RAS Academician Vladimir P. Shorin and diffractive computer optics

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Abstract. The paper briefly describes the main achievements in the area of laser technologies and the application of diffractive computer optics of Academician of the Russian Academy of Sciences, Doctor of technical sciences, Professor, Honoured Scientist and Engineer of the RSFSR, Laureate of the State Award of the Russian Federation in the area of science and technology Vladimir P. Shorin.

1. Introduction
The full member of the Russian Academy of Sciences Vladimir P. Shorin is a well-known academic figure in Russia. He is the author of more than 350 scientific papers, including 70 invention certificates and patents for inventions. V.P. Shorin made an immense contribution into the organization of education in the post-Soviet Russia, and into the development of the integration of higher education and basic science. V.P. Shorin led the development of technical guides for aviation equipment providing a unified methodology for the design of vibration suppression devices in hydro-gas and fuel systems of aircrafts and engines, which has significantly reduced the time required for finishing the products. The developed vibration dampers and corrective devices ensured the efficiency of the hydraulic system of the AN-124 aircraft, the hydraulic system of the drive unit of actuators of launch vehicles, and the fuel systems of aircraft engines. Gas dampers found application in the fuel supply systems of low-thrust liquid-fuel rocket engines. The methods and technologies ensuring the stability of regulators of pneumatic-hydraulic systems of rocket technology products have been introduced at the enterprises of the Russian Federation. The accelerated life test methods for aircraft units, pipelines and their connections developed under the leadership of V.P. Shorin produced significant economic effect. In addition to the aviation, rocket and space equipment, V.P. Shorin also led the development of vibroacoustic loads reduction means for stationary power plants (CHP), ammonia compressor station hydraulic system and Don-1500 combine harvester hydraulic transmission. Highly efficient exhaust silencers for production equipment and manual pneumatic tool silencers developed under his guidance are used in the automotive industry. Vladimir P. Shorin paid a lot of attention to the development of laser technologies. This aspect of his scientific and organizational activities is described in the present article.

2. Milestones
Vladimir P. Shorin (Fig. 1) was born on July 27, 1939 in the city of Nizhny Lomov, Penza Region. In 1956, after graduating from high school, V.P. Shorin entered the Penza Agricultural Institute, and in 1959 he was transferred from the said institute to the Kuybyshhev Aviation Institute (at present - the Samara National Research University named after academician S.P. Korolev) to continue his studies at
the Faculty of Aircraft Engines. After graduating the institute with honors in 1963, he stays to continue his scientific and teaching activities. By 1990 V.P. Shorin has worked his way up from an engineer and a graduate student to a vice-rector and rector of the institute. During this period, he prepared and defended Ph.D. and doctoral dissertations in technical sciences, obtained the academic rank of associate professor, and then - professor. The scientific school “Dynamic Processes in Engines and Power Plants” created by him ranks among the leading scientific schools of the Russian Federation.

Figure 1. RAS Academician Vladimir P. Shorin.

In 1990, V.P. Shorin was elected to the Supreme Soviet of the RSFSR, where he headed the Committee on Science and Public Education. In the course of his parliamentary activities, he initiated a Resolution of the Supreme Soviet on the establishment of the Russian Academy of Sciences and took an active part in its formation. He also headed and participated himself in development of drafts of the Decree of the President of Russia No. 1 and the Law of the Russian Federation on education and drafts of other laws and regulations to govern the activities in the area of science and education. V.P. Shorin made a significant contribution to the integration of science and education in the position of the executive director of federal target programs "State support of the integration of higher education and basic science" (1997-2001) and "Integration of science and education in Russia" (2002-2004). During the implementation of these programs on the territory of Russia, a network of infrastructural organizations was created to ensure the coordination of university and academic science in order to develop science and to train highly qualified personnel [1]. V.P. Shorin played a crucial role in the development of the Samara Scientific Center of the Russian Academy of Sciences [2].

In 1991, V.P. Shorin was elected a full member of the Russian Academy of Sciences, and from 1994 to 2017 he headed the Samara Scientific Center of the Russian Academy of Sciences.

V.P. Shorin's professional achievements have been recognized and brought him a number of state awards: the Order of the Red Banner of Labor, the Order of Honor, the Order of Friendship, the honorary title "Honored Scientist and Engineer of the RSFSR." He is the laureate of the State Award of the Russian Federation in the area of science and technology, the laureate of the awards of the Government of the Russian Federation in the field of science and technology and in the field of education.

3. Creation of integrated laser technologies with diffractive optical elements

In 1982, a Department of Automatic Systems of Power Plants was opened at the Faculty of Aircraft Engines. Vladimir P. Shorin was the founder and head of the said Department, as well as the R&D group, and the R&D Laboratory of Power Plants, which the R&D group was transformed into due to
the increased amount of contractual works. In the same year, together with the opening of a new specialization “Laser Systems” at this Department, a new technological scientific area was established – the use of lasers in various technological processes.

Due to major organizational and methodological efforts of the teachers and staff of the department, the educational process on the specialization "Laser Systems" was formed in the shortest possible time. This was facilitated by the fact that in the first academic year the studies were held not with students, but with the trainees of the Faculty of Advanced Training of engineering and technical associates of enterprises engaged in developing and operating of laser equipment. As early as in 1985 several laboratory works on laser technology and material processing were performed [3-5]. Further equipment of the department laboratories with laser machining systems (for example, LK-1300 "Hebr", LATUS-31, Kvant-15, GOS-1000, OGM-20), modern recording and measuring equipment, as well as systematization of graduation works of the trainees of the Faculty of Advanced Training, and teachers' internships at the laser divisions of enterprises allowed to complete the formation of such disciplines as “Laser material processing”, “Laser optics”, “Measurement and operation of laser systems” by 1986. The experience gained by the department in training of highly qualified specialists, the teaching and research base equipped with both serial and experimental laser equipment, made it possible to open the specialty 131200 “Laser Systems” in 1988. This helped to solve many organizational, educational and methodical issues related to the workload of teachers, the work of the educational and methodical council, and strengthened the relations with enterprises. Greater attention was paid to the occupational guidance for schoolchildren in graduation classes performed by the department staff to identify and attract talented youth to the specialty. The leading role of the team in the training of mechanical engineers of laser systems was recognized by the RF State Committee on Education, which entrusted the teachers of the Department of Automatic Systems of Power Plants to develop the state educational standard for the specialty 131200 “Laser Systems" in 1994. Later the department also developed the state educational standard for the specialty 200202 "Laser systems in rocket technology and cosmonautics."

Along with other research fields, one of the main areas was the development of emerging laser material processing technologies. The research team led by V.P. Shorin gained significant results in the areas of laser cutting and welding of metals and alloys, laser annealing before metal forming, hardening, etc. However, the greatest effect of applying lasers in various technological processes was achieved when using computer-aided diffractive optical elements (DOEs) developed at the Department of Technical Cybernetics and at the Image Processing Systems Institute of the Russian Academy of Sciences headed by Viktor A. Soifer. DOEs for the beam shaping of industrial lasers have unique capabilities [6-9]. These elements can control laser beam, intensity in the beam and the shape of the treatment area.

In 1988, the "Computer Optics" journal published a paper [10] describing the technological possibilities of applying DOEs for laser material processing. It presented the results of experimental studies of laser annealing, surface alloying of steel, welding of polymeric materials using DOE redistributing laser beam in a straight-line segment. An industrial CO2 laser was used in single-mode and multimode continuous wave laser operation. It was shown that the use of DOE provides an opportunity to significantly improve the performance of parts after the laser processing, to increase the efficiency of these manufacturing processes and to reduce material costs. The listed scientific provisions were developed further when designing advanced technological processes for manufacturing of parts for aircrafts and their engines [11-14], the methods for laser processing of objects using mobile DOEs have been patented in our country and abroad [15-22].

As a result of the research, it was found that the use of integrated plasma, ion-plasma vacuum and laser technologies with diffractive optical elements allows to produce parts and coatings with unique properties for various functional purposes. In 1992, V.P. Shorin together with a team of contributors was honoured with the State Award of the Russian Federation in the area of science and technology for the development and implementation of such integrated laser and plasma technologies for creating new technological products for aviation and space purposes. This area of research is reflected in the works [23-25], which solve the problems of integrating laser and machine-building technologies when developing competitive industries for the production of reliable modern machines and devices.
operating in high-heat and aggressive media conditions. The above works also suggest the methods for eliminating manufacturing defects in the form of cracking, peeling of coatings, warping of products, etc. by adjustment of thermal effect of laser and combined laser-plasma energy flows.

4. Development of laser technologies with diffraction computer optics

In 2007, a scientific and educational center for laser systems and technologies was created in the Samara State Aerospace University named after academician S.P. Korolev at the Faculty of Aircraft Engines headed by Academician of RAS V.P. Shorin in the framework of the National Project "Education" and the innovative educational program "Development of the Competence Center and training of world-class specialists in the field of aerospace geoinformation technologies." The scientific and educational center was created on the educational and pedagogical base of the specialty 200202 “Laser systems in rocket technology and cosmonautics” of the Department of Automatic Systems of Power Plants. In addition to active assistance in training and retraining of teachers and industry associates in the field of laser technology, one of the main tasks of the scientific and educational center was to help industrial enterprises and small enterprises to create, develop and transfer laser technology into production. There was created a unique laboratory, equipped with a powerful technological gas laser ROFIN DC 010 and an automated coordinate device; a specialized welding unit based on a solid-state laser Rofin Star Weld was purchased.

The creation of the scientific and educational center contributed greatly to the preparation of a number of textbooks, including the textbook [26], by teachers of the department in a fairly short time. One of the sections provided the analysis of optical systems for the conversion of beam parameters used to shaping of beams of high-power industrial lasers. It indicated that the use of laser technology leads to a careful selection of optical systems for transportation and shaping of beam. In some cases, such systems provide an opportunity to achieve the required type of the energy impact. However, none of the optical systems except DOE beam focusing devices can provide a simultaneous combination of such properties as high reliability, the required intensity distribution, and concentration of laser beam energy in the impact zone of a given shape, which largely determine the efficiency of processes and the level of sophistication of laser technology. In addition to the calculation of the shape of the working surface of reflecting DOEs within the provisions of geometrical optics for various operations of laser processing, the work [26] describes the DOE-based technological device used for the industrial laser material processing. The scientific and educational center of laser systems and technologies is still an important institution contributing to the development of laser technologies, the training of specialists and the provision of technical assistance to industrial enterprises.

By the Order of the Government of the Russian Federation of October 25, 2010 No. 1868-p the Academician of the Russian Academy of Sciences, Doctor of technical sciences, Chairman of the Samara Scientific Center of the Russian Academy of Sciences, Professor of the Department of Automatic Systems of Power Plants of the Samara State Aerospace University V.P. Shorin together with a team of contributors was honoured with the Award of the Government of the Russian Federation for the year 2010 in the field of education with the title "Laureate of the Government of the Russian Federation in the Field of Education" for the scientific, practical and methodical development of “Creating an innovative scientific and educational system for training of highly qualified personnel in the field of laser technology for processing of materials”.

Laser technologies with DOEs are developing rapidly [27-31]. The team of the scientific and educational center of laser systems and technologies created the methods and means of generating energy deposition with the distribution of laser beam power density controlled according to a given change of the state of technological objects [32-36]. The methods have been developed to improve the properties of engine parts of aircrafts by laser treatment using DOE: thermal hardening, deposition and sintering of coatings [37-39], laser annealing of sheet metal materials [40-42]. A technological method has been developed to improve the performance characteristics of engine parts of aircraft by laser processing. The method differs from the existing ones in that the shape of the laser spot and the distribution of the beam power density are considered as the main parameters of the processing mode, the choice of parameters of the laser source and the development of technological optical systems is carried out in accordance with the results of solution of an inverse heat conduction problem [43].
In the works [44-48], the possibilities of generating nanomaterials were examined and the synthesis of nanoporous and composite nanomaterials based on ZnO by pulsed-periodic laser irradiation was performed. For the first time, a significant increase (several times compared with thermal effect alone) of the diffusion coefficient in a metallic material due to the synergy of thermal effect and laser-induced vibrations (mainly in the sound frequency range) caused by a pulsed-periodic laser beam with a pulse duration of microsecond and millisecond range [49-52]. The condition for the intensification of mass transfer in the solid phase of selectively oxidizable copper-zinc metallic materials was identified as a non-stationary stress-strain state caused by laser-induced sound waves [53-55].

In experimental studies, optical systems with new DOE beam focusators were used for targeted change of the power density distribution of the laser radiation [56-60]. The use of such systems allowed for the microstructuring of the surface of carbide silicon ceramics by the method of pulse-periodic laser treatment to reduce the friction coefficient at contact stresses arising in the elements of rolling bearings in actual operating conditions [61, 62]. In the measurement range, the friction coefficient after laser treatment was more than 30 % less compared to the initial structure. A significant reduction of friction in rolling bearings to this level provides an opportunity to increase the efficiency of various machines. Laser welding of various metallic materials using DOE-focused beam is also promising [63]. An efficient method for the manufacturing of DOE is nanostructuring of the surface of e.g. copper-containing, film-coated molybdenum and other materials using continuous radiation [64-65], short and ultrashort laser pulses [66-68] (Fig. 2). The periodic surface structures obtained by this method can, for example, decompose incident light into spectral components.

![Figure 2](image-url)  
*Figure 2.* The result of treatment of a copper plate with a focused femtosecond laser beam [66] (pulse frequency is 1 kHz, pulse duration is <30 fs, central wavelength is 800 nm, movement speed is 135 mm/min; the resulting colour of the material depends on the direction of movement indicated by arrows).

5. Conclusion
In conclusion, we would like to wish Vladimir P. Shorin good health, inexhaustible energy and new achievements for the benefit of our country and the national science!

6. References
[1] Shorin V P 1999 Education and scientific research: A program of integration *Vestnik Rossijkoj Akademii Nauk* 69(7) 606-617  
[2] Shorin V P, Lazarev N Yu 2000 The samara science center is ten *Vestnik Rossijkoj Akademii Nauk* 70(5) 441-445  
[3] Shorin V P, Zhuravlev O A, Medinskaya L N, Osadchuk A G and Tokarev V V 1985 Laser velocity photorecording of injector spray plume *Soviet Aeronautics* 28(2) 128-130
[4] Shorin V P, Zhuravlev O A, Logak L G, Medinskaya L N and Fedosov A I 1985 Holographic apparatus for study of two-phase flows *Instruments and experimental techniques* 28(5) 1163-1166

[5] Shorin V P, Mordasov V I and Zhuravlev O A 1984 Development of laser technological installation and its application for processing of sheet materials *Deposited VINITI* 6890-84 p 11

[6] Golub M A, Sisakian I N and Soifer V A 1991 Infra-red radiation focusators *Optics and Lasers in Engineering* 15(5) 297-309 DOI: 10.1016/0143-8166(91)90017-N

[7] Doskolovich L L, Kazanskiy N L, Kharitonov S I and Uspleniev G V 1991 Focusators for laser-branding *Optics and Lasers in Engineering* 15(5) 311-322 DOI: 10.1016/0143-8166(91)90018-0

[8] Doskolovich L L, Golub M A, Kazanskiy N L, Soifer V A and Uspleniev G V 1993 Diffractive optical elements for laser processing *Proceedings of SPIE* 1983(2) 647-648 DOI: 10.1117/12.2308686

[9] Kazanskiy N L, Uspleniev G V and Volkov A V 2000 Fabricating and testing diffractive optical elements focusing into a ring and into a twin-spot *Proceedings of SPIE* 4316 193-199 DOI: 10.1117/12.4076768

[10] Sisakyan I N, Shorin V P, Soifer V A, Mordasov V I and Popov V V 1990 Technological capabilities of focusators in laser-induced material processing *Computer Optics* 3(2-1) 85-88

[11] Sisakyan I N, Shorin V P, Soifer V A and Mordasov V I 1987 Application of focusators in laser processing of materials *Application of lasers in technology and information transmission systems: Abstracts of the 3rd All-Union conference* 179

[12] Shorin V P, Mordasov V I, Morozov A N and Murzin S P 1988 Enhancement of resistance high temperature protective and wear resistant coatings by laser sintering *Application of lasers in national economy: abstracts of the III All-Union conference* 108

[13] Shorin V P, Soifer V A, Mordasov V I and Murzin S P 1988 Application of phase elements of flat optics in laser technology of aircraft engines production *Structural strength of engines: Abstracts of XI All-Union scientific and technical conference* 168-169

[14] Shorin V P, Mordasov V I and Murzin S P 1990 Investigation of laser surface treatment of gas turbine engine parts *Aviation industry* 4 18-20

[15] Danilov V A, Popov V V, Prokhoren A M, Sisakian I N, Sagatelian D M, Soifer V A, Sisakyan E V, Naumidi L P, Danileiko Ju K, Terekhin Ju D, Akopian V S, Murzin S P, Shorin V P and Mordasov V I 1992 Device for laser treatment of an object *United States Patent* 5103073. PCT Filed 28.08.1987

[16] Danilov V A, Popov V V, Prokhoren A M, Sisakyan I N, Sagatelian D M, Sisakyan E V, Soifer V A, Akopyan V S, Danileiko Ju K, Naumidi L P, Terekhin Ju D, Shorin V P, Mordasov V I and Murzin S P 1989 Method and device for laser processing of an object *European Patent Application* 0329787. Priority to PCT/SU1987/000098 28.08.1987

[17] Danilov V A, Popov V V, Prokhoren A M, Sisakyan I N, Sagatelian D M, Sisakyan E V, Soifer V A, Akopyan V S, Danileiko Ju K, Naumidi L P, Terekhin Ju D, Shorin V P, Mordasov V I and Murzin 1991 Method and device for laser processing of an object *Japan Patent* JPH03500620. Priority to PCT/SU1987/000098 28.08.1987

[18] Sisakyan I N, Shorin V P, Soifer V A, Mordasov V I and Murzin S P 1991 Device for local annealing of sheet bars *Invention Certificate* 1706219. Supposed 4168247/31-02, 27.10.1986

[19] Shorin V P, Soifer V A, Mordasov V I, Murzin S P and Popov V V 1993 Method of sheet bar softening before stamping and the corresponding device *Invention Certificate* 1839119. Supposed 4150175/31-27, 17.11.1986

[20] Shorin V P, Mordasov V I and Murzin S P 1990 Method for continuous overlap welding of polymeric materials and the corresponding device *Invention Certificate* 1599239, IPC5 B 29 C 65/16. Supposed 4218379, 05.01.1987

[21] Shorin V P, Mordasov V I and Murzin S P 1999 Method of manufacturing of curved parts from sheet bars *Invention Certificate* 1515495. Supposed 4238550/27, 03.02.1987
[22] Sisakyan I N, Shorin V P, Soifer V A, Mordasov V I and Murzin S P 1991 Device for surface treatment of materials by radiation Invention Certificate 1646295, IPC5 C 29 D 1/09. Supposed 4406312/31-02, 29.02.1988

[23] Barvinon V A, Mordasov V I and Shorin V P 1997 Highly Effective laser–plasma technologies in mechanical engineering (Moscow: International center for scientific and technical information) p 76

[24] Mordasov V I, Murzin S P, Sazonnikova N A and Shuvaev A A 2001 On the formation of plasma-laser coatings Russian Metallurgy (Metally) 3 291-293

[25] Mordasov V I, Murzin S P, Sazonnikova N A and Shuvaev A A 2001 Formation of plasma-laser coatings Metally 3 79-82

[26] Shorin V P, Murzin S P 2006 Laser Optics: Textbook (Samara: publishing House of Samara State Aerospace University) p 146

[27] Kazanskiy N L, Murzin S P, Osetrov Ye L and Tregub V I 2011 Synthesis of nanoporous structures in metallic materials under laser action Optics and Lasers in Engineering 49(11) 1264-1267 DOI: 10.1016/j.optlaseng.2011.07.001

[28] Bielak R, Bammer F, Otto A, Stiglbrunner C, Colasse C and Murzin S P 2016 Simulation of forming processes with local heating of dual phase steels with use of laser beam shaping systems Computer Optics 40(5) 659-667 DOI: 10.18287/2412-6179-2016-40-5-659-667

[29] Murzin S P, Kazanskiy N L, Liedl G, Otto A and Bielak R 2017 Laser beam shaping for modification of materials with ferritic-martensitic structure Procedia Engineering 201 164-168

[30] Murzin S P, Liedl G 2017 Laser welding of dissimilar metallic materials with use of diffractive optical elements Computer Optics 41(6) 848-855 DOI: 10.18287/2412-6179-2017-41-6-848-855

[31] Liedl G, Vázquez R G and Murzin S P 2018 Joining of aluminium alloy and steel by laser assisted reactive wetting Lasers in Manufacturing and Materials Processing 5(1) 1-15

[32] Kazanskiy N L, Murzin S P, Mezhenin A V and Osetrov E L 2008 Formation of the laser radiation to create nanoscale porous materials structures Computer Optics 32(3) 246-248

[33] Murzin S P, Tregub V I, Melnikov A A and Tregub N V 2013 Application of radiation focusators for creation of nanoporous metal materials with high specific surface area by laser action Computer Optics 37(2) 226-232

[34] Bolotov M A, Pechenin V A and Murzin S P 2016 Method for uncertainty evaluation of the spatial mating of high-precision optical and mechanical parts Computer Optics 40(3) 360-369 DOI: 10.18287/2412-6179-2016-40-3-360-369

[35] Murzin S P, Liedl G and Bielak R 2017 Redistribution of the laser beam power using diffractive optical elements Proc. SPIE 10342 103420G

[36] Murzin S P, Kazanskiy N L 2018 Laser beam shaping with purposefully changing of spatial power distribution Proc. SPIE 10774 107740Q

[37] Murzin S P 2016 Formation of structures in materials by laser treatment to enhance the performance characteristics of aircraft engine parts Computer Optics 40(3) 353-359 DOI: 10.18287/2412-6179-2016-40-3-353-359

[38] Smelov V G, Sotov A V and Murzin S P 2016 Particularly selective sintering of metal powders by pulsed laser radiation Key Engineering Materials 685 403-407

[39] Murzin S P, Tisarev A Yu, Blokhin M V and Afanasiev S A 2017 Development of mathematical model of laser treatment heat processes using diffractive optical elements CEUR Workshop Proceedings 1900 101-105

[40] Murzin S P 2016 Local laser annealing for aluminium alloy parts Laser. Eng. 33(1-3) 67-76

[41] Murzin S P 2018 Formation of a non-detachable welded titanium-aluminium compound by laser action IOP Conference Series: Materials Science and Engineering 302(1) 012072

[42] Murzin S P, Kazanskiy N L 2018 Softening of low-alloyed titanium billets with laser annealing IOP Conference Series: Materials Science and Engineering 302(1) 012070

[43] Murzin S P, Bielak R and Liedl G 2016 Algorithm for calculation of the power density distribution of the laser beam to create a desired thermal effect on technological objects Computer Optics 40(5) 679-684 DOI: 10.18287/2412-6179-2016-40-5-679-684
[44] Murzin S P 2011 The research of intensification’s expedients for nanoporous structures formation in metal materials by the selective laser sublimation of alloy’s components Computer Optics 35(2) 175-179
[45] Murzin S P, Shakhmato v E V, Igolkin A A and Musakhunova L F 2015 A study of vibration characteristics and determination of the conditions of nanopores formation in metallic materials during laser action Procedia Engineering 106 266-271
[46] Murzin S P, Kryuchkov A N 2015 Influence of conditions of the samples fixation on the intensity of the nanoporous structure formation in the metallic material by laser action with thermocycling Procedia Engineering 106 272-276
[47] Murzin S P 2015 Formation of nanoporous structures in metallic materials by pulse-periodic laser treatment Optics and Laser Technology 72 48-52
[48] Murzin S P, Kryuchkov A N 2017 Formation of ZnO / CuO heterostructure caused by laser-induced vibration action Procedia Engineering 176 546-551
[49] Kazanskiy N L, Murzin S P and Tregub V I 2010 The optical system for the selective laser sublimation of the components of the metal alloys Computer Optics 34(4) 481-486
[50] Murzin S P, Tregub V I, Shokova E V and Tregub N V 2013 Thermocycling with pulse-periodic laser action for formation of nanoporous structure in metal material Computer Optics 37(1) 99-104
[51] Murzin S P 2014 Synthesis of metal materials nanoporous structures with cyclic elasto-plastic deformation under laser treatment using radiation focusators Computer Optics 38(2) 249-255
[52] Murzin S P, Prokofiev A B and Safin A I 2017 Study of Cu-Zn alloy objects vibration characteristics during laser-induced nanopores formation Procedia Engineering 176 552-556
[53] Murzin S P 2015 Determination of conditions for the laser-induced intensification of mass transfer processes in the solid phase of metallic materials Computer Optics 39(3) 392-396 DOI: 10.18287/0134-2452-2015-39-3-392-396
[54] Murzin S P, Prokofiev A B, Safin A I and Kostriukov E E 2018 Creation of ZnO-based nanomaterials with use synergies of the thermal action and laser-induced vibrations J. Phys. Conf. Ser. 1096(1) 012150
[55] Murzin S P, Afanasiev S A and Blokhin M V 2018 Pulse-periodic laser action to create an ordered heterogeneous structure based on copper and zinc oxides J. Phys. Conf. Ser. 1096(1) 012139
[56] Kazanskiy N L, Kharitonov S I and Soifer V A 1996 Application of a pseudogeometrical optical approach for calculation of the field formed by a focusator Optics & Laser Technology 28(4) 297-300 DOI: 10.1016/0030-3992(95)00103-4
[57] Kazanskiy N L, Soifer V A 1994 Diffraction investigation of geometric-optical focusators into segment Optik 96(4) 158-162
[58] Kazanskiy N L 2012 Research & education center of diffractive optics Proceedings of SPIE 8410 84100R DOI: 10.1117/12.923233
[59] Kazanskiy N L, Kharitonov S I, Kozlova I N and Moiseev M A 2018 The connection between the phase problem in optics, focusing of radiation, and the Monge–Kantorovich problem Computer Optics 42(4) 574-587 DOI: 10.18287/2412-6179-2018-42-4-574-587
[60] Kazanskiy N L, Skidanov R V 2019 Technological line for creation and research of diffractive optical elements Proc. SPIE 11146 111460W DOI: 10.1117/12.2527274
[61] Murzin S P, Balyakin V B, Melnikov A A, Vasiliev N N and Lichtner P I 2015 Determining ways of improving the tribological properties of the silicon carbide ceramic using a pulse-periodic laser treatment Computer Optics 39(1) 64-69 DOI: 10.18287/0134-2452-2015-39-1-64-69
[62] Murzin S P, Balyakin V B 2017 Microstructuring the surface of silicon carbide ceramic by laser action for reducing friction losses in rolling bearings Optics and Laser Technology 88 96-98
[63] Murzin S P, Liedl G 2017 Laser welding of dissimilar metallic materials with use of diffractive optical elements Computer Optics 41(6) 848-855 DOI: 10.18287/2412-6179-2017-41-6-848-855
[64] Volkov A V, Kazanskiy N L, Moiseev O Yu and Poletayev S D 2015 Thermal oxidative degradation of molybdenum films under laser ablation Technical Physics 60(2) 265-269 DOI: 10.1134/S1063784215020255

[65] Kazanskiy N L, Moiseev O Yu and Poletayev S D 2016 Microprofile formation by thermal oxidation of molybdenum films Technical Physics Letters 42(2) 164-166 DOI: 10.1134/S1063785016020085

[66] Liedl G, Pospichal R and Murzin S P 2017 Features of changes in the nanostructure and colorizing of copper during scanning with a femtosecond laser beam Computer Optics 41(4) 504-509 DOI: 10.18287/2412-6179-2017-41-4-504-509

[67] Murzin S P, Liedl G, Pospichal R and Melnikov A A 2018 Study of the action of a femtosecond laser beam on samples of a Cu-Zn alloy J. Phys. Conf. Ser. 1096(1) 012138

[68] Tukmakov K N, Komlenok M S, Pavelyev V S, Kononenko T V and Konov V I 2018 A continuous-profile diffractive focuser for terahertz radiation fabricated by laser ablation of silicon Computer Optics 42(6) 941-946 DOI: 10.18287/2412-6179-2018-42-6-941-946