results of three-year (2022–2024) field studies of the effects of apokamp plasma decay products on potatoes. They prove that despite the differences in the climatic conditions of cultivation in these years, processing accelerates the growth and maturation of plants, which in turn increases yields by 18–30%. The yield formula for the specified years has been determined. It was previously noted that processing tends to decrease the concentration of nitrates in the crop. Experimental data also suggest that the effect is provided by the combined effect of plasma decay products and radiation from an apocampal discharge in the air.

The studies were performed in the framework of the State Task for IHCE SB RAS, project N FWRM-2021-0014.

G-7

APPLICATION OF TIME-RESOLVED LUMINESCENCE SPECTROSCOPY FOR TEMPERATURE MEASUREMENT USING NANOSENSORS BASED ON $NaYF_4:Yb^{3+}/Tm^{3+}$ COMPLEXES

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Currently, despite significant progress in the field of luminescent thermometry of biological objects, the problem of autofluorescence of biological tissue, which overlaps with the photoluminescence spectrum of most nanoparticles-thermosensors, remains relevant.

In order to solve this problem, the use of luminescent complexes doped with rare earth elements (REE) seems promising, since in REE anti-stokes (upconversion) luminescence can be realized. Such complexes usually consist of an inert matrix doped with two types of REE, one of which (sensitizer) absorbs exciting radiation in the IR range, transmits it to the other (activator), which, in turn, emits luminescence in the visible range of the spectrum. The luminescent response of such complexes depends on the ambient temperature, which can be used for elaboration of temperature nanosensor.

In this work, nanocomplexes $NaYF_4:Yb^{3+}/Tm^{3+}$ with upconversion luminescence were used to determine the local temperature of the medium. For this, the dependences of the parameters of the kinetic curves of luminescence decay were used. For excitation of the signal intense nanosecond laser radiation at a wavelength of 975 nm was used. The sensing of the medium was performed using receiving and transmitting fiber cable. The proposed technique has been tested on various biological media – water, urine, blood plasma, and muscle tissue.

The proposed approach provided not only high accuracy of determining the local temperature - up to 0.5 °C, but also made it possible to determine the temperature in any biological environment with the same accuracy.

The study was supported by the Russian Science Foundation grant N 25-22-00411: https://rscf.ru/en/project/25-22-00411.

G-8

IR-THz SPECTROSCOPY AND GAS CHROMATOGRAPHY METHODS FOR ANALYSIS OF EUTROPHICATION OF WATER BODIES

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Eutrophication of freshwater and marine water bodies, which is one of the key environmental problems, is associated with excessive input of biogenic elements (nitrogen, phosphorus) and mass development of phytoplankton, including toxic cyanobacteria. Traditional methods of monitoring this phenomenon, such as laboratory chemical analysis, have the number of limitations. They are labor-intensive, time-consuming and do not always allow for prompt assessment of a pollution degree. In this regard, there is the growing interest in modern instrumental methods, including terahertz (THz) and infrared (IR) spectroscopy and gas chromatography, which provide high accuracy, high speed of analysis and the ability to automate monitoring. THz waves are sensitive to fluctuations in the hydrogen bonds and large molecular complexes, which allows them to be used to assess phytoplankton biomass and degree of organic pollution. IR spectroscopy, especially in combination with Fourier transform spectroscopy, is effective for detecting dissolved nutrients such as nitrates (NO_3^-) and phosphates (PO_4^{3-}) by their characteristic absorption bands. Gas chromatography with mass spectrometry (GC-MS) is used to analyze volatile organic compounds released by cyanobacteria during metabolism. In the report the development directions of portable THz and IR spectrometers, as well as their integration with machine learning algorithms for early warning of environmental risks are discussed.

The work was performed according to the Government research assignment for TSU, project FWRW-2025-0038.

G-9

SPECTRAL OPTICAL CHARACTERISTICS OF CHROMOPHORIC DISSOLVED ORGANIC MATTER IN MEROMICTIC WATER BODIES OF THE WHITE SEA COAST

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Natural waters always contain chromophoric dissolved organic matter (CDOM), which plays an important role in natural biogeochemical processes. Its composition and concentration determine the optical properties of natural water, which affects the functioning of aquatic ecosystems. From the point of view of studying composition and distribution of CDOM, the meromictic water bodies are of particular interest. The meromictic water reservoirs are those with stable vertical stratification, which occurs due to the difference in the density of water layers. The examples of such reservoirs are coastal reservoirs isolated from the White Sea, which density stratification is the result of overlapping seawater with fresh runoff. Natural CDOM effectively absorbs the UV light and emit fluorescence, therefore absorption and fluorescence spectroscopy are widely utilized for its study. The aim of this work is to compare the spectral and luminescent properties of natural CDOM in several meromictic water bodies with sulfide anoxia located on the coast of the Kandalaksha Gulf of the

White Sea. These reservoirs differ in the vertical distribution of hydrological characteristics, and due to this, differences in the chemical composition and optical properties of CDOM are possible.

To study CDOM, water samples were filtered through nylon filters with a pore size of 0.22 μm before spectral measurements. Absorption spectra were recorded using Solar PB2201 spectrophotometer, fluorescence spectra were measured with Solar CM2203 luminescence spectrometer at excitation wavelength λ_{ex} varying from 250 to 500 nm. The absorbances decrease along with rising wavelength, with a small "shoulder" noticeable around 260–270 nm due to the presence of phenolic groups or aromatic amino acids. When excited at 270 nm, the CDOM fluorescence spectrum shows two overlapping bands: a "protein-like" band with a maximum at 300–350 nm and a humic type emission band with a maximum at 450–500 nm. The dependence of the wavelength of the spectrum maximum λ_{max} on the λ_{ex} is non-monotonic, the shift of the maximum of the emission towards shorter wavelengths with a change in the λ_{ex} from 280 to 310 nm corresponds to the so-called "blue shift" characteristic of natural humic substances. With a further increase in λ_{ex}, the emission maximum shifts towards longer wavelengths. An informative optical indicator for natural CDOM is the fluorescence quantum yield. Its dependences on the λ_{ex} in different water bodies have a similar character (maxima are observed at 340 and 370–390 nm), but the absolute values of the fluorescence quantum yield vary significantly in water layers taken at different horizons, which may indicate the variability in the CDOM structural characteristics.

Studies of this kind are important for understanding the mechanisms of formation of CDOM optical properties in natural waters of various origin, studying the habitat conditions of microbial communities through the water column, as well as for understanding the evolution of meromictic water bodies and for developing methods for environmental monitoring of water bodies with sulfide anoxia, including relict water bodies of the Arctic zone.

The study was supported by the Russian Science Foundation (grant N 24-24-00008; https://rscf.ru/project/24-24-00008/).

G-10

MEASUREMENT OF CONCENTRATION OF VETERINARY ANTIBIOTICS IN SOIL EXTRACTS AND NATURAL WATER USING SPECTRAL METHODS

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The uncontrolled spread of antibiotics in wastewater and natural environments currently poses a serious environmental threat in all countries. This is primarily due to the accumulation of genes of resistance to pharmacological drugs in bacteria, as well as the disruption of the stable functioning of all trophic levels of ecosystems. In such industries as agriculture, veterinary medicine and fish farming, pharmaceuticals are widely used not only as therapeutic and prophylactic agents, but also to stimulate growth. Therefore, the development of rapid methods for detecting antibiotics in natural environments is extremely relevant.

The work studied the spectral characteristics of three antibiotics (tylosin, tetracycline, ciprofloxacin) of different concentrations in the presence of organic substances of natural origin or by-products of animal husbandry (natural water, aqueous extracts of soils and organic fertilizers). Absorption spectra were measured in quartz cuvettes using a Solar PB2201 spectrophotometer, and fluorescence spectra were registered using a Solar CM 2203 luminescence spectrometer.

All three antibiotics demonstrated absorption bands in the UV region, which were separated by mathematical processing from the broad background of absorption of natural organic matter of water, soil or organic fertilizers, monotonically decreasing with rising wavelength. The concentration of the antibiotic was determined by the area of the absorption band or optical density at a fixed wavelength using calibration dependencies. In this way, it is possible to determine concentrations of tylosin up to 100 mg/l, and for tetracycline and ciprofloxacin up to 60 mg/l. At higher concentrations it is necessary to dilute the samples or use the absorption at longer wavelengths.

Fluorescence spectroscopy was also used to monitor concentrations of ciprofloxacin below 5 mg/l. The emission band of ciprofloxacin partially overlaps with the fluorescence band of organic matter in water and soil, so to isolate the contribution of this antibiotic to the spectra, synchronous fluorescence spectra were measured with a constant difference in excitation and recording wavelength equal to 160 nm. In this case, the antibiotic concentration was determined by the area of the synchronous fluorescence spectrum band in the UV range of 270–370 nm after subtracting a similar spectrum measured for a sample without antibiotic.

The studies are being carried out within the framework of the RSF project N 5-24-00486.

G-11

PHOTOACOUSTIC SPECTROMETER BASED ON THE HELMHOLTZ RESONATORS AND QUARTZ FORK RESONATORS FOR ENVIRONMENTAL AND MEDICAL APPLICATIONS

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Eutrophication of water bodies caused by excessive input of biogenic elements leads to mass reproduction of phytoplankton and cyanobacteria that secrete toxins. The traditional monitoring methods are time-consuming. In this regard, the development of compact and highly sensitive devices for express analysis of eutrophication marker gas emissions in the field is relevant. The photoacoustic spectrometer (PAS) is a suitable tool for this task. PAS allows monitoring eutrophication markers: methane, carbon dioxide, methanol, dimethyl sulfide, chlorophyll-a, pheophytin, and dissolved organic matter. Helmholtz resonators and quartz tuning forks (QTFs) are used to amplify the acoustic signal in PAS. QTFs provide high sensitivity, resistance to external noise and response speed, but are demanding on radiation characteristics. Helmholtz resonators can be used for a wide range of sources, which increases the range of target molecules. Using PAS based on QTFs and Helmholtz resonators are relevant for highly sensitive monitoring of the concentration of the wide range of the eutrophication markers.

The work was performed according to the Government research assignment for TSU, project FWRW-2025-0038.

G-12

THE MOBILE TERAHERTZ SENSOR COMBINED WITH THE MULTI-PASS CYLINDRICAL CELL WITH VARIABLE OPTICAL PATH LENGTH FOR ENVIRONMENTAL AND MEDICAL APPLICATIONS

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The problem of surface water pollution is becoming more and more urgent every year. Eutrophication leads to the disruption of normal biogeochemical processes in water bodies and, as a consequence, swamping due to mass reproduction of aquatic plants and pathogenic microflora. The processes of anaerobic decomposition of organic matter and bacterial activity lead to an increase in greenhouse gas emissions from the surface of water bodies. In addition to the main greenhouse gases (CH_4 and CO_2), gas emissions from swamps are characterized by NH_3, H_2S, C_2H_6, PH_3, CO, H_2, as well as more complex hydrocarbons such as propane and ethylene.

Monitoring of these gases in the field can be implemented using terahertz and infrared absorption spectrometers. Mobility is the critical parameter when working in the field, so classic single-pass cells are too cumbersome. In this context, the multi-pass cylindrical Heriott cells are of particular interest, as they feature the ability to increase the optical path length while maintaining a small physical size and volume. The paper discusses the mobile terahertz sensor using the multi-pass cylindrical cell with variable optical path length, suitable for environmental and medical applications.

The work was performed according to the Government research assignment for TSU, project FWRW-2025-0038.

Session H
PHOTOPHYSICAL PROCESSES, CONVERSATION OF LASER RADIATION, NONLINEAR OPTICS AND LASER SYNTHESIS OF NANOSTRUCTURES

H-1

NEW POSSIBILITIES OF PARAMETRIC FREQUENCY CONVERTERS OF LASER EMISSION IN OXIDE NONLINEAR CRYSTALS

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For the first time specific optical properties of negative biaxial nonlinear LBO crystal are discovered that allows someone to create new type of parametric frequency converters with extended output parameters for application in Lidar systems. These sources are operating in the long wavelength part of the mid-IR and/or THz ranges, and demonstrate specific abilities. In particular, it is shown that someone can transfer one-by-one all three samples of the crystal cut orthogonal to its optical axes by temperature control into single axis ones. When all three above mentioned samples will change their signs the crystal will became a positive one. New crystal sign allows someone to realize respective another types of the frequency conversion processes. The crystal temperature control also allows someone to shift the crossing points, i.e. to optimize the frequency conversion processes.

The valence of the Ga and Se in the GaSe is equal to 1. The Al valence is equal to 3. However, it is established that doping with Al is possible but limited by about 1% level. The doping is due to both by intercalation process into growth layers and into interlayer spaces. The Al doping results in sever increases of the crystal hardness, but no significant changes have been observed in the optical loss coefficient. Frequency conversion into the THz range in ultra thin, down to single layer, GaSe samples are also considered.

H-2

NONLINEAR OPTICAL GENERATION OF TERAHERTZ RADIATION IN THE VICINITY OF PHONON ABSORPTION OF CRYSTALS

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Terahertz (THz) frequency use creates opportunities for future telecommunications system development, necessitating the search for new materials and technologies that can function in the presently underutilized spectral region. Since modern telecom systems are based on optical solutions, an important task is to increase the efficiency of wave mixing processes of optical and THz radiation. Such processes are signal generation/detection and modulation/demodulation. These interactions are possible due to nonlinear-optical effects in crystals, but their efficiency remains relatively low at about 0.01%. The efficiency can be significantly increased by converting frequencies near the regions of resonant phonon absorption of the media where the value of the nonlinear coefficient increases radically. A method for producing THz radiation by increasing the laser's frequency conversion efficiency close to phonon resonance is covered in the report. Calculations are presented for various types of media ranging from simple single-phonon semiconductors to complex molecular crystals and ferroelectrics.

The work is carried out with the support of the Russian Science Foundation, project N 24-22-00442.

H-3

LASER FLASH PHOTOLISIS OF THE DERIVATIVES BASED ON BENZOTHIAPHENE – ACID PHOTOGENERATORS

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Photochemical acid generators (PAG) are compounds that decompose under the influence of light to form acids. PAG are a key material in microlithography, cationic photopolymerization and are increasingly used in biology, in particular, in the synthesis of oligonucleotides. In this work, photolysis of chloro- and sulfo-substituted benzothiophene carboxanilides was carried out using the 3rd harmonic radiation of a NdYAG laser (355 nm) in solutions. During the irradiation process, an acid is formed, the detection of which is recorded by the formation of a protonated form of the compound 4,6-Bis(5-(9-ethyl-9H-carbazol-3-yl)thiophen-2-yl)pyrimidine, which serves as an indicator. The mechanism of phototransformation of the studied compounds is discussed, and the quantum efficiency of acid photogeneration is assessed depending on the nature of the solvent used.

The study was carried out within the framework of state assignment N FEWM-2024-0001.

H-4

FORMATION OF BISMUTH OXOHALIDE NANOSTRUCTURES BY LASER PLASMA TREATMENT OF BISMUTH NPs IN AQUEOUS SOLUTIONS OF POTASSIUM HALIDES

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High-energy laser irradiation is an effective tool to synthesize nanomaterials with unique properties that find application in various fields. In recent years, great progress has been made in understanding the mechanisms and controlling the processes of nanoparticle formation and the variability of approaches in laser synthesis. This allows for targeted production of complex nanostructures with specified parameters and properties, such as core@shell, decorated and composite nanoparticles.

This paper presents the results of a study of the laser synthesis of complex semiconductor oxides, namely, bismuth oxohalides Bi*OX* (X = Cl, Br, I), which are promising as photocatalysts. A colloidal solution of metallic bismuth nanoparticles was preliminarily obtained by pulsed laser ablation in water, to which a halogen precursor was added. Then, the colloid was irradiated with focused laser radiation to forma plasma in the beam waist region. It is shown that such a plasma mode of laser treatment facilitates particle fragmentation and the interaction of bismuth with the corresponding halogen, which leads to the effective formation of layered particles of bismuth oxohalides. As a result of the developed approach, nanostructures of tetragonal BiOCl and monoclinic $Bi_4O_5Br_2$ and $Bi_4O_5I_2$ bismuth oxohalides were obtained.

The photocatalytic properties of the synthesized nanoparticles were investigated in the selective oxidation of 5-hydroxymethylfurfural (5-HMF). It was found that the catalysts $Bi_4O_5Br_2$ and $Bi_4O_5I_2$ exhibited high conversion and selectivity in the 5-HMF oxidation to high-added-value products 5-formyl-2-furancarboxylic (FFCA) and 2,5-furandicarboxylic (FDCA) acids.

This work was supported by the Russian Science Foundation (grant N 19-73-30026-P).

H-5

QUANTUM-CHEMICAL CALCULATIONS OF STRUCTURAL AND ELECTRONIC PROPERTIES OF Gd AND Zn METALLATED PORPHYRIN DERIVATIVES INTENDED FOR PHOTOMEDICINE

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Metallated porphyrin derivatives and their diades are increasing interest in the photophysics of coordination compounds for applications in medical diagnostics and therapy. Complexes with gadolinium have significant practical potential, as it acts as a source of paramagnetic and radiopharmaceutical properties, as well as an amplifier of the spin-orbit interaction of singlet-triplet transitions, leading to an increase in the intensity of oxygen-dependent phosphorescence. Zinc tetraphenylporphyrin (ZnTPP) and its functional derivatives are convenient model complexes for use in biochemical processes, catalysis, and materials science. The porphyrin fragment often acts as a photosensitizer, which explains the use of Zn-porphyrins in chemical sensors and phototherapy. All metallated derivatives inherit intense absorption bands in the near-UV and visible regions (Soret band ~ 420–440 nm) and weak long-wavelength Q-bands (500–600 nm) of porphyrin.

Using quantum chemical calculations of optimized structures, molecular orbital energies, and thermodynamic parameters, the formation of metallated porphyrin derivatives from crystalline salts and dibasic porphyrin in the presence of solvent molecules was investigated. The obtained data allowed for a discussion of the electronic structure features and their influence on the optical transitions of the studied coordination compounds.

Based on calculations, it was shown that for porphyrin complexes with gadolinium, the energetically most favorable multiplicity is 7, which in turn does not allow theoretically studying the spectral-luminescent properties of such compounds within the framework of modern methods of excited-state calculations. However, an analysis of their electronic structures provides a qualitative picture of excited-state energy dissipation.

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H-6

OPTICAL PROPERTIES OF THE BULK β-BBO CRYSTAL GROWN FROM $BaO–B_2O_3–Na_2O–WO_3$ SYSTEM

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Achieving maximum efficiency when using nonlinear optical crystals depends not only on their intrinsic physical properties but also on the level of crystal growth technology, which determines the final quality and size of the produced samples. The beta-barium borate (β-BBO) crystal is one of the most widely used materials for nonlinear optical frequency conversion in the visible and ultraviolet spectral ranges. Although this crystal was first synthesized in the late 1980s, the search for new growth techniques that allow for larger high-optical-quality elements remains a relevant challenge.

This work presents a comparison of the optical properties of β-BBO crystals grown from a promising flux system — $BaO–B_2O_3–Na_2O–WO_3$ — and those grown from the reference system $BaB_2O_4–NaBaBO_3$. The use of the novel flux system resulted in an increased defect-free region in the final crystal, with only a slightly lower growth yield (1.54 g/kg · °C vs. 1.69 g/kg· °C) compared to the reference flux system.

Optical properties were measured across a broad spectral range (0.26–2000 μm) using polarized radiation. A prism spectrophotometer Cary 100 (Varian, Australia) with film polarizers was employed in the wavelength range of 0.26–0.75 μm. For the range 0.65–3.2 μm, a Cary 5000 spectrophotometer (Varian, Australia) with holographic KRS-5-based polarizers was used. Mid-infrared measurements from 2.5 to 30 μm were carried out using a Tensor 27 Fourier-transform infrared (FTIR) spectrometer (Bruker, Germany), also equipped with KRS-5-based polarizers. Additionally, a ccustom-made time-domain terahertz spectrometer with a tandem polarizer setup was used to collect data in the 200–2000 μm range.

The β-BBO crystal grown from the novel flux system demonstrated superior optical quality: on average, three times lower absorption coefficient in the visible range and reduced absorption in the THz spectral region compared to those from the reference system.

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H-7

SYNTHESIS OF NANOCARBON FILM STRUCTURE ON THE POLYIMIDE FILM SURFACE USING PULSED DIODE LASER

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The synthesis of nanocarbon porous electrically conductive film structures by laser pyrolysis of polyimide film surface in air has found widespread application in the development and creation of microsupercapacitors, a variety of flexible electronics devices for everyday wear, and a wide range of detectors and sensors for multiple purposes. In the relevant literature, this material is referred to as "laser-induced graphene" (LIG).

This report presents the findings of an investigation into the synthesis of LIG by means of pyrolysis of polyimide film surfaces using radiation from commercial pulsed-periodic diode lasers operating at a wavelength of 450 nm. The synthesis was conducted in both line-by-line and raster modes. The output power of the laser heads was regulated by pulse-width modulation. The temporal profile of the heads' radiation has been observed to vary according to the level of conditional power (expressed in percentage). As demonstrated in the research, at an average laser power of more than 0.12 W, depending on the treatment mode (line-by-line or raster), it is possible to synthesize LIG with different thickness, structure and water wettability. It has been established that LIG synthesized in raster mode is more heterogeneous in thickness and structure than that obtained in line-by-line mode. It has been demonstrated that in order to execute a valid comparison of the parameters of LIG obtained using different diode lasers, it is imperative to control the radiation parameters using calibrated measurement tools.

The research was performed under the auspices of a state assignment (state reg. N 1022040600237-3-1.3.2) of the Ministry of Science and Higher Education of the Russian Federation, utilizing the equipment of Core shared research facilities "Center of physical and physical-chemical methods of analysis, investigations of properties and characteristics surface, nanostructures, materials and samples" of UdmFRC UB RAS.

H-8

THz IMAGING AT DIFFERENT FREQUENCIES WITH SINGLE-COLOR FILAMENTATION

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The study experimentally demonstrates terahertz imaging at frequencies ranging from 1 to 10 THz using femtosecond filamentation. When terahertz radiation with a hollow-cone angular distribution is generated during single-color filamentation without an external electrostatic field, the irregular structure leads to poor image quality. However, applying an external electrostatic field results in an axisymmetric unimodal angular pattern of the terahertz radiation, significantly enhancing the image quality. To illustrate the method, images of a multi-component inhomogeneous object at various terahertz frequencies were obtained, enabling the analysis of its spectral and spatial properties. The results show that terahertz radiation from laser filaments can be effectively used for imaging complex objects.

H-9

PHOTODYNAMICAL DEPROTONATION OF PHENOL-SUBSTITUTED ENVIRONMENTAL POLLUTANTS

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Many phenol-substituted including the parent molecule are classified as a hazardous pollutant due to wide using in various chemical industries and petrochemical production. The development of sensitive analytical approaches requires quantitative information about spectral characteristics as well as photodissociation processes of the target pollutants among the other tools. On the other hand, diagnostic and treatment using ultrafast photodynamic processes based on femtosecond lasers are swiftly being developed and applied in therapy. The rapid development of such technologies has facilitated the detection and observation of ultrafast including femtoseconds electron excitations with following dissipations and transformations in chromophore molecules. This progress has, in turn, driven the advancement of theoretical methods to study such processes.

The research protocol for comprehensive spectral-luminescence and photodynamical analysis of vibronic transitions with quantum-classical static optical spectra, conical intersection and nonadiabatic molecular dynamic approaches was suggested and applied to study photoinduced phenol, p-cresol and vanillin deprotonation in vacuum and aqueous solvent. The specific conditions of hydroxyl bond cleavage and process evolutions for each the compound were elucidated using the methods.

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H-10

4,6-BIS(5-(9-ETHYL-9H-CARBAZOL-3-YL)THIOPHEN-2-YL)PYRIMIDINE AS AN INDICATOR OF PHOTOGENERATED ACIDS

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At certain stages of many technological processes (initiation of the polymerization reaction, synthesis of oligonucleotides) it is necessary to include acid. For these purposes, acid photogenerators (APG) are used – compounds that decompose under the influence of light to form acids. Currently, APGs are an important component of many materials for dentistry, printing inks, varnishes, etc. To control the formation of acid during the irradiation of APG, an instrument (indicator) is required that changes its properties in an acidic environment. In this paper, 4,6-Bis(5- (9-ethyl-9H-carbazol-3-yl)thiophen-2-yl)pyrimidine is proposed for this purpose, which reacts subtly to the presence of acid in the environment with the formation of a protonated form and, importantly, visually changes the color of the solution to bright crimson. In addition, the advantages of this indicator are its operation in organic aprotic solvents and the spectral location of the protonated form in the region free from absorption of APG. Using the proposed indicator, the effectiveness of a number of new FGCs was assessed.

The study was carried out within the framework of state assignment N FEWM-2024-0001.

H-11

DETRILATION OF PHOSPHORAMIDITES BY PHOTOGENERATED ACIDS

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At certain stages of oligonucleotide synthesis, it is necessary to "open" the functional groups of the oligonucleotide chain that have been protected until then. This primarily concerns the hydroxyl group at the 5' position of the carbohydrate moiety of the nucleoside protected with dimethoxytrityl (DMT). Traditionally, this process is carried out by introducing dichloroacetic acid or trichloroacetic acid of a certain concentration. In recent years, there has been a trend towards using photogenerated acids formed by irradiating reagents with light. During the detrilation process, the DMT cation is formed, which is easily detectable in the absorption spectrum at a wavelength of 506 nm and colors the solution orange. In this work, 15 new compounds with halogen and sulfonic acid substituents were investigated for photogeneration of acids upon irradiation with the 2nd harmonic of a NdYAG laser and the efficiency of removing the DMT group from amidophosphits in different solvents.

The study was carried out within the framework of state assignment N FEWM-2024-0001

H-12

UV RADIATED DEGRADATION OF DRUGS IN WATER

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Ultraviolet (UV) radiation is a powerful tool for studying the stability of drugs and their photodegradation products. The photophysical and photochemical reaction pathways of drugs exposed to UV light are important to ensure their efficacy and safety throughout their shelf life.

UV irradiation has been used to model both drug aging and to conduct a more in-depth analysis of the photoproducts formed. Antibiotics and antivirals have been selected. It is especially important to understand what leads to the formation of toxic photoproducts. Environmental factors such as light, temperature and humidity also affect drug stability. The diagnosis of residual amounts of the active substance, identification and characterization of photoproducts formed as a result of their degradation are important for assessing drug safety. UV-Vis spectroscopy allows determining the amount and presence of photoproducts. This is important for understanding the potential toxicity The report will discuss the spectral and luminescent characteristics of sulfanilamide, paracetamol and chloramphenicol in biological systems using electron spectroscopy and luminescence. The spectra of drug compounds with components of biological systems were obtained using a Shimatzu UV-1700 spectrophotometer and a VARIAN Cary 5000 Scan UV-VIS-NIR and VARIAN Cary Eclipse spectrofluorimeter (AgilentTech, USA-Netherlands-Australia) in the range from 200 to 1100 nm. The patterns of interaction of drug compounds (sulfanilamide, paracetamol, chloramphenicol) with components of the biological system were revealed using the fluorescence quenching method.

H-13

PHOTOLYSIS AND RADIOLYSIS OF PARACETAMOL

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The widespread production and use of pharmaceuticals leads to their release into the environment. Incomplete removal of drugs and their metabolites at wastewater treatment plants has become the reason for their accumulation in surface waters. The use of e-beam installations holds great potential for reducing the concentration of unwanted pollutants, among which pharmaceutical compounds are among the most common. This work focuses on studying the efficiency of paracetamol transformation, synthesized by the commercial firm Central Drug House (P) Ltd. Co. (art. 001205, CAS 103-90-2, New Delhi, India) with a guaranteed purity of 99%, in water under the action of e-beam radiation. Experiments on irradiation were conducted using a vertical e-beam from the RADAN-300 generator installed in the laboratory of quantum electronics (Institute of Electrophysics, Ural Branch of the Russian Academy of Sciences, Ekaterinburg, Russia). The studied paracetamol solution $C = 1$ mm was irradiated with a pulsed e-beam with a duration of 2 ns, an average electron energy of 170 keV, and a current of 130 A, resulting in an energy density in the beam pulse of 44.2 mJ/cm^2. The number of irradiation pulses with a repetition rate of 1 Hz varied from 50 to 3200 After irradiation, the resulting sample was diluted to $C = 0.1$ mm with distilled water to record the absorption and fluorescence spectra. To assess the efficiency of transformation, the conversion of paracetamol after irradiation with an e-beam was calculated. Folin-Ciocalteu reagent was used to determine the total phenol content in the products of paracetamol transformation.

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H-14

HIGH-POWER PULSED FIBER LASER WITH SECOND HARMONIC GENERATION

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The design, fabrication, and experimental investigation of a pulsed fiber laser with an average output power of 1 kW have been performed. The pulse duration is 25 ns and the repetition rate is 2–4 MHz. The laser is assembled according to the MOPA scheme, in which the master oscillator is a semiconductor laser diode with a wavelength of 1064 nm and linear polarization.

The laser radiation is converted into the second harmonic with output average power of 250 W.

H-15

INVESTIGATION OF SHG IN $TbAl_XGa_{3-X}(BO_3)_4$ CRYSTALS BY THE KURTZ-PERRY METHOD

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The widespread use of lasers devices in various fields requires improvement and optimization of the physical parameters and structural qualities of known optical materials that have already proven themselves in practice, with further control of their properties. Among them one can highlight the huntite family compounds with the general formula $LnM_3(BO_3)_4$ (Ln = La–Lu, Y; M = Al, Ga, Sc, Cr, Fe; space group: *R*32). Pure and activated huntite family compounds as well as their-based solid solutions are promising materials for lasers, nonlinear optics, and photonics, which are characterized by multifunctional properties depending on a composition and crystal structure.

This work is dedicated to study the second harmonic generation (SHG) response in new terbium orthoborates ($TbAl_xGa_{3-x}(BO_3)_4$) crystals using the Kurtz-Perry powder test. The dependences of the effective nonlinearity coefficient (d_{eff}) and the laser damage threshold on the Al/Ga ratio in the crystals chemical composition were determined.

The work was supported by Russian Science Foundation (project N 23-19-00617).

H-16

CONTRIBUTION OF THE ABSORPTION OF RADIATION FROM THE STOKES COMPONENT OF THE SRS OF PULSED SOLID-STATE LASERS BY ATMOSPHERIC GASES TO THE SIGNAL OF AN OPTICAL-ACOUSTIC DETECTOR

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The method of optical-acoustic detection is used to study the dependence of the absorption of gas medium and atmospheric air on the intensity of the laser pulse interacting with the gas. The small length of the gas cell of the optical-acoustic detector allows, when focusing the radiation, to obtain intensity values under study, at which, along with the radiation of the excitation laser, the Stokes component of the SRS is generated (in atmospheric nitrogen).

In laser wavelength tuning, the wavelength of the Stokes component is also tuned and can be absorbed by the molecular components of the air, contributing to the value of the recorded signal.

The report estimates the value of this additional absorption for two types of solid-state lasers Nd: YAG and Nd: YLF and the molecular components of atmospheric air CO, SO_2, CH_4, C_2H_2, N_2O, NH_3 using an optical-acoustic detector.

H-17

PHOTOPHYSICAL PROCESSES IN ZINC PORPHYRIN OLIGOMERS

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The meso-to-meso ethyne-bridged zinc(II)-porphyrin oligomers exhibit unique photophysical properties, including high fluorescence quantum yields in the near-infrared region, minimal solvent sensitivity, and exceptional stability. A particularly intriguing aspect is the nonlinear dependence of their quantum yield on the number of monomer units.

In this work, we conducted a comprehensive investigation of the photophysical properties of a series of meso-to-meso ethyne-bridged zinc(II)-porphyrin oligomers (PZn_n, n = 2–5) using TDDFT and CC2 computational methods. Our findings reveal that as the number of monomer units (n) increases, the S_1 excitation energy decreases from 16400 cm^{-1} for $n = 2$ to 12500 cm^{-1} for $n = 5$, while the oscillator strengths show a corresponding increase.

A detailed analysis of the photophysical rate constants indicates that for the dimer ($n = 2$), fluorescence quenching occurs predominantly through $S_1 \rightarrow T_2/T_3$ intersystem crossing, with an exceptionally high rate constant ($k_{ISC} \sim 10^{10}\ s^{-1}$) due to the small energy gap (~ 0.02 eV) and significant spin-orbit coupling matrix elements (5.4 cm^{-1}). This rapid intersystem crossing process accounts for the dimer's low fluorescence quantum yield of just 1%. The relative positions of the T_2/T_3 energy levels in the dimer are influenced by the nature of the substituents, which explains the observed variations in quantum yields. For oligomers with $n \geq 3$, the primary deactivation pathway of the S_1 excited state shifts to internal conversion.

The nonlinear dependence of fluorescence quantum yield in the series of zinc(II) porphyrin oligomers (PZn_n, n = 2–5) can be explained by the competition betweeb two factors: the increase in radiative rate constants and the enhanced probability of nonradiative processes as the number of monomer units increases.

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H-18

SOME VARIANTS OF SOLVING THE PROBLEM OF GENERATING THE SECOND HARMONIC OF LASER RADIATION IN NONLINEAR UNIAXIAL CRYSTALS

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The theory of harmonic generation (HG) in quadratically nonlinear uniaxial crystals is an important section of nonlinear optics, which explores the possibilities of expanding the spectral range of laser radiation (LR) by means of such nonlinear processes as second harmonic generation (SHG), as well as the generation of sum and difference frequencies. The area of practical applications of devices based on LI harmonic generators is extremely broad – from various scientific tasks to industrial installations, for example, isotope separation. Research aimed at highly efficient harmonic generation, which allows obtaining coherent radiation in spectral ranges where it is impossible to obtain laser radiation, is the most relevant. In general, the implementation of HG processes with sufficient power for practical purposes involves solving an optimization problem – determination of conditions that ensure maximum efficiency of nonlinear transformation. At this stage the theoretical studies of the characteristics of the selected nonlinear process become an extremely desirable condition for the successful solution of the formulated problem. It is known that the theory of HG is based on the solution of the corresponding systems in the general case of three nonlinear wave equations, the specific form of which is found directly from the Maxwell's equations.

In the paraxial approximation, which is used in the overwhelming majority of theoretical studies, the mentioned system of vector equations is reduced to a system of truncated scalar equations for complex amplitudes of interacting waves, which are also called "slowly varying". For the specified approximation, in this paper the general solution of the system of truncated equations is presented in the form of fairly simple recurrent formulas, which are convenient for carrying out numerical calculations. A special case that is important for practice is considered in detail: the approximation of a given field, within the framework of which the solution of a nonlinear problem is significantly simplified and reduced to the numerical calculation of a double integral.

H-19

SINGLE- AND TWO-PHONON EXCITED FLUORESCENCE OF LIQUID AEROSOL. DEPENDENCE ON FLUOROPHORE CONCENTRATION AT DIFFERENT LASER INTENSITIES

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The fluorescence pattern of Rhodamine 6G from a liquid aerosol was studied experimentally with varying concentration of the fluorophore irradiated by nanosecond laser pulses with a wavelength of 1.06 μm. A dependence of the fluorescence signal in the "backward" direction on the concentration of R6G molecules was found: with an increase in the fluorophore concentration from 10^{-2} to 5% in an ethanol solution, a decrease in the fluorescence intensity by almost two times is observed for both single-photon-excited fluorescence and two-photon fluorescence. The fluorescence signal increases with increasing pump energy. At high dye concentrations, signal saturation with increasing pump energy is observed for single-photon excited fluorescence. For two-photon fluorescence, the energy dependence is preserved even at high concentrations. The dependence of the fluorescence radiation pattern shape at different dye concentrations and pump energies is established.

H-20

STABILITY OF SELF-CHANNELING OF LASER PULSES IN A KERR-NONLINEAR TURBULENT MEDIUM

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The effect of self-channeling of laser pulses in a Kerr-nonlinear turbulent medium is theoretically investigated. It is shown that there are conditions for stable nonlinear propagation of laser radiation in a turbulent medium. The modes of weak and strong phase fluctuations of a light wave are considered. A model of a diffraction-ray tube under conditions of fluctuations in the permittivity of the medium is used to describe the laser beam.

H-21

EVALUATION OF THE EFFECTIVE NONLINEAR SUSCEPTIBILITY OF THE $LiNa_5Mo_9O_{30}$:Li CRYSTAL OBTAINED BY SPONTANEOUS CRYSTALLIZATION

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The optical crystal $LiNa_5Mo_9O_{30}$ is a promising material for nonlinear optical applications. It exhibits a broad transparency range from 357 to 5260 nm. Compared to the well-known nonlinear crystal LBO, which belongs to the same *mm*2 point group symmetry, it demonstrates on average four times higher values of effective nonlinear susceptibility coefficients, while having a similar bulk optical damage threshold – approximately 2.6 GW/cm^2 under nanosecond laser pulses.

In this work, the optical and nonlinear optical properties of powdered samples of $LiNa_5Mo_9O_{30}$ and $LiNa_5Mo_9O_{30}$:Li crystals were investigated. The crystals were grown by spontaneous crystallization using a low-gradient Czochralski technique at the Institute of Geology and Mineralogy SB RAS and the Institute of Inorganic Chemistry SB RAS.

The bandgap energies of the studied materials were determined using the Tauc plot method and derivative absorption spectrum fitting (DASF). The powder second-harmonic generation (SHG) test based on the Kurtz–Perry method was employed to evaluate the effective nonlinear susceptibility of the crystals. Fractionated samples of LBO and KTP nonlinear crystals were used as reference materials in the powder test.

The studied nonlinear crystals demonstrate an unusually strong dependence of the intensity of second-harmonic generation (SHG) of Nd:YAG laser radiation on the particle size compared to the reference samples. For large particle sizes, the SHG intensity of the $LiNa_5Mo_9O_{30}$ crystal grown from a melt with excess lithium concentration was found to be 6 times higher, whereas for the sample obtained from a stoichiometric melt composition – 4 times higher than that of the LBO crystal.

H-22

ORGANIC LIGHT-EMITTING DIODES BASED ON FLUORENE COPOLYMERS

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Based on a number of copolymers of (9,9- dioctyl) fluorene, OLED devices were obtained, that emit on the blue, yellow and red regions of the spectrum. The highest value of current efficiency at a brightness of 1000 cd/m^2 was 1.75 cd/A for a device emitting in the yellow region of the spectrum; the lowest was 0.28 cd/A for a device emitting in the blue region of the spectrum.

Fluorene copolymers were investigated, which were modified by introducing various monomers into the main chain: 9,9-bis-(4-diphenylaminophenyl) fluorene (DPAPF), 9,9-bis-(6,6'-diethoxyphosphorylhexyl) fluorene (DEPHF), 2,1,3-benzothiodiazole (BT), 4,7-bis(5-thienyl)-2,1,3-benzothiodiazole (TBT), N-[6-(carbazol-9-yl) hexyl]-[(tetrahydrooxazine-1,4)-4-yl]-1,8-naphthalimide (NI), 1,4-difluorobenzene (DFB), triphenylamine (TPA). The copolymers were obtained by polycondensation according to the Suzuki mechanism.

Polymer RI-2 contained 50 mol.% fluorene units, 25 mol.% DEPHF, 17.5 mol.% EFGF, 5 mol.% BT, 2.5 mol.% TBT. Composition N-112 – 87 mol.% fluorene, 10 mol.% BT, 3 mol.% TFA. Copolymer B-27 was – 50 mol.% fluorene, 17 mol.% DPAPF, 33 mol.% DFB. B-28 differed from B-27 in that it contained not 17 mol.% DPAPF, but 16.8 mol.% DPAPF and 0.2 mol.% NI.

All fabricated OLED devices had the following structure: ITO (100 nm) / PEDOT:PSS (30 nm) / copolymer / LiF (1 nm) / Al (100 nm).

The study of the volt-ampere, volt-brightness and spectral characteristics of the created OLED structures was carried out inside a glove box in a dry nitrogen atmosphere on a measuring complex consisting of a Keithley 237 voltage analyzer source and an AvaSpec-ULS-2048×64 (Avantes) fiber-optic CCD spectrometer, pre-calibrated to perform absolute radiometric measurements using an AvaSphere-50-LS-HAL-CAL spherical lamp.

Electroluminescent characteristics of devices based on the selected copolyfluorenes were obtained. The emission of the RI-2 copolymer has color coordinates of 0.570; 0.385 (red-orange emission), N-112 – 0.370; 0.585 (yellow-green); B-27 – 0.210; 0.235 (blue) and B-28 – 0.165; 0.90 (blue).

The maximum brightness of the RI 2 -based OLED reached 180 cd/m^2 at a voltage of 15 V. The other OLEDs showed significantly higher results:

N-112 – 4600 cd/m^2 (10 V), B-27 – 1030 cd/m^2 (10 V), 2030 cd/m^2 (10 V).

The study reveals that fluorene-based copolymers can achieve efficient electroluminescence over the full visible range, though red-emitting structures necessitate more precise structural design.

The work was supported by Russian Scientific Foundation (Grant N 23-73-10081).

PLENARY SESSION

P-1

DISTINCTIVE FEATURES OF THE IR SPECTRA OF CRUDE OIL OF THE ABSHERON PENINSULA

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The present study determines the feasibility of using Fourier transform infrared spectroscopy (FTIR) as a substitute for traditional petrochemical methods for determining the characteristics of crude oil and various methods for determining the source of a crude oil leak. FTIR provides very important information about the chemical composition and various chemical inclusions of crude oil. For example, the presence or absence of functional groups of hydrocarbons can be quantified. It is known that there are 12 oil and gas producing companies (OGPC) in the Republic of Azerbaijan, including 8 owned by Azerbaijan and 4 owned by joint-stock companies. Experience shows that in most cases of an oil spill, it is desirable to have more than one experimental method to determine the source of the alleged spill of crude oil and its properties. In our previously published articles, we described the results of analyzing the spectra of laser-induced fluorescence and combinational light scattering of crude oil samples taken from 12 OGPC in Azerbaijan and discussed their distinctive features in the observed spectra. In this article, we present the results of IR transmission spectra of crude oil samples taken from 12 OGPC in the Republic of Azerbaijan. These data will be used to create a Database of IR absorption spectra of crude oil producing in the Republic of Azerbaijan.

P-2

RESEARCH PROGRESS OF GREEN DISINFECTION TECHNOLOGY OF SURFACE BASED ON GAS DISCHARGE PRINCIPLE

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In recent years, major epidemics caused by respiratory pathogenic microorganisms such as the SARS-CoV-2 have raged around the world, and there have been numerous cases of pathogenic microorganisms on the surface of objects in public places such as shopping malls, hospitals and schools. Disinfection of objects is a necessary link to impede the spread of the epidemic, which is in urgent need and has a huge volume.

However, current methods such as irradiation with deep ultraviolet light (mercury lamp, LED, etc.) and spraying disinfection agents (sodium hypochlorite, peracetic acid, etc.) have strong irritation to the human body, and the disinfection speed and safety are not compatible, and it is impossible to achieve non-toxic and harmless surface disinfection under human-machine coexistence.

In this work, 222 nm far ultraviolet light was used to replace the 254 nm deep ultraviolet light while plasma-activated-mist (PAM) [3–4] was used to replace the disinfection preparation, and a composite disinfection strategy of 222 nm far ultraviolet light-PAM was formed. On the basis of optimizing the technical performance of 222 nm far ultraviolet light and PAM, this work qualitatively and quantitatively measured the key disinfection factors (ultraviolet light, discharge active particles (such as O2-, 1O2, OH, etc.). The dose-survival curves of killing common pathogenic microorganisms (Staphylococcus aureus, H1N1 virus, etc.) by deep ultraviolet light, PAM and their composite disinfection technology were obtained, respectively. The mechanism of killing pathogenic microorganisms based on the novel composite disinfection technology was initially revealed through the detection of bacterial level active oxygen species and contents leakage.

In addition, the toxicity tests of 222 nm ultraviolet light and PAM were carried out based on the double-layer/single-layer cell model, and the skin irritation, O_3 concentration and corrosiveness of mice were tested according to the relevant standards.

The work was supported by the National Key Research and Development Program (N 2023YFC2604600), Beijing Natural Science Foundation (N L233013) and the Youth Innovation Promotion Association CAS (N 2022136).

P-3

THE STUDY OF KINETICS OF N_2 AND N_2^+ ELECTRONICALLY EXCITED STATES IN SPRITES AND PULSE DISCHARGES

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To study the properties of sprites and laboratory pulse discharges, a model of kinetics of N2 and N_2^+ electronically excited states for a mixture of N_2 and O_2 gases was developed. The model includes the kinetics of the triplet ($A^3\Sigma_u^-$, Σ_u^+, $B^3\Pi_g$, $W^3\Delta_u$, $B'^3\Sigma_u^-$, $C^3\Pi_u$) states of N_2 and the doublet $B^2\Sigma_u^+$ state of N_2^+, taking into account the excitation energy transfers during inelastic molecular collisions and spontaneous radiative transitions. The quantum yields of various states in molecular collisions as a result of inelastic interactions calculated by theoretical approximations (Landau-Zener and Rosen-Zener) are taken into account. The model allows the calculation of emission intensities of bands of the first 1+ (radiative transitions $B^3\Pi_g \rightarrow A^3\Sigma_u^+$), the second 2+ (radiative transitions $C^3\Pi_u \rightarrow B^3\Pi_g$) positive systems of N_2 and the first negative 1– system (radiative transitions $B^2\Sigma_u^+ \rightarrow X^2\Sigma_g^+$) of N_2^+ in a mixture of N_2 and O_2 gases during electric discharges.

The results of modeling of the N_2 and N_2^+ emission spectra for bands of the 1+, 2+, 1– systems are compared with the results of experimental measurements at pressures corresponding to altitudes above sea level of 40–90 km. It is shown theoretically and experimentally that inelastic molecular collisions with an increase in the medium density lead to a significant decrease in the populations of various vibrational levels of the B3Πg state and a decrease in the emission intensities of the 1+ bands of molecular nitrogen N_2. The theoretically calculated and experimentally measured ratios of the spectral densities of the emission W_1^+/W_2^+ and W_1^+/W_1^- – are compared for considered pressure range. It is shown that the considered ratios strongly depend on the pressure and can be used to estimate the temperature of the discharge electrons.

For the first time, the rate constants of the interaction processes of two metastable nitrogen molecules $N_2(A^3\Sigma_u^+,\ v' = 0,1) + N_2(A^3\Sigma_u^+,\ v'' = 0,1) \rightarrow N_2(C^3\Pi_u,\ v = 0\text{–}4) + N_2(X_1\Sigma_g^+,\ v^*)$ with the formation of electronically excited molecule $N_2(C^3\Pi_u)$ were calculated. The calculation results were compared with experimental data. It was shown that similar processes involving $N_2(A^3\Sigma_u^+,\ v > 1)$ molecules are important when the relative content of molecular oxygen in a mixture of N_2 and O_2 decreases.

The Russian Science Foundation under grant N 25-22-00158 supported this study.

P-4

ADVANCES IN REMOTE SENSING TECHNIQUES FOR ATMOSPHERIC TRACE GASES

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The environmental changes occurring throughout the world have become the focus of global scientific research. Greenhouse gas emission reduction and air pollution control have significant synergy, and they have the same roots and both involve changes in atmospheric composition. The solution of atmospheric environmental problems depends on the development of environmental monitoring technology. Spectroscopy monitoring technology has obvious advantages in the field of atmospheric stereoscopic monitoring and has become the leading direction of the development of environmental monitoring technology based on its strong scalability, non-contact, high sensitivity, and wide detection targets. At present, a series of mature atmospheric optical monitoring technologies, such as differential optical absorption spectroscopy, lidar technique, cavity ring-down spectroscopy, Fourier transform infrared spectroscopy, tunable diode laser absorption spectroscopy, and laser induced fluorescence technology by gas expansion, have been developed based on satellite, ground-based, and mobile platforms. In addition, the atmospheric environmental space-air-ground integrated stereoscopic monitoring technology based on multiple platforms has played an important role in pollution and carbon reduction. Promoting the localization of monitoring equipment and the monitoring technology to stereoscopic, automated, and intelligent applications through interdisciplinary integration has become the main development direction of atmospheric environmental optics in the future.

P-5

FROM LIGHT BEAM SELF-FOCUSING TO SINGLE-CYCLE LIGHT BULLET: A HISTORICAL RETROSPECTIVE

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2025 year marked the 60th anniversary of the first published experimental confirmation by N. Pilipetskii and A. Rustamov of the self-focusing phenomenon in light beams predicted by G. Askarian in 1962. This report presents a retrospective analysis of the development of notions in nonlinear optics: from beam self-focusing and pulse filamentation to light bullets (LBs) – wave packets extremely compressed in space and time during laser light propagation in the bulk of a transparent medium. We describe the state of the art in studies of mid-IR light bullets performed jointly by the Institute of Spectroscopy, Russian Academy of Sciences, and Lomonosov Moscow State University. LB is a near single-cycle wave packet that is formed in the result of the light field self-organization in a nonlinear dispersive medium under matched spatiotemporal radiation self-compression in the regime of anomalous group-velocity dispersion. The formation of each LB is accompanied by the generation of a discrete portion of supercontinuum in the anti-Stokes region. LB is a short-lived robust object which parameters are determined by fundamental properties of the medium and the laser pulse central wavelength. The scenario of supercontinuum and light field evolution from odd harmonics generation to the appearance of broadband spectrum and pulse compression up to a single-cycle light bullet accompanied by the onset of isolated an anti-Stokes wing in spectra and high-frequency modulation of the light field is shown. Experimentally demonstrated that a light bullet retains the capability of self-restoration in a nonlinear dispersive medium after both free diffraction in air over an interval no greater than 1000 um and total internal reflection.

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P-6

STRATEGIES FOR ADDRESSING ENERGY CONSTRAINTS IN POST-COMPRESSION METHODS

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In post-compression techniques, intense pulses exiting a conventional CPA laser are spectrally broadened by self-phase modulation (SPM) in a nonlinear material, followed by dispersion compensation. The use of Herriott-type multipass cells (MPCs) with concave mirrors and various gases as nonlinear media have recently demonstrated post-compression of pulses with energies exceeding 100 mJ. However, further energy scaling is limited by ionization of the gas. For Joule-level energy large size MPC setups are required to maintain a relatively large focal spot and prevent ionization, with the distance between the mirrors exceeding tens of meters.

To overcome the pulse energy limitation of spectral broadening a free beam propagation at high intensities was proposed and demonstrated. The optical scheme with flat mirrors to fold the beam similar to MPC was used for reducing footprint of the setup. Self-focusing compensation by initial wavefront tailoring allowed achieving long propagation distance while avoiding beam collapse for pulses exceeding the critical power for self-focusing. A spherical convex initial wavefront is an example of this tailoring. A numerical estimation shows that the critical power for self-focusing can be significantly mitigated by increase of the beam divergence, which was demonstrated in our experiments. In this scheme the intensity of Gaussian beam remained nearly constant along the length of propagation, allowing efficient light-gas interaction throughout the entire beam volume. Furthermore, this configuration simplifies the need for complicated optical schemes and optical elements.

In our proof of principle experiments a Yb:YAG CPA laser system (λ = 1030 nm) was used to generate pulses of 65–300 mJ energy with duration of ~ 6 ps at 10 Hz repetition rate. The beam was directed to undergo folded beam propagation in atmospheric air in a compact set up, which consists of two 2.5 × 10 cm rectangular HR dielectric flat mirrors, positioned at near normal incidence. The distance between these mirrors was 2 m. After 20 passes between the mirrors, the beam was compressed. Experiments conducted in atmospheric air with the average pulse intensity of ~ 0.05 TW/cm^2 allowed to reach the spectral broadening factor of ~ 5.6, and subsequent compression of the pulse from 6 to 1 ps. Spectral inhomogeneities across the beam profile were characterized by a V-factor, which was over 85% within the FW1/e2M of the beam diameter. The Small Scale Self-Focusing (SSSF) prevented a further increase of energy. Nevertheless, two method allowed to shift this limitation significantly far. The experiments with pulse energy of 130 mJ split by polarization on two equivalent channels like those discussed above was one of them. Another one was modernized SSSF filtration method that allowed to enlarge the energy up to 300 mJ.

P-7

FUSION REACTOR MATERIALS SIGNIFICANCE – IMPACT OF HIGH THERMAL AND ELECTROMAGNETIC FLUX

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The production of clean, carbon-free energy, high power density and reliable energy is of great interest in the world in this moment. In this context, nuclear fusion energy as a serious candidate for this purpose and the related research are of high importance. The main investigations in numerous laboratories are focused on the fusion reaction between deuterium and tritium (D-T reaction). Among various fluxes existing in the reactor, thermal and electromagnetic (EM) fluxes are present. In general, to make fusion a reality some problems related to plasma physics and reactor technology should be overcome. Closely related to reactor technology is the development/selection of materials with extraordinary characteristics and they should satisfy, among other, some requirements: (i) to have a high ability to withstand thermal loading; (ii) to be resistant to neutron and EM fluxes; (iii) to have a low affinity for H-isotopes absorption; (iv) to have a desirable rapid induced radioactive decay. The focus of this presentation will be on the behaviour of reactor materials exposed to high thermal and EM fluxes which can be simulated with a relatively new approach, i.e. by laser-based methods/techniques.

Some results obtained at the VINCA Institute regarding plasma facing and structural materials of the fusion reactor, like the tungsten, ODS steel, will be presented.

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Session Y
YOUNG SCIENTISTS SESSION

Y-1

RECOGNITION OF THE POLARIZATION STRUCTURE OF SYNTHESIZED VECTOR BEAMS IN A TURBULENT ATMOSPHERE FROM INTENSITY IMAGES BY NEURAL NETWORKS

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Recently, there has been an active study of various methods for increasing the information capacity of communication channels using laser beams. It is important task in atmospheric optical communication to determine the characteristics of beams that can carry additional information when distorted by turbulent atmosphere. Coherent beam combining systems offer promise for transmitting information encoded in the polarization structure of laser beam, as they allow for high-frequency changes in this structure. In addition to developing techniques for encoding information using structured beam parameters, it is also essential to develop methods for decoding this information. Determining the polarization structure of a beam distorted by the atmosphere is a challenging task. The aim of this research is to investigate the possibility of using neural networks to determine the polarization structure of synthesized laser beams through intensity distribution images distorted by atmospheric turbulence. for the first time, it has been shown that the use of neural networks makes it possible to distinguish a linearly polarized synthesized beam from a beam with an inhomogeneous polarization distribution formed by azimuthally or radially distributed directions of polarization of sub-beams in a turbulent atmosphere. The study was performed on the basis of numerical simulation

Y-2

STRUCTURED ILLUMINATION MICROSCOPY USING SYNTHESIZED BEAMS

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Optical microscopy plays an important role in biological research due to the possibility of non-contact observation and measurement of living samples. However, conventional optical microscopy has limitations. Due to the diffraction limit, its spatial resolution is about 200 nm. The use of structured lighting makes it possible to increase the spatial resolution by more than 2 times, and the addition of polarization control makes it possible to expand the system to study anisotropic transparent and opaque objects. In addition, structured lighting allows you to get a three-dimensional image of an object.

Recent advances in laser technology allow us to propose a new approach to the formation of structured lighting. In this paper, the possibility of implementing microscopy with structured illumination using synthesized beams is shown numerically for the first time. The source is a matrix of coherent lasers that allows you to control the distribution of the phase, amplitude and polarization of the beam. The proposed experimental scheme does not require a feedback loop to stabilize the phases, which distinguishes it from the coherent addition scheme. The surface under study was modeled numerically. On the part of the resolution enhancement algorithm, the well-known SIM-SR method has been applied, which has proven itself well in solving a similar problem.

The application of the proposed approach to microscopy problems with structured illumination will make it possible to reduce the cost of the microscope design while increasing the measurement speed of objects.

Y-3

THE PHOTOLYSIS OF SULFAMETHOXAZOLE IN WATER

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This work presents the results of photolysis study of sulfamethoxazole in water synthesized by commercial firm Central Drug House (P) Ltd. Co. (art. no. PCT2135, CAS 723-46-6, New Delhi, India) with a guaranteed purity of 98%. Irradiation experiments were carried out under stationary photoreactor conditions using excilamps KrCl (222 nm), XeBr (282), XeCl (308 nm), and UVb-04 bactericidal irradiator (180–275 nm) as UV light sources. A solution of sulfamethoxazole with C = 0.05 mM was irradiated in a glass beaker with a diameter of 4.6 cm at a distance of 4 cm from the radiation window. The control irradiation times were 0, 1, 2, 4, 8,16, 31, 64 and 128 min.Absorption and fluorescence spectra of the solutions before and after irradiation were recorded on a VARIAN Cary 5000 UV-VIS-NIR spectrophotometer and a VARIAN Cary Eclipse spectrofluorometer (AgilentTech., USA-Netherlands-Australia) at room temperature in the range from 190 to 800 nm. The conversion of sulfamethoxazole after irradiation in the photoreactor was calculated to evaluate the photolysis efficiency. To determine the total phenolic content (TPC) of sulfamethoxazole photoproducts, Folin–Ciocalteu reagent synthesized by Central Drug House (P) Ltd. Co. (art. N 835020, New Delhi, India). The formation of fluorescent photoproducts was detected. It was shown that after 16 min of KrCl excilamp irradiation, the TPC increased to 385.56 mgGAE/g compared to the initial solution.

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Y-4

LASER SYNTHESIS AND PHOTOCATALYTIC PROPERTIES OF $Bi_2SiO_5/Bi_{12}SiO_{20}$ COMPOSITE NANOPARTICLES

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The development of laser methods for the synthesis of nanomaterials is relevant for various applications including catalysis, optics. Important advantages of laser synthesis are versatility, absence or minimisation of precursor use, environmental friendliness, and the possibility to obtain metastable phases. By combining different laser synthesis approaches, complex structures consisting of multiple phases can be obtained. Laser synthesis is a suitable technique for the synthesis of highly efficient photocatalysts, which are used for pollutant decomposition, hydrogen production, CO_2 reduction, and biomass processing. One way to increase the activity of photocatalysts is to create composite particles with heterojunctions that promote efficient charge separation and enhance the oxylation-reduction potential.

In the present work, an approach combining laser ablation of Si and Bi targets in water and laser treatment of mixed colloidal solutions by Nd:YAG laser irradiation is proposed for the directed synthesis of $Bi_2SiO_5/Bi_{12}SiO_{20}$ heterostructures based on bismuth silicates. As a result of laser treatment there is an effective interaction of particles of different compositions with the formation of composite particles. The final semiconductor structures of bismuth silicates are formed after drying and calcination of powders at 500°C. To obtain composites with the formation of heterostructures in this work we used non-stoichiometric for monophase bismuth silicates ratios Bi:Si = 4:1, 6:1, 8:1.

The obtained particles were investigated by XRD, TEM, FT-IR and UV-visible DRS spectroscopy, which confirmed the formation of heterostructures. It was found that the formation of $Bi_2SiO_5/Bi_{12}SiO_{20}$ composite with type II heterojunction leads to a significant increase in photocatalytic activity in the reactions of rhodamine B decomposition and selective oxidation of 5-HMF, compared to monophase Bi_2SiO_5 and $Bi_{12}SiO_{20}$ samples. The optimum ratios of components in composite particles for maximum photocatalysis efficiency were determined.

This work was supported by the Russian Science Foundation, Grant N 19-73-30026-P.

Y-5

THE INVESTIGATION OF AlN FILM THICKNESS IMPACT GROWN BY MAGNETRON SPUTTERING ON OPTICAL PROPERTIES IN THE IR AND THz RANGES

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Nowadays, photonic technologies are being introduced for space applications, in particular, for environmental monitoring tasks from orbital stations. In this regard, it is urgent to search for new materials capable of operating at extreme temperatures, as well as efficiently receiving and transmitting large amounts of information at frequencies in the terahertz (THz) range One of the materials that shows promise in this field is aluminum nitride (AlN) films. This is due to their exceptional fundamental physical and chemical properties. A high thermal conductivity of more than 200 W/(m · K) and a broad band gap of about 6.2 eV are two of them that allow for the use of this material in integrated photonics devices without causing significant energy losses. Despite many studies aimed at studying the properties of aluminum nitride films, their characterization in the far infrared and THz ranges, depending on various parameters, is still an urgent task.

In this work, the effect of the thickness of AlN films on their optical properties in the far infrared and THz ranges was investigated. The films were sprayed by magnetron sputtering with different thicknesses: 2227, 3026, 4524, 6980 and 9350 nm. The study was performed using IR-Fourier spectroscopy and pulsed terahertz spectroscopy. The optical characteristics of the films, including the refractive index, dielectric constant, the positions of phonon peaks, and the dependence of their position on the elemental composition of the films, determined by X-ray diffraction analysis, have been revealed from the acquired spectra.

The study revealed the following phonon peaks: in the vicinity of 679 ± 5 cm^{-1}, corresponding to the E_1(TO) photon; in the vicinity of 800 cm^{-1}, the appearance of which is caused by a large amount of oxygen, and 582 cm^{-1}, presumably associated with the resonant optical mode E_2. Model refractive index curves for AlN samples in the range of 370–7500 cm^{-1} are constructed.

Model refractive index curves for AlN samples in the range of 370–7500 cm^{-1} are constructed. It is shown that in the range of 0.1 – 2 THz, the refractive index of the samples is within 3.0 ± 0.2, which is in good agreement with the research results of other authors for the case of thin films of aluminum nitride, and also fits with reliable accuracy on the model curves extracted from the IR Fourier spectroscopy data. It was also found that an increase in the thickness of the films leads to an increase in the amplitude of the phonon peak, as well as to its broadening. The exception is the sample with a thickness of ~ 7 microns, which may be due to the peculiarities of the elemental composition of this sample.

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Y-6

EFFECT OF THE METHOD OF DECORATING ZNO NANOPARTICLES WITH SILVER ON THEIR PHOTOCATALYTIC PROPERTIES

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The photocatalysis successfully applied for decomposition organic and nonorganic p pollutants, processing of biomass into useful products, obtaining hydrogen, CO_2 recovery and other processes. One of the most effective and safe semiconductor photocatalysts for water purification is zinc oxide. For increase effective and to expand the spectral range, different approaches are used, including modification with plasmonic nanoparticles (NPs).

For obtain nanoparticle ZnO in the work were used methods pulsed laser ablation (PLA). Target of Zn in the water were irradiated with focused pulses Nd:YAG laser (1064 nm, 20 Hz, 7 ns, 150 mJ). Obtained colloid were blown with air for 5 min for better oxidation metallic zinc and averting formation of zinc hydroxycarbonate and dried. ZnO decoration with silver was conducted two methods: co-deposition and photoreduction. In the first case, PLA target of Ag in the water were received a colloidal solution of NPs and mixed with a colloidal solution of ZnO, also was prepared by PLA. After, mixed colloid dried on air (samples ZnO–Ag–CO). In the second case, powder of ZnO dispersed in the water solution $AgNO_3$, irradiated UV light, centrifuged, cleaned and dried (samples ZnO–Ag–Photo). Concentration of silver in samples composed 1 mass.%. Photocatalysts were analyzed by XRD, IR, UV-vis spectroscopy methods. Test of photocatalytic activity were conducted in the decomposition reaction rhodamine B under irradiated LED different wavelength

Availability of silver in decorated NPs reduce to supplementary absorption in region 400-550 nm, but the bandgap band of ZnO (3.3 eV) didn't change. Photocatalytic activity of composite also was increased in 3–6 times relative to the initial ZnO, both at UV excitement in absorption band edge zinc oxide (375 nm), and at excitement in absorption NPs silver (410, 470 nm). The role silver was discussed in photocatalytic activity decorated ZnO.

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Y-7

N_2^+ LASING UNDER TWO-COLOR PUMPING

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Cavity-free lasing of molecular nitrogen ions is a perspective phenomenon that has attracted much attention due to its promising applications in standoff spectroscopy and remote atmospheric sensing. In particular, it is known that one can obtain lasing on different vibrational transitions of molecular nitrogen ion using different pumping wavelengths.

In this study, we demonstrate that using two-color pumping scheme (950 and 475 nm) makes it possible to simultaneously obtain lasing at the wavelengths of 391.4, 427.8 and 423.6 nm which correspond to the $B^2\Sigma_u^+(\nu' = 0) - X^2\Sigma_g^+(\nu'' = 0)$, $B^2\Sigma_u^+(\nu' = 0) - X^2\Sigma_g^+(\nu'' = 1)$, and $B^2\Sigma_u^+(\nu' = 1) - X^2\Sigma_g^+(\nu'' = 2)$ transitions respectively. It is shown that second harmonic radiation increases the intensity and stability of supercontinuum radiation which seeds the lasing at corresponding wavelengths. The possibility of obtaining lasing at the wavelength of 423.6 nm and driving its intensity is demonstrated. Obtained results can be useful for clarifying the mechanisms concerning the origin of optical gain and population inversion in lasing process and other various applications.

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Y-8

CuBr-LASER NON-TYPICAL RADIATION MODE

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Active medium pumping is an essential part of laser radiation forming. The typical excitation mode for metal and metal halide vapor active media is a direct discharge of a storage capacitor towards a gas discharge tube (GDT) using a high voltage switch. Traditionally, the pumping pulse repetition frequency (PRF) is in the range between 10 and 20 kHz. In this work, the non-typical excitation mode was introduced. Two power sources were applied: the first one was called primary, the second one – auxiliary.

The primary power source enables the pulse periodic mode of the investigated copper bromide active medium. If the auxiliary power source is applied during pumping, this will lead to the pre-ionization pulses forming. As a result, the radiation pulse power will be either decreased or, in some cases, completely suppressed. This feature can be explained by metastable level population. However, a non-typical active medium operational mode was discovered during the experiment. When the time delay (td) between the pre-ionization and the pumping pulse was less than 300 ns and the power of the auxiliary source had particular values, the additional radiation pulse before the primary one occurred. This non-typical excitation mode can be called the double-The time delay (td) was varied from 40 to 300 ns by changing the discharge circuit inductance for each power source. The radiation power (Pi) was recorded for each time delay (td) value. The ratio between the measured radiation power (Pi) and the radiation power in the pulse-periodic mode (PG) was called the conversion factor η. This factor indicated the percentage of the radiation power in the double-pulse mode to the radiation power in the pulse-periodic mode. The GDT active zone length was 90 cm, the discharge channel diameter was 5 cm.

The double-pulse mode has been discovered for the first time and can be interesting both for scientific and practical application. Such a mode can provide radiation power prompt adjustment and increase temporal resolution of active optical systems.

Y-9

TERAHERTZ OPTICAL PROPERTIES OF LITHIUM TERNARY CHALCOGENIDE CRYSTALS

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Terahertz (THz) band (0.1–10 THz) of the electromagnetic spectrum holds significant potential for modern technologies: from medical diagnostics and security systems to next-generation wireless communications (6G). However, the development of these applications is limited by the lack of materials suitable for the efficient generation and detection of terahertz radiation. Therefore, the study and investigation of optical materials with optimal characteristics for this spectral range is highly relevant.

Chalcogenide crystals, in particular ternary compounds of type I-III-VI_2, possess a unique combination of wide transparency range and high nonlinear susceptibility. In recent years, applications of materials of this class have been reported for the generation of broadband terahertz radiation in the optical rectification of femtosecond laser pulses. However, their systematic study in the terahertz range has not been carried out.

In this work, the optical properties of $LiInS_2$, $LiGaS_2$, $LiInSe_2$ and $LiGaSe_2$ crystals have been investigated using time-domain terahertz spectroscopy. For each crystal, samples with two different thicknesses (1 and 0.3 mm) and two orthogonal cuts along different optical axes were prepared. This approach allowed detailed measurements of the refractive index and absorption coefficient dispersion for the three principal components. The experimental data were fitted using Sellmeier equations. Furthermore, the electro-optical coefficients and the effective nonlinear coefficients for near-infrared-to-THz downconversion were estimated using polarization-optical detection techniques. Finally, the prospects of these crystals for applications in terahertz photonics and optoelectronics are discussed.

Y-10

THROUGH-HOLES VIAS CERAMIC MICROSTRIP BOARDS METAL FILLING BY ELECTROCHEMICAL DEPOSITION

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Currently, there is a need in the microelectronics market for the production of components required for the manufacture of hybrid-monolithic integrated circuits based on 3D integration, designed to process super-high-frequency (SHF) signals, promising radar systems for microwave equipment, optoelectronic devices, electronic countermeasures, identification, communication and control. This paper describes the technology of filling through vias in microstrip boards made of Al2O3, AlN or Si with copper / gold, which provides electrical resistance between the front and back sides of the board < 0.01 Ohm. The use of this technology will qualitatively improve the process of developing the topology of microstrip boards, due to the possibility of using a through hole filled with copper or gold, which will: increase the power of the boards, reduce the number of vias, and abandon the end metallization, which will significantly simplify the process of manufacturing boards. The results of the work will be in demand by enterprises in the electronics industry that produce microstrip boards based on Al_2O_3, AlN or Si.

Y-11

ELONGATION OF PROPAGATION DISTANCE OF HIGH-INTENSITY FEMTOSECOND POST-FILAMENTATION CHANNEL

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The propagation of high-intensity laser pulses in air using a cascade of glass plates has been experimentally investigated. This method allows the maintenance of high intensity over extended distances due to Kerr lensing in a condensed medium. An analysis of the effect of the glass plate thickness on the characteristics of the post-filamentation channel has been carried out. Additionally, as a result of applying the plate cascade, the laser ignition of a high-voltage discharge using the post-filamentation channel has been successfully achieved at distances several times greater than in the case of free propagation. The results suggest that the glass plate cascade can significantly enhance the propagation range of high-intensity laser pulses, offering a promising approach for future applications in optical communications, remote sensing, and other fields requiring long-distance delivery of intense radiation.

The research is performed under the financial support of the Russian Science Foundation, grant N 24-12-0005.

Y-12

INCREASING THE SENSITIVITY OF THE Fs-LIBS METHOD BY CONTROLLING THE TYPE OF LASER RADIATION POLARIZATION

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Emission analysis of matter by femtosecond laser-induced breakdown spectroscopy (Fs-LIBS) has great interest in various fields: science, technology, medicine, and environmental monitoring. This method allows to carry out qualitative and quantitative analysis of matter in any aggregate state. The sensitivity of this method depends on many parameters of laser radiation, one of which is polarization.

The report presents the results of a study the effect of laser radiation polarization on the intensity of the plasma emission lines. River sand was used as the test mixture, it mainly consists of SiO_2 and FeO. River sand is a good imitation of particles carried during dust storms. Tracking and controlling dust storms is an urgent task in the problem of environmental monitoring and improving the efficiency of agricultural management in arid zones.

The study shows that when changing the polarization type of the excitation radiation and approaching a circular polarization state, the intensity of Si, O, and Fe emission lines increases by 80%.

These results have important practical significance in the problem of increasing the sensitivity of the fs-LIBS method.

Y-13

APPLICATION OF KTP CRYSTAL TO CHANGE PLASMA TEMPERATURE IN EMISSION ANALYSIS PROBLEM

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Nonlinear crystals have found wide application in laser technology for solving such problems as converting laser radiation into the second harmonic or for electro-optical modulation.

Along with the second harmonic generation, the KTP crystal can be used to increase the kinetic energy of an electron in plasma by controlling the type of laser radiation polarization. This phenomenon has great importance for performing elemental analysis of a substance by femtosecond laser-induced breakdown spectroscopy method (Fs-LIBS).

The report presents the results of study the effect of laser radiation polarization on the plasma temperature when implementing the Fs-LIBS method depending on the crystal rotation angle and effective second harmonic generation. It is shown that the increasing of the phase difference between ordinary and extraordinary radiation, the plasma temperature increases, which leads to a non-selective increase in the intensity of the emission lines of the substance. When the type of laser radiation polarization approaches the circular type, the line intensity increases by 80%.

The obtained results have great practical importance in the problem of increasing the sensitivity of the Fs-LIBS method.

Y-14

TERAHERTZ SENSOR FOR CORTISOL DETECTION

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The steroid hormone cortisol has essential functions in humans and animals. According to the ratio of concentrations of cortisol and its reversible metabolite cortisone in blood, e.g. in oncology, it is possible to determine the degree of malignancy, give a prognosis of the disease and select the optimal therapy. In recent decades, terahertz (THz) metamaterials of various structures have been developed for the detection of biological molecules with high sensitivity. One of the most common designs of THz metamaterials is the split-ring resonator (SRR) or its modifications, whose resonances have a high quality factor (Q). The aim of this work was to design, fabricate and test a new polarization-sensitive THz sensor with resonant frequencies of 0.66, 1.52 and 1.87 THz. The design of the THz sensor refers to a modified SRR on a high resistivity silicon substrate, and the conductive layer is an aluminum. The main parameters of the sensor were calculated: sensitivity (S), Q and figure of merit (FOM). Cortisol and cortisone solutions, as well as their mixture, have been analyzed. It was shown that the dependence of the sensor absorbance on the amount of cortisol is described by Hill's equation. THz sensor allows to detect the amount of cortisol in the range from 14 to 40 nmol.

The work was partially carried out within the state assignment of IA&E SB RAS and NRC "Kurchatov Institute" (manufacturing of the THz sensor) and Lomonosov Moscow State University (THz sensor design).

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Y-15

DOUBLE PULSE MODE PROSPECTS IN VISUAL-OPTICAL DIAGNOSTICS

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Due to their unique features, metal and metal halide vapor active media are widely used to design laser monitors for visual-optical diagnostics. Narrow spectral lines (≤ 10 pm), high gain coefficients (10^3÷10^4), and high optical homogeneity of these active media ensure research object image forming even in the presence of powerful background lighting.

The laser monitor operation principle is based on optical image formation by amplified spontaneous emission. Traditionally, optical imaging occurs at pulse repetition frequencies (PRF) between 10 and 20 kHz. There are some technical solutions to increase the PRF but their practical implementation is neither possible nor relevant. Consequently, it is noteworthy that the double-pulse mode may expand laser monitor capabilities, as its application allows doubling temporal resolution.

It is important to emphasize that it is not the PRF increase in its usual sense. Such a non-typical operation mode implementation forms a pair of radiation pulses with the same frequency as in the typical pulse-periodic mode. These radiation pulses are generated by two active medium excitation pulses with the time delay between 50 and 300 ns. This imaging technique enables additional frame registration of the investigated process. Hence, the technical problem of matching the frequency, time and energy parameters of the primary and the auxiliary power sources should be solved. Another technical problem is to synchronize the exposure pulses of two independent cameras with the amplified spontaneous radiation pulses. During this approach the first pulse will be recorded by the first camera, and the second pulse – by another one. After the inter-pulse pause, the registration order will remain the same.

In this work, technical solutions to implement the test object imaging using copper bromide vapor as the active medium in the double pulse mode are proposed. The GDT active zone length was 90 cm, and the channel diameter was 5 cm. The imaging results with a time delay (50÷300) ns between two adjacent frames have been obtained for the first time.

Y-16

MULTIFOCAL STRUCTURE OF HIGH-POWER FEMTOSECOND LASER RADIATION DURING FILAMENTATION IN PRESSURED GASES

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The results of numerical simulation of self-focusing and filamentation of high-power femtosecond laser pulses with varying pressure of the gas medium in which the radiation propagates are presented. The use of this approach is associated with the possibility of using the results obtained in laboratory conditions with abnormally high pressure at distances of several meters for scaling to real atmospheric paths hundreds of meters long at normal pressure. The practical significance of these studies is the possibility of remote diagnostics of atmospheric components and delivering energy along extended paths in the atmosphere. This approach also has its advantages in carrying out numerical calculations, since it allows reducing the time of calculations and decreasing the required computing power.

The modeling is carried out for cases of propagation of high-power femtosecond laser pulses in the self-focusing and filamentation mode under conditions of increased pressure (by 64 times). The formation of the filamentation multifocal structure is considered in detail. This case is much in evidence under conditions of increased pressure of the propagation medium. The angular beam divergence is estimated for cases of different peak pulse power with varying gas pressure of the propagation medium.

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Y-17

SECOND-HARMONIC GENERATION OF LASER INFRARED RADIATION IN LITHIUM-SODIUM MOLYBDATE CRYSTAL UNDER SSF-PHASE-MATCHING CONDITIONS

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Lithium-sodium molybdate $LiNa_5Mo_9O_{30}$ (LNM) is a fairly new biaxial nonlinear-optical (n–o) crystal. This material is transparent in 0.36–5.26 μm wavelength range, it has high laser damage threshold 2.64 GW/cm^2 (at 1064 nm wavelength, 10 ns pulses, 1 Hz repetition rate), high birefringence ($\Delta n = 0.1932$ at 1014 nm wavelength) and nonlinear optical coefficients

d_{31} = 1.4 pm/V, d_{32} = 4.3 pm/V, d_{33} = 1.1 pm/V. As follows, LNM crystals are good candidates for the fabrication of both the polarization prisms with high radiation strength, and the elements that efficiently convert the frequency of laser radiation in the visible and near infrared (IR) ranges.

Previously, the possibility of efficient second harmonic generation (SHG) in LNM crystals was theoretically substantiated. In this work, SHG of nanosecond IR laser radiation (λ = 1030 nm, τ = 2.4 ns, f = 100 kHz, $2\omega_0$ = 30 µm) under ssf-phase-matching conditions (LNM crystal 3.0×3.3×9.0 mm^3, I type: θ = 90°, φ = 28°) was experimentally implemented. The dependences of second harmonic (SH) power and generation efficiency on pump power were measured. The highest SH power of 2 W was achieved at 20 W pump power, the highest conversion efficiency 13.5% was achieved at 12 W pump power.

Thus, the functional capabilities of LNM crystals for n-o frequency conversion of laser radiation are demonstrated and the SHG efficiency of more than 10% was obtained for the first time.

The work was carried out within the framework of the state task of the Kotelnikov Institute of Radioengineering and Electronic of RAS.

Y-18

TECHNOLOGY OF MANUFACTURING PASSIVE ELEMENTS OF OPTOELECTRONIC BOARDS WITH AIR-BRIDGES

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In the standard technology of optoelectronic boards, discrete silicon or ceramic capacitors are widely used in signal filtering and separation circuits, the use of which is accompanied by the need to install wire jumpers by welding methods, which leads to a mismatch with the wave impedance of microstrip lines due to a violation of the planarity of the structure and partial reflection of the microwave signal. Also, the intrinsic inductance of wire connections becomes significant at frequencies above 10 GHz, which leads to signal losses. In order to eliminate these shortcomings, this paper proposes a technology for manufacturing optoelectronic boards with thin-film capacitors and air jumpers manufactured using planar technology on a single substrate in one technological cycle using standard highly efficient methods of magnetron sputtering and galvanic deposition.

Y-19

LASING IN AN ORGANIC ACTIVE WAVEGUIDE

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Recent years have seen growing interest in the development of polymer-based photonic integrated circuits (PICs) due to their expanding range of applications. PICs are now widely used in optoelectronics, sensor technologies, lighting, and optical computing. Of particular relevance is the integration of laser dyes with polymers to create coherent light sources in the visible spectrum. The polymer platform offers a pathway toward cost-effective roll-to-roll manufacturing of photonic circuits in the future.

When a polymer matrix is doped with a dye, various photophysical processes can occur, including aggregation-caused quenching (ACQ), aggregation-induced emission (AIE), and aggregation-enhanced emission (AEE), all of which significantly influence emission properties. The complexity of dye-matrix interactions makes it challenging to predict which polymer-dye combination will yield a waveguide emitting at a desired wavelength. Therefore, experimental studies of active waveguides for optoelectronic applications remain crucial.

This work presents the results of a study on active planar waveguides based on a PMMA matrix doped with Chromene-3 dye. We investigated the dynamics of spectral line narrowing and the threshold pump power characteristics of these waveguides. Significant differences were observed between the lasing wavelength of polymethymethacrylate (PMMA) doped with Chromen-3, in toluene and that in a planar waveguide. An optimal thickness of the PMMA doped with Chromen-3 waveguide layer was identified. Additionally, saturation of the spectral linewidth was achieved, independent of the thickness in a single-mode PMMA-based planar active waveguide.

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Y-20

OPTICAL SENSING CAPABILITIES OF ORGANIC ACTIVE WAVEGUIDES

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A sensor is the primary component of any security technology system. The applications of sensors are diverse, ranging from environmental monitoring to the detection of terrorist threats and drug smuggling. They are used to measure substance concentrations in the air: such as ammonia in refrigeration plants, methane in mines, and carbon monoxide in exhaust gases. Sensitive elements enable process control in chemical industries and the detection of explosive and flammable substances.

Existing optical sensors based on photoluminescence phenomena, where the presence of detected substances is inferred from emission characteristics, suffer from insufficient sensitivity and response time. One promising approach to enhance sensitivity and reduce response time is to induce lasing conditions in a photoluminescent sensor. This requires designing the sensing element as an active planar waveguide.

This study investigates the sensing capabilities of active organic waveguides doped with a laser dye sensitive to the detected substance in a gas environment. The research not only revealed complexation processes leading to photoluminescence quenching but also identified additional physical mechanisms affecting lasing generation, resulting in a reduced threshold pump power density. For instance, the depopulation of the lower laser level to the ground state was observed due to inelastic collisions between analyte molecules and dye molecules adsorbed on the waveguide surface. The system demonstrated sensitivity to specific chemical compounds (CO_2, N_2O, CO) in gas mixtures.

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Y-21

DEVELOPMENT OF A CONTROLLED RADIATION SOURCE POWER SUPPLY SYSTEM

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An adjustable radiation source is a technical device capable of changing the wavelength of its own radiation depending on the set external or internal parameters. This functionality opens up broad prospects for applications in various fields, including lidar atmospheric sensing, spectroscopic methods for analyzing gas composition, and other high-tech tasks.

Semiconductor emitting devices such as laser diodes or ultra–bright LEDs play a special role in the implementation of such sources. These devices have a pronounced dependence of the spectral characteristics of radiation on both the magnitude of the current flowing through them and the temperature of the active region. Based on these physical properties, a design of an adjustable radiation source has been developed, equipped with the possibility of remote control to ensure flexibility in setting the emitted parameters.

A power supply system has been developed for this device that allows manual parameter adjustment with the possibility of switching to remote control, which increases the user-friendliness and expands the functionality of the system.

As part of the research, a basic electrical circuit of the device was developed and calculated, its technical implementation was tested, and experimental measurements of the spectral characteristics of an ultra-bright LED were carried out. The results obtained confirmed the existence of a clear dependence of the radiation wavelength on the operating current and core temperature, which serves as the basis for further improvement of such systems and their practical application.

Y-22

DEVELOPMENT OF A REMOTE CONTROL SYSTEM FOR A REGULATED RADIATION SOURCE

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Remote control systems are of particular importance in the field of lidar sensing of the atmosphere, a method of analyzing the composition of air, water and soil using laser radiation. To improve the accuracy of measurements, it is necessary to flexibly control the parameters of the radiation source, such as the wavelength, which depends on various parameters. The Institute of Archaeology of the Siberian Branch of the Russian Academy of Sciences has developed a remote control system for a regulated radiation source based on the Raspberry Pi3 model B microcontroller in order to control the radiation spectrum of a laser diode by changing temperature and current. A web server was also implemented on the microcomputer for remote monitoring and control of all parameters. The system has been tested to test the accuracy and stability of its operation. After testing, it was revealed that the controlled temperature corresponds to the real temperature with a small error, and with the help of an external ammeter, it was found that the system correctly calculates the current through the laser diode.

In the course of studying various ways of changing the spectrum in a laser diode, two methods were chosen, namely changing the spectrum by increasing and decreasing temperature and current. After conducting experiments, it was found that the specified values of the set parameters correspond to reality.

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