Preface

Fifth International Conference on Atomic and Molecular Pulsed Lasers AMPL'01

The Fifth International Conference "Atomic and Molecular Pulsed Lasers AMPL'01" was held on September 10–14, 2001. This conference is a traditional biennial scientific forum, which is being held in Akademgorodok (Academic Town) of Tomsk, an ancient Siberian city. The AMPL conference is getting increasingly popular, and this is reflected in the number of reports presented and published in eight topical issues of *Atmospheric and Oceanic Optics* journal and three topical issues of the *Proceedings of SPIE* (**2619**, 1995; **3403**, 1997; and **4071**, 1999), as well as this issue and the forthcoming issue No. 3 of the 2002 volume.

The program of the AMPL'01 was traditional and included the following sessions:

– gas and plasma lasers (Session A),

– metal-vapor lasers (Session B),

– dye lasers and photoprocesses in complex organic molecules (Session C),

– physical processes in gas lasers (Session D),

– laser systems and their applications (Session E),

– sources of noncoherent UV and VUV radiation, and laser output conversion; optoelectronic devices (Session F).

The conference was supported by the Russian Academy of Sciences, Siberian Branch of the Russian Academy of Sciences, Russian Foundation for Basic Research, Ministry of Education of the RF, Administration of Tomsk Region, and Surgut State University.

More than 150 specialists from Russia, U.S.A., Germany, France, Bulgaria, Yugoslavia, Japan, Iran, Estonia, and Latvia took part in the AMPL'01 conference with over 70 oral and 120 poster presentations.

The **Plenary Session** was held on September 10 and included the presentations on urgent problems in the development of pulsed lasers. The session was opened with the report by Professor G.K. Vasil'ev (Institute of Problems of Chemical Physics, RAS, Chernogolovka), devoted to an urgent problem of the development of superpowerful lasers on chain chemical reactions for studying dense relativistic plasma and laser fusion. Significant interest was aroused by the reports concerning shortwave lasers. Thus, Doctor J.M. Pouvesle (State University, Orleans, France) reported on the development of a new X-ray laser based on capillary discharge. Professor Wataru Sasaki (Miyazaki University, Japan) reported on the development of a VUV krypton excimer laser and presented data on lasing and amplification at the wavelength of 146 nm. The report presented by Doctor B.V. Lazhintsev (Russian Federal Nuclear Center, Sarov) was entitled "Scaling of pulsed-periodic electric-discharge wide-aperture lasers." Doctor A.E. Hill (Texas A&M University) reviewed various laser plasma electrical excitation methods. An interesting report was presented by Professor S.I. Yakovlenko (General Physics Institute RAS, Moscow); it concerned the properties of laser-produced ultracold plasma. The mechanisms of damage of transparent optics of short-pulse CO_2 lasers, as well as the methods for improving the laser strength were considered by Doctor S.G. Kazantsev (SLC "Raduga," Raduzhniy).

Below we present a brief review of the most interesting reports from all sessions.

Gas and Plasma Lasers

The Session **Gas and Plasma Lasers** was opened by Professor T. Goto (Osaka, Japan), who reported on the development of laser gain technologies based on argon dimers (wavelength of 126 nm) in a discharge with plasma electrodes. Professor V.A. Burtsev in his report presented the calculated results on conditions for the development of high-efficiency VUV lasers with electron-beam pumping. Doctor H. Tomizawa (Japan Synchrotron Radiation Research Institute, Hyogo, Japan) devoted his report to the properties of a particle-beam-pumped Ar–Xe laser as functions of temperature of the working mixture. The studies of chemical lasers were considered by Doctor M.A. Azarov (Russian Scientific Center "Applied Chemistry," St. Petersburg), Doctor K.N. Firsov (General Physics Institute RAS, Moscow), and Doctor V.M. Orlovskii (Institute of High-Current Electronics SB RAS, Tomsk). The problems in the development of high-efficiency ArF and KrF lasers were analyzed by researchers from the Institute of Laser Physics SB RAS (Novosibirsk). Professor M.S. Trtica (The Vinca Institute of Nuclear Sciences, Belgrade, Yugoslavia) presented the data on small-scale pulsed CO_2 lasers and their applications. High activity was demonstrated by scientists from the Institute of High-Current

0235-6880/01/11 905-06 $02.00

Electronics SB RAS. Professor Yu.I. Bychkov made a presentation on modeling of a XeCl laser, Doctor V.F. Losev presented data on the effect of inhomogeneities of an active medium on the divergence of radiation of an electric-discharge long-pulse XeCl amplifier. A.N. Panchenko in his report considered the development of electric-discharge exciplex lasers pumped by generators with inductive energy storage and semiconductor opening switch. The overall of 50 oral and poster presentations were presented within the framework of this session. Therefore, we can draw the following conclusion: the investigations into the gas and plasma lasers are being continued and gas lasers are still superior devices for obtaining shortwave UV and VUV radiation.

Metal-Vapor Lasers

At the AMPL'01, a particular attention was traditionally paid to metal-vapor lasers and their applications (about 50 papers). Most of these papers dealt with the copper-vapor laser. A wide range of problems was discussed, namely,

– scaling of laser systems (Yu.I. Savchenko et al., V.V. Ivanov, N.A. Yudin);

– factors limiting the frequency and the mean power (P.A. Bokhan, G.G. Petrash, G.S. Evtushenko);

– the effect of admixtures in the active medium (D.N. Astadjov, G.G. Petrash);

– stability of repetitively pulsed discharges (V.M. Klimkin),

– cataphoresis and mass transfer in discharges (G.D. Gradoboev);

– modernization of power supply circuits, including thyristor circuits, transistor circuits, circuits with compression elements, etc. (V.V. Tatur, O.V. Zhdaneev, N.A. Yudin, L.M. Gabchenko, et al.);

– industrial production of active elements (N.A. Lyabin);

– construction of generator–amplifier schemes (M.A. Kazaryan, A.G. Filonov);

– control of output parameters through power supply systems (A.N. Soldatov).

Interest is kept in lead and bismuth-vapor lasers in connection with the possibility of generating shortwave radiation, as well as of obtaining lasing from chemically active high-temperature elements (thulium, dysprosium). In particular, A.V. Pavlinsky and his co-authors reported on the development of a lead bromide vapor laser operating at two lines (red and blue) simultaneously with no forced circulation of the working mixture, and the paper by V.A. Gerasimov was devoted to discrete tuning of the pulsed gas-discharge thulium vapor laser in the near-IR spectral region.

Traditional applications of copper-vapor lasers are medicine, projection systems, and isotope separation. The problems in this field have been considered in the Section **Laser Systems and Their Applications**.

Presentation by P.A. Bokhan and D.E. Zakrevskiy on "Physical-technical conditions of the development of different mechanisms of Cu laser output power limitation" has initiated a wide discussion within this section. This report was the first in the session, and to avoid too lengthy discussion at the regular session, it was decided to discuss the problem of limitation of frequency and power parameters of metal-vapor lasers (as being of principle importance) at the Round Table session.

Dye Lasers and Photoprocesses in Complex Organic Molecules

The interest in the study of photoprocesses in complex organic molecules has aroused in recent years as many new applications have been reported in literature of solid-state materials based on such molecules to optoelectronics: light-emitting diodes, optical radiation limiters, microlasers, and various devices in telecommunication systems. It is an urgent problem nowadays to develop and create various organic molecules thermally stable and efficiently emitting in the solid state at optical excitation and excitation by electric current: complex molecular systems with transfer of electronic excitation energy, luminescent polymers, solid solutions of organic molecules in various matrices. The results of such studies were presented at this session and at the **Plenary Session**: A. Penzkofer (Regensburg University, Germany) "Photophysical and lasing characterization of some phenylenevinylene based polymers," V.I. Yuzhakov (Moscow State University, Russia) "Photophysics of symmetrical bis-cyanins and their aggregations in solutions," and T.N. Kopylova (Siberian Physical Technical Institute, Tomsk, Russia) "Organic compounds in matrixes – new substances for optical applications."

This session has demonstrated the abilities of scientists in studying the photoprocesses in complex organic molecules under optical excitation. Thus, R.T. Kuznetsova in her paper considered some peculiarities in the photostability of laser dyes at high-power laser excitation (power density of the exciting radiation achieved 300 MW/cm^2). It was shown that the laser photostability and the quantum yield of phototransformations of laser dyes depend on the intensity and polarization of the exciting radiation.

The report of A.A. Zemlyanov and V.A. Donchenko with co-authors was devoted to the study of two-photon excited luminescence in organic dye drops in high-power light fields. It should be noted that this phenomenon has attracted considerable interest of the participants and it undoubtedly will find its use in atmospheric physics studies.

The particular attention was paid to presentation by A.V. Kukhto with co-authors (Institute of Molecular and Atomic Physics, Minsk, Belarus and Chuvash State University, Cheboksary, Russia) devoted to energy conversion in laser dyes under electron excitation. Such studies are needed in seeking organic molecules fluorescing under the excitation by electric current.

The studies of properties of organic molecules in thin films (report by A.O. Bulanov with co-authors, Rostov, Russia) are now extremely urgent. Numerous results on nonsilver light-sensitive materials give the priority to the most important classes of organic photochroms: spiropyrans and spirooxazines. Photochroms showing their properties in solid phase are the most practically feasible for obtaining of photochromic materials. This report discussed the results of studying the photochromic properties of indolinospiropyran in polymer matrices and in polydisperse films. The photochromic properties of the materials in solid phase are characterized by high values of free activation energy of the thermal cycle opening reaction.

Complex molecular systems like biphosphors are promising for new applications. For these reasons, presentations by G.V. Maier, V.Ya. Artyukhov, and V.I. Yuzhakov with co-authors attracted much interest.

The studies of photoprocesses in complex organic molecules with the use of quantum-chemistry methods, were widely presented at the AMPL'01 (reports by V.Ya. Artyukhov, N.Yu. Vasil'eva, O.K. Bazyl', et al.).

The reports on ecological subject were connected with the study of photoprocesses in organic toxicants and the development of method for their optical diagnostics and destruction (presentation by I.V Sokolova, O.N. Tchaikovskaya, V.A. Svetlichnyi, E.A. Sosnin, N.B. Sul'timova, et al.).

Physical Processes in Gas Lasers

The paper by A.N. Tkachyov and S.I. Yakovlenko was devoted to modeling of the process of plasma formation in the near-electrode layer of high-voltage discharge in xenon at high pressure. The parameters that determine the process of reconstruction of ionization and electron drift were calculated. Some equations describing the transition of the ion current into the electron one near a cathode were solved.

V.P. Demkin, E.V. Koryukina, and O.G. Revinskaya (Tomsk) presented the results on studying the asymmetry of spectral line profile of atom in the external electric field. The data obtained allow analysis of the mechanism of the line profile formation.

A.G. Bessonov and A.L. Magazinnikov considered the problems of modeling the radiation propagation in a laser system with the active medium including phase inhomogeneities. They studied a XeCl laser system with pulsed discharge and calculated the beam intensity, cross phase distribution, and the surface of the wave front.

The joint report by the Russian and French scientists: Yu.I. Bychkov, S.L. Gorchakov, A.G. Yastremskiy (Tomsk, Russia), B. Lacour, S. Pasquiers, C. Postel, and V. Puech (Orsay, France) presented the results of studying the properties of electric discharges in gas mixtures based on SF_6. The discharge inhomogeneity caused by appearance of channels with increased conductivity is an important problem in achieving of optimal output characteristics. Recent studies have shown that these channels are caused by hot spots existing on the cathode. The discharge is compressed under conditions that the channels with increased conductivity develop from one or several hot spots on the cathode. The properties of the discharge in SF_6 and SF_6–C_2H_6 mixture were studied in a wide range of pumped energy. It was shown that discharges in gas media are more homogeneous and stable. A single hot spot allows obtaining the discharge current of 2–3 kA at the energy of 1–3 J without disturbing the discharge homogeneity.

The presentation by V.V. Appolonov, S.Yu. Kazantsev, A.V. Saifulin, K.N. Firsov, and A.A. Belevtsev (Moscow) was devoted to studying the effect of ion-ion recombination on the discharge characteristics in non-chain electric discharge in a HF laser. The recombination coefficients were estimated in the diffusing plasma of SF_6 and SF_6–C_2H_6 mixtures at the mixture pressure of 15–90 Torr.

G.V. Kolbychev (Tomsk, Russia) presented his study of the efficiency of generation of an electron beam in an abnormal glow discharge. The coefficient α of ionization by running away electrons in strong and moderate fields was calculated. The opinion that the coefficient α is a constantly varying parameter under conditions of running away electrons was shown to be a mistake. It was also shown that the efficiency of formation of an electron beam in abnormal glow discharge is about 50–70%. Let us note, for a comparison, that in the open discharge the efficiency is about 80–90%.

A.R. Sorokin (Novosibirsk, Russia) in his report considered the mechanism of the so-called open discharge development. A long delay was experimentally found in the formation of the area of cathode potential drop with respect to the discharge current. This is indicative of very high emission of electrons from the cathode as compared to the abnormal glow discharge. It was shown experimentally that electron beam generation correlates with the discharge induced by this beam. The efficiency of electron beam generation in the transition photoelectron phase was found to achieve about 75–95%, whereas in the abnormal glow discharge it is about 20–30%.

T. Goto, T. Jitsuno, K. Nakamura, et al. (Osaka, Japan) in the report "Gain measurement of ultra-high pressure Ar_2 laser using plasma electrodes" reported the development of highly homogeneous discharge in pure argon at the pressure of 6–20 atm. They have measured the time-resolved electron density and the gain with the nanosecond time resolution. The electron density achieved more than 10^{16} cm^{-3} at the pressure of 10 atm. The maximum gain at λ = 176 nm was observed at the pressure of 20 atm and was 8.6%/cm.

The report by E.L. Latush, O.O. Prutsakov, and G.D. Chebotarev (Rostov-on-Don, Russia) was devoted to the study of cataphoresis dynamics in repetitively pulsed discharge. Criteria were found for the axial homogeneity in the distribution of metal vapor. Time intervals for the establishment of the homogeneous distribution of vapor were determined for typical repetitively pulsed discharges of metal-vapor lasers.

The report by A. Treshchalov with co-authors (Tartu, Estonia) considered the problems of formation of powerful pump for ArF and F_2 lasers in high-power discharge without hot spots on the cathode and filament instabilities. The laser had a modified excitation scheme: combination of sliding discharge (automatic preionization) and volume discharge (main pumping). Spectroscopic diagnostics of the discharge has been carried out. It was found that at the maximum pulse repetition frequency the discharge compression begins from overheating of the gas layer adjacent to the cathode surface. The rate of gas exchange between neighboring laser pulses is lower for the boundary layers as compared with the entire discharge volume.

Laser Systems and Their Applications

More than 50 papers were presented in this section including 14 oral presentations.

W. Stoll (Institute for the Industrial Environment, Hanau, Germany) presented the paper on the state of the art in industrial isotope separation with the use of laser technologies. In the report, he described briefly the principles of laser isotope separation based on the isotopic effect in absorption spectra of atoms and molecules. This fact allows one to isotopically selectively excite such atoms. An atom or molecule being in the excited state can enter into a chemical reaction or can be ionized or dissociated under further interaction with laser fields. Due to this fact, the high degree of enrichment can be achieved. It was noted that laser methods of isotope separation are rather promising for many elements and allow obtaining high degree of enrichment.

This subject was also considered by M.A. Kazaryan and P.A. Bokhan with co-authors. M.A. Kazaryan considered laser separation of silicon isotopes in atomic vapor by the method of selective photoionization with the use of tunable narrow-band dye lasers. A scheme was proposed for ionization of atoms to the upper states with the following excitation of the photoionization state. Estimates were given for the total flux of ions and their limiting concentration at the given output power of 1 W in every channel, the pulse repetition frequency of 10 kHz, and 0.6-liter active zone volume. It was noted that the state of the art of laser technologies allows the maximum productivity in producing highly enriched ^{28}Si isotope to be estimated as 0.1 g/h. The report by P.A. Bokhan with co-authors was devoted to the problems of laser separation of lead, zinc, and rubidium isotopes.

The report presented by A.A. Zhupikov on behalf of a group of authors (Institute of Laser Physics SB RAS, Novosibirsk, Russia) and dealing with the application of excimer lasers to ophthalmology, cardiosurgery, neurosurgery, and dentistry was very interesting and important from the viewpoint of promises of medical and biological applications of lasers. This report gave detailed analysis of medical systems for ophthalmology. The peculiarities of the influence of shortwave radiation on a human body were discussed with the allowance for possible mutagenic effect of shortwave radiation. The obtained parameters were analyzed comparatively with the data of other research teams in Russia and in foreign countries, and the competitive strength was demonstrated.

A considerable attention at this session was paid to the problems of applying laser systems to diagnostics and treatment of oncological diseases (A.V. Ivanov with colleagues, V.A. Evtushenko, et al.).

I.B. Kovsh, President of the Laser Association of the Commonwealth of Independent States, in his report presented the data on the general state of research in laser physics and the situation in laser industry of the Russian Federation. More than 900 universities, companies, clinics, and business enterprises are involved in this field. The Russian industry produces almost all types of lasers and laser systems (more than 2000 models), but the home demand for such devices is still very low. Except for Moscow (where more than 50% of distributive laser firms are concentrated), there are powerful laser companies in St. Petersburg, Novosibirsk, Nizhni Novgorod, Samara, and Tomsk. The number of specialists with high education dealing with lasers exceeds 15 thousands. I.B. Kovsh noted that leaders of the Russian laser centers are well-known abroad, and the potential of these centers is rather high. And underestimation of this potential is a regrettable mistake of the state officials.

Non-coherent UV and VUV Sources. Laser Output Conversion. Optoelectronic Devices.

A total of 47 reports were presented within the framework of this section. Doctor A. Skudra (Institute of Atomic Physics and Spectroscopy, Riga, Latvia) presented some interesting data on the development of HF electrodeless lamps for the UV and VUV spectral regions. Doctor A.A. Senin presented the report of Professor J.G. Eden (University of Illinois, Urbana, USA) "Microdischarge arrays as new ultraviolet sources," which gave the characteristics of light sources based on discharges in microholes. Doctor Yu.M. Andreev (Tomsk) in his detailed report considered the properties of new crystals for frequency conversion of gas lasers operating in the IR and visible spectral regions. The report by Doctor V.D. Bochkov (Pulsed Technologies Ltd., Ryazan, Russia) contained the data on newly developed high-voltage switches for lasers and other pulsed devices. It is worth noting the cycle of works completed at the Institute of High-Current Electronics SB RAS and devoted to new models and applications of excilamps. Thus, in particular, M.I. Lomaev (Tomsk) reported on the development of a barrier-discharge pumped KrCl excilamp (wavelength of 222 nm) with the output power of 100 W.

Round Table

AMPL'01 was concluded with the Round Table session devoted to the discussion of physical factors limiting the output and operating characteristics of metal-vapor lasers (MVL).

In particular, Professor G.G. Petrash (Moscow, Russia) believes that the main factor limiting the output characteristics of the copper-vapor laser is effective (parasitic) population of lower working levels of the copper atom in the process of pumping. In his opinion this is connected with the fact that the rates of electron-impact excitation of metastable and resonance states are close in absolute value, as follows from the experimental data. In his opinion, certain promises in the development of metal vapor lasers lie in the transition from pure copper vapor to some compounds, in particular, copper bromide. The practical efficiency of such a laser proves to be higher and achieves 4%. The limiting pulse repetition frequencies are higher too (up to 300 kHz), and, as he thinks, it is related to the presence of electro-negative additions (like HBr) in the discharge of the CuBr laser that positively affect the lasing characteristics (through the electron component).

Doctor P.A. Bokhan (Novosibirsk, Russia) has defended a different point of view, according to which the main factor limiting the MVL output parameters at high pulse repetition frequency is high pre-pulse electron density preventing efficient pumping of the upper working states while, at the same time, favoring "parasitic" population of the lower working states at the leading front of the excitation pulse. The many-year discussion of these leading specialists is reflected in some publications in *Russian Quantum Electronics* and other journals. It should be noted that their positions in the physics and technology of MVL have become closer in recent years.

The discussion involved Professor S.I. Yakovlenko (Moscow, Russia), Professor M.F. Sem (Rostov-on-Don, Russia), Doctor G.S. Evtushenko (Tomsk, Russia), Professor V.F. Tarasenko (Tomsk, Russia), and Doctor D. Astadjov (Sofia, Bulgaria).

Thus, in the Yakovlenko's opinion it follows from calculations by a simple kinetic model that there exists some "critical" value of the pre-pulse electron density, above which MVL lasing does not occur.

Professor V.F. Tarasenko noted one more factor limiting the efficiency of MVL, namely, possible "parasitic" charging of a capacitor at incomplete breakdown and reported that the lasing efficiency of the copper-vapor laser achieves 4% of the deposited energy in a tube of a medium diameter.

Doctor G.S. Evtushenko gave some examples of the positive effect of minor uncontrolled admixtures on the lasing characteristics of MVL. This is likely connected with the presence of residual hydrogen in the MVL discharge. Doctor D. Astadjov told about the positive effect of hydrogen on the lasing characteristics of the CuBr laser and the technical implementation of the sealed-off $CuBr+H_2$ laser and gave additional details to his earlier report. It should be noted that the increase in the output power of the copper-vapor laser was observed for the first time by P.A. Bokhan with colleagues.

Thus, the participants of the Round Table noted that the MVL potential is not still completely realized.

In addition to the sessions described above, the AMPL'01 program included excursions to the laboratories of the Institute of High-Current Electronics SB RAS, Institute of Atmospheric Optics SB RAS, Tomsk State University, and Siberian Physical Technical Institute.

At the AMPL'01 closing session on September 14 of 2001, Russian and foreign scientists noted high scientific and organizational level of the conference and active participation of young scientists and postgraduate students, as well as expressed the wish for the next AMPL'03 conference to be held in September of 2003 in Tomsk.

Additional information on the AMPL conference can be found on the Internet site of the Institute of Atmospheric Optics: http://symp.iao.ru

G.S. Evtushenko, V.M. Klimkin, Institute of Atmospheric Optics SB RAS,
T.N. Kopylova, V.D. Kuznetsov Siberian Physical Technical Institute,
A.N. Soldatov, A.M. Yancharina, Tomsk State University,
V.F. Tarasenko, Institute of High-Current Electronics SB RAS