Academician Evgeny Pavlovich Velikhov and computer optics

N L Kazanskiy¹,²

¹Image Processing Systems Institute of RAS - Branch of the FSRC “Crystallography and Photonics” of RAS, Molodogvardejskaya Street 151, Samara, Russia, 443001
²Samara National Research University, Moskovskoe Shosse 34A, Samara, Russia, 443086

Abstract. The article describes the role played by Academician Evgeny P. Velikhov in the development of the scientific direction “computer optics”. It talks about the creation of the journal “Computer Optics”, the establishment of the Research & Education Center “Spectrum”, the support of the Image Processing Systems Institute of the RAS.

1. Introduction
February 2, 2020, our esteemed contemporary, Academician of the Russian Academy of Sciences Evgeny Pavlovich Velikhov has turned 85. Evgeny Pavlovich is the Honorary Secretary of the Civic Chamber of the Russian Federation, the Honorary President of the National Research Center “Kurchatov Institute”, and Chairman of the Presidium of the Russian public organization “Russian Association for the Advancement of Science”. On January 31, 2020, the President of Russia awarded E.P. Velikhov the title of “Hero of Labor” in recognition of his meritorious labor for the country and the people.

Evgeny Pavlovich had a major impact on many aspects of the scientific and public life of our country while working as a Vice-President of the USSR Academy of Sciences, Academician-Secretary of the Department of Nanotechnology and Information Technology of the Russian Academy of
Sciences, Secretary of the Civic Chamber of the Russian Federation. The article briefly describes the role of E.P. Velikhov in the formation and development of the scientific field “computer optics”.

2. Creating the journal

Fundamental research performed at the turn of the 70-80s of the last century by the joint efforts of the research groups from Moscow and Kuibyshev (now Samara) under the guidance of Academician A.M. Prokhorov, Professor I.N. Sisakyan and Professor V.A. Soifer provided for the creation of new types of optical elements [1–8] allowing to solve problems beyond the scope of classical optics. It became clear that a new field of research emerged at the interface of information technology, laser physics, optics and microelectronics, this area of research became known as “diffractive computer optics.” The creation of the international collection of scientific articles “Computer Optics” in 1987 provided significant support in the formation and recognition of the new scientific direction. The initiative of Academician E.P. Velikhov, Academician A.M. Prokhorov and Professor I.N. Sisakyan on the publication of the collection of scientific articles was supported by the heads of the USSR Academy of Sciences and the Integrated Program for the Scientific and Technological Advancement of the Member Countries of the Council for Mutual Economic Assistance, and in 1987 the first issue of the international collection of scientific articles “Computer Optics” with the subtitle “Physical Principles” was published. In the early years, the collection of scientific articles “Computer Optics” was edited by Academician E.P. Velikhov and Academician A.M. Prokhorov.

In his introduction to the first issue, Academician E.P. Velikhov, in particular, noted [9]: “Computers have indeed played a revolutionary role in the production of a fundamentally new class of optical elements such as radiation focusers, wavefront correctors, radiation mode-component analyzers, and so on. The use of computers in computer optics has been manifold: the solution of inverse problem in diffraction theory, simulations, control automata, processing, data visualization and interpretation, optimization of synthesizer-element parameters, data-base creation, and so forth.” Now, in 2020, the brilliance of Evgeny Pavlovich’s scientific insight is evident: as early as in 1987 [9] he said: “… Computer optics is not just computers in optics, but also optics in computers. A host of optical elements already in production are being applied in information processing, and in solving a whole series of interesting problems.” The fact is that the development of electronics, which has changed significantly the technology of the last century, is entering a new phase today. The degree of integration of modern electronic computing devices is getting close to fundamental physical limitations, which inevitably entails a slowdown in the growth rate of their speed and efficiency. Scientists and designers hope that photonics will be able to provide further progress in the performance of computing systems. Leading computer equipment producers (IBM, Intel) are developing technologies for creating computer systems that use optical signals instead of electric ones as storage medium, and since 2015 they have launched the production of chips with photonic components. At the same time, advancement in the design and production of metasurfaces and metamaterials provided for a breakthrough in the creation of optical elements for analog electronic-optical computing systems, and elements of nanophotonics are considered as a new element base for analog calculations and optical information processing [10–19]. Russian specialists in computer optics make a significant contribution to the development of the elemental base of optical calculations [20–37] by proposing new diffractive structures and confirming their effectiveness not only by means of mathematical simulation, but also by an optical experiment [34].

Starting from 2007, the collection “Computer Optics” has become a scientific journal, its articles have been indexed in Scopus since 2008 and in the Web of Science Core Collection since 2015 [38]. The editorial board includes five academicians, one corresponding member of the Russian Academy of Sciences, 6 doctors of sciences, scientists from the UK, Germany, India, China, the USA and Finland. By the resolution of the Bureau of the Department of Information Technology and Computing Systems of the Russian Academy of Sciences dated March 22, 2007, No. 2–8, the Corresponding Member of the RAS (now – the Academician of the RAS) V.A. Soifer was appointed the chief editor of the journal. Due to the circumspect development strategy of the journal [39], the
efficient organization of the editorial staff work and the review process [40], the journal articles are of considerable interest to the scientific community and are actively cited [41–64]. Judging by the indicators in the Scopus bibliometric database (https://www.scimagojr.com/journalsearch.php?q=21100203110&tip=sid&clean=0), Computer Optics is one of the leading Russian journals.

3. Supporting the integration of basic science and higher education

The scientific results obtained in the field of computer optics together with the Moscow colleagues [1–8] in 1986 allowed to form the Kuibyshev department of the Central Design Bureau of Unique Instrumentation of the USSR Academy of Sciences (CDB UI, Moscow), created on the basis of the scientific group of V.A. Soifer with the support of the head – the chief designer of the CDB UI, Professor Iosif Norairovich Sisakyan [65]. In 1988, on the basis of this department, the Kuibyshev branch of the Central Design Bureau of Unique Instrumentation of the USSR Academy of Sciences was formed (from 1993 – the Image Processing Systems Institute of the RAS, IPSI RAS; from 2016 - the Image Processing Systems Institute of the RAS – a branch of the FSRC “Crystallography and Photonics” of the RAS).

A significant support for the newly created branch was the possibility of active interaction with the university, from the scientific group of which the branch was created. A substantial support removing some of the interdepartmental barriers was provided by an order to establish a joint research and education center, signed on behalf of the Academy of Sciences by the Vice-President of the USSR Academy of Sciences Academician E.P. Velikhov in December 1988 (Fig. 2).

The Research and Education Center (REC) “Spectrum” was created in December 1988 by the joint order No. 167 of the Vice-President of the USSR Academy of Sciences Academician E.P. Velikhov and the Deputy Minister of Higher and Secondary Special Education of the RSFSR O.M. Petrov on the basis of the Kuibyshev branch of the CDB UI (KB CDB UI) and the Kuibyshev Aviation Institute (now Samara National Research University named after Academician S.P. Korolev). Professor V.A. Soifer, Doctor of Technical Sciences, was appointed the head of the REC “Spectrum” by a joint order of the Kuibyshev Aviation Institute (KuAI) and the Central Design Bureau of Unique Instrumentation of the USSR Academy of Sciences. In 1990, V.A. Soifer was elected the rector of KuAI, remaining the director of the KB CDB UI in parallel. Such a one-man management, as well as the scientific and administrative talents of V.A. Soifer ensured high efficiency of interaction between research and educational institutions [66], gave the opportunity to develop jointly the centers for the collective use of equipment [67], to win many prestigious contests, to provide project-based training for the students, and to ensure a constant influx of talented young personnel oriented at scientific work to the academic institute.

4. Attention to the problems of the Institute

Throughout all the years of their work, scientists and the administration of the Image Processing Systems Institute of the RAS have felt friendly and attentive attitude of the administration of the Department of Nanotechnology and Information Technology of the Russian Academy of Sciences (DNIT RAS). The academician-secretary of the DNIT RAS supported the IPSI RAS applications for various competitions, financing programs, purchase of equipment and vehicle, repair of premises, etc. E.P. Velikhov included into the Institute audit commissions the prominent members of the Department – Academicians V.B. Betelin, A.A. Orlikovsky, V.Y. Panchenko, the leading specialists of the DNIT RAS administration – S.A. Vlasov, L.P. Obukhova, N.V. Popenko, V.N. Filippow. The proposals of the IPSI RAS Director V.A. Soifer on presentation of scientific reports at the Presidium of the Russian Academy of Sciences [68, 69] have always been supported, the findings of the Institute scientists have regularly been included into the reports of the Russian Academy of Sciences to the Government of the Russian Federation.
Приказ – Распоряжение

14.12.88
Москва

№ 187

О создании научно-учебного центра "Спектр"

В целях дальнейшего укрепления связей научных учреждений Академии наук СССР и Минвуза РСФСР, активного привлечения ученых АН СССР к решению задач повышения качества подготовки и переподготовки специалистов, а также исполнения приказа-распоряжения Минвуза СССР и Президиума академии наук СССР от 01.03.88 № 155/43 Минвуз РСФСР и Президиум АН СССР

ПРИКАЗЫВАЕТ:

I. Создать на базе Куйбышевского авиационного института и Куйбышевского филиала ЦКБ Универсального приборостроения НТО АН СССР научно-учебный центр "Спектр".

II. Утвердить Положение о научно-учебном центре "Спектр".

Заместитель министра высшего и среднего специального образования РСФСР, генеральный директор Хозрасчетного научного объединения прорабов
Петров О.М.

Вице-президент Академии наук СССР академик
Велихов Е.П.

Figure 2. Order on the establishment of the Research and Education Center “Spectrum”.
It would be incorrect to underestimate the support provided by the academician-secretary of ONIT RAS Academician E.P. Velikhov during the election to the full members of the Russian Academy of Sciences in 2016, when V.A. Soifer became an academician in the section of information technology and automation, while Evgeny Pavlovich being its member.

During more than 10 years when V.A. Soifer was the Chairman of the Civic Chamber of the Samara Region, he has repeatedly turned for help to the Secretary of the Civic Chamber of Russia, E.P. Velikhov, and Evgeny Pavlovich have always found a way to support this public institution.

5. Conclusion
The multifaceted activities of Academician Evgeny Pavlovich Velikhov made an indelible contribution to the cause of peace, to the creation of the ITER thermonuclear experimental reactor, to the elimination of the consequences of the Chernobyl accident, to the scientific and public development of Russia. In this article I tried to talk about small episodes of his work that had a decisive influence on the development of the scientific direction “computer optics” and the Image Processing Systems Institute of the Russian Academy of Sciences.

On my own behalf and on behalf of the IPSI RAS team, I cordially congratulate Academician of the Russian Academy of Sciences Evgeny Pavlovich Velikhov on this glorious anniversary and wish him good health, bright ideas and achievements, and inexhaustible energy to accomplish everything that he has planned for the benefit of the world science and our country!

6. References
[1] Golub M A, Zhivopistsev E S, Karpeev S V, Prokhorov A M, Sisakyan I N and Soifer V A 1980 Obtaining aspherical wave fronts with computer holograms Soviet Physics. Doklady 25(8) 627-629.
[2] Golub M A, Karpeev S B, Prokhorov A M, Sisakyan I N and Soifer V A 1981 Focusing light into a specified volume by computing-synthesized holograms Soviet Technical Physics Letters 7(5) 264-266.
[3] Golub M A, Degtyareva V P, Klimov A N, Popov V V, Prokhorov A M, Sisakyan E V, Sisakyan I N and Soifer V A 1982 Computer synthesis of focusing elements for a CO2 laser Soviet Technical Physics Letters 8(4) 195-196.
[4] A.M. Prokhorov, I.N. Sisakyan, M.A. Golub, V.A. Soifer and S.V. Karpeev 1987 Method of focusing monochromatic radiation and device for its implementation Inventor’s certificate SU 1302233 A1, 07.04.1987 Application No 3408156 of 09.03.1982.
[5] Golub M A, Prokhorov A M, Sisakyan I N and Soifer V A 1982 Synthesis of spatial filters for investigation of the transverse mode composition of coherent radiation Soviet Journal of Quantum Electronics 9(9) 1866-1868.
[6] Golub M A, Karpeev S V, Krivoshlykov S G, Prokhorov A M, Sisakian I N and Soifer V A 1983 Experimental investigation of spatial filters separating transverse modes of optical fields Soviet Journal of Quantum Electronics 13 1123-1124.
[7] Bereznyi A E, Prokhorov A M, Sisakyan I N and Soifer V A 1984 Bessel optics Soviet Physics. Doklady 29(2) 115-117.
[8] Garitchev V P, Golub M A, Karpeev S V, Krivoshlykov S G, Petrov N I, Sissakian I N, Soifer V A, Haubenreisser W, Jahn J-U and Willsch R 1985 Experimental investigation of mode coupling in a multimode graded-index fiber, caused by periodic microbends using computer-generated spatial filters Optics Communications 55(6) 403-405 DOI: 10.1016/0030-4018 (85)90140-3.
[9] Velikhov E P 1989 Foreword 1 Computer Optics 1(1) 1.
[10] Ferrera M, Park Y, Razzari L, Little B E, Chu S T, Morandotti R, Moss D J and Azaña J 2010 On-chip CMOS-compatible all-optical integrator Nature Communications 1(3) DOI: 10.1038/ncomms1028.
[11] Silva A, Monticone F, Castaldi G, Galdi V, Alù A and Engheta N 2014 Performing Mathematical Operations with Metamaterials Science 343 161-163.
[12] Sun C, Wade M T, Lee Y, Orcutt J S and Alloaati L 2015 Single-chip microprocessor that communicates directly using light Nature 528 534-538.
[13] Solli D R and Jalali B 2015 Analog optical computing Nature Photonics 9 704-706.
[14] Fors A, Nielsen M G and Bozhevolnyi S I 2015 Analog Computing Using Reflective Plasmonic Metasurfaces Nano Lett. 15(1) 791-797.
[15] Abdollahramezani S, Chizari A, Dorche A E, Jamali M V and Salehi J A 2017 Dielectric metasurfaces solve differential and integro-differential equations Opt. Lett. 42 1197-1200.
[16] Zhu T, Zhou Y, Lou Y, Ye H, Qiu M, Ruan Z and Fan S 2017 Plasmonic computing of spatial differentiation Nature Communications 8 15391.
[17] Guo C, Xiao M, Minkov M, Shi Y and Fan S. 2018 Photonic crystal slab Laplace operator for image differentiation Optica 5 251-256.
[18] Wesemann L, Panchenko E, Singh K, Gaspera E D, Gómez D E, Davis T J and Roberts A 2019 Selective near-perfect absorbing mirror as a spatial frequency filter for optical image processing APL Photon 4 100801.
[19] Wang H, Guo C, Zhao Z and Fan S 2020 Compact incoherent image differentiation with nanophotonic structures ACS Photonics 7(2) 338-343 DOI: 10.1021/acsphtotonics.9b01465.
[20] Bykov D A, Doskolovich L L and Soifer V A 2011 Temporal differentiation of optical signals using resonant gratings Optics Letters 36(11) 3509-3511.
[21] Gavrilov A V and Soifer V A 2012 Prospects of optical analog computers development Computer Optics 36(2) 149-150.
[22] Bykov D A, Doskolovich L L and Soifer V A 2012 Integration of optical pulses by resonant diffraction gratings JETP Letters 95(1) 6-9.
[23] Bykov D A, Doskolovich L L and Soifer V A 2012 On the ability of resonant diffraction gratings to differentiate a pulsed optical signal Journal of Experimental and Theoretical Physics 141(5) 724-730.
[24] Kazanskiy N L, Serafimovich P G and Khonina S N 2013 Use of photonic crystal cavities for temporal differentiation of optical signals Optics Letters 38(7) 1149-1151 DOI: 10.1364/OL.38.001149.
[25] Kazanskiy N L and Serafimovich P G 2014 Coupled-resonator optical wave-guides for temporal integration of optical signals Optics Express 22(11) 14004-14013 DOI: 10.1364/OE.22.014004.
[26] Doskolovich L L, Bykov D A, Bezus E A and Soifer V A 2014 Spatial differentiation of optical beams using phase-shifted Bragg gratings Optics Letters 39 1278-1281.
[27] Bykov D A, Doskolovich L L, Bezus E A and Soifer V A 2014 Optical computation of the Laplace operator using phase-shifted Bragg gratings Optics Express 22(21) 25084-25092.
[28] Golovastikov N V, Bykov D A, Doskolovich L L and Bezus E A 2015 Spatial optical integrator based on phase-shifted Bragg gratings Optics Communications 338 457-460.
[29] Doskolovich L L, Bezus E A, Bykov D A and Soifer V A 2016 Spatial differentiation of Bloch surface wave beams using an on-chip phase-shifted Bragg grating Journal of Optics 18(11) 115006.
[30] Emelyanov S V, Bykov D A, Golovastikov N V, Doskolovich L L and Soifer V A 2016 Differentiating space–time optical signals using resonant nanophotonics structures Doklady Physics 61(3) 108-111.
[31] Golovastikov N V, Bykov D A, Doskolovich L L and Soifer V A 2016 Analytical description of 3D optical pulse diffraction by a phase-shifted Bragg grating Optics Express 24(17) 18828-18842.
[32] Golovastikov N V, Bykov D A and Doskolovich L L 2017 Temporal differentiation and integration of 3D optical pulses using phase-shifted Bragg gratings Computer Optics 41(1) 13-21 DOI: 10.18287/2412-6179-2017-41-1-13-21.
[33] Doskolovich L L, Bezus E A, Golovastikov N V, Bykov D A and Soifer V A 2017 Planar two-groove optical differentiator in a slab waveguide Optics Express 25(19) 22328-22340.

[34] Bykov D A, Doskolovich L L, Morozov A A, Podlipnov V V, Bezus E A, Verma P and Soifer V A 2018 First-order optical spatial differentiator based on a guided-mode resonant grating Optics Express 26(8) 10997-11006.

[35] Golovastikov N V, Doskolovich L L, Bezus E A, Bykov D A and Soifer V A 2018 An optical differentiator based on a three-layer structure with a W-shaped refractive index profile Journal of Experimental and Theoretical Physics 127(2) 202-209.

[36] Bezus E A, Doskolovich L L, Bykov D A and Soifer V A 2018 Spatial integration and differentiation of optical beams in a slab waveguide by a dielectric ridge supporting high-Q resonances Optics Express 26(19) 25156-25165.

[37] Golovastikov N V, Bykov D A and Doskolovich L L 2020 Arbitrary-order optical differentiation in reflection by sequence of first-order differentiators Journal of Physics: Conference Series 1461(1) 012050.

[38] Stafeev S S 2017 Indexing of Computer Optics in the Emerging Sources Citation Index database Computer Optics 41(4) 592 DOI: 10.18287/2412-6179-2017-41-4-592.

[39] Soifer V A 2014 Quo Vadis Computer Optics 38(4) 589.

[40] Kudryashov D V, Kirsh D V 2019 Regulations for the editors of journal “Computer Optics” Journal of Physics: Conference Series 1368(2) 022077 DOI: 10.1088/1742-6596/1368/2/022077.

[41] Soifer V A and Kupriyanov A V 2011 Analysis and recognition of the nanoscale images: conventional approach and novel problem statement Computer Optics 35(2) 136-144.

[42] Ilyasova N Y 2013 Methods for digital analysis of human vascular system. Literature review Computer Optics 37(4) 511-535.

[43] Kotlyar V V, Kovalev A A and Soifer V A 2014 Diffraction-free asymmetric elegant bessel beams with fractional orbital angular momentum Computer Optics 38(1) 4-10.

[44] Fursov V A, Bibikov S A and Bajda O A 2014 Thematic classification of hyperspectral images using conjugacy indicator Computer Optics 38(1) 154-160.

[45] Denisova A Y and Myasnikov V V 2014 Anomaly detection for hyperspectral imaginary Computer Optics 38(2) 287-296.

[46] Murzin S P 2014 Method of composite nanomaterials synthesis under metal/oxide pulse-periodic laser treatment Computer Optics 38(3) 469-475.

[47] Egorov A V, Kazanskiy N L and Serafimovich P G 2015 Using Coupled Photonic Crystal Cavities for Increasing of Sensor Sensitivity Computer Optics 39(2) 158-162 DOI: 10.18287/0134-2452-2015-39-2-158-162.

[48] Bolotov M A, Pechenin V A and Murzin S P 2016 Method for estimating the uncertainty 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.

[49] Soifer V A, Korotkova O, Khonina S N and Shchepakina E A 2016 Vortex beams in turbulent media: review Computer Optics 40(5) 605-624 DOI: 10.18287/2412-6179-2016-40-5-605-624.

[50] Panyaev I S and Sannikov D G 2017 Spectral properties of nonlinear surface polaritons of mid IR range in a «semiconductor–layered metamaterial» structure Computer Optics 41(2) 183-191 DOI: 10.18287/2412-6179-2017-41-2-183-191.

[51] Gorevoy A V and Machikhin A S 2017 Optimal calibration of a prism-based videoendoscopic system for precise 3D measurements Computer Optics 41(4) 535-544 DOI: 10.18287/2412-6179-2017-41-4-535-544.

[52] Myasnikov E V 2017 Hyperspectral image segmentation using dimensionality reduction and classical segmentation approaches Computer Optics 41(4) 564-572 DOI: 10.18287/2412-6179-2017-41-4-564-572.

[53] Kotlyar V V and Nalimov A G 2017 A vector optical vortex generated and focused using a metalens Computer Optics 41(5) 645-654 DOI: 10.18287/2412-6179-2017-41-5-645-654.
[54] Nikonorov A V, Petrov M V, Bibikov S A, Kutikova V V, Morozov A A and Kazanskiy N L 2017 Image restoration in diffractive optical systems using deep learning and deconvolution Computer Optics 41(6) 875-887 DOI: 10.18287/2412-6179-2017-41-6-875-887.

[55] Rozhkov O V, Piskunov D E, Nosov P A, Pavlov Y Yu, Khorokhorov A M and Shirankov A F 2018 Bauman MSTU scientific school “Zoom lens design”: features of theory and practice Computer Optics 42(1) 72-83 DOI: 10.18287/2412-6179-2018-42-1-72-83.

[56] Stafeev S S and Nalimov A G 2018 Longitudinal component of the poyniting vector of a tightly focused optical vortex with circular polarization Computer Optics 42(2) 190-196 DOI: 10.18287/2412-6179-2018-42-2-190-196.

[57] Plotnikov D E, Kolbudaev P A and Bartalev S A 2018 Identification of dynamically homogeneous areas with time series segmentation of remote sensing data Computer Optics 42(3) 447-456 DOI: 10.18287/2412-6179-2018-42-3-447-456.

[58] Maksimov A I and Gashnikov M V 2018 Adaptive interpolation of multidimensional signals for differential compression Computer Optics 42(4) 679-687 DOI: 10.18287/2412-6179-2018-42-4-679-687.

[59] Shirokanev A S, Kirsh D V, Ilyasova N Y and Kupriyanov A V 2018 Investigation of algorithms for coagulate arrangement in fundus images Computer Optics 42(4) 712-721 DOI: 10.18287/2412-6179-2018-42-4-712-721.

[60] Rytsoarev I A, Kirsh D V and Kupriyanov A V 2018 Clustering of media content from social networks using bigdata technology Computer Optics 42(5) 921-927 DOI: 10.18287/2412-6179-2018-42-5-921-927.

[61] Kropotov Y A, Proskuryakov A Y and Belov A A 2018 Method for forecasting changes in time series parameters in digital information management systems Computer Optics 42(6) 1093-1100 DOI: 10.18287/2412-6179-2018-42-6-1093-1100.

[62] Evsutin O O, Kokurina A S and Meshcheryakov R V 2019 A review of methods of embedding information in digital objects for security in the internet of things Computer Optics 43(1) 137-154 DOI: 10.18287/2412-6179-2019-43-1-137-154.

[63] Thanh D N H, Prasath V B S, Son N V and Hieu L M 2019 An adaptive image inpainting method based on the modified Mumford-Shah model and multiscale parameter estimation Computer Optics 43(2) 251-257 DOI: 10.18287/2412-6179-2019-43-2-251-257.

[64] Morozov O G and Sakhabutdinov A J 2019 Addressed fiber Bragg structures in quasi-distributed microwave-photonic sensor systems Computer Optics 43(4) 535-543 DOI: 10.18287/2412-6179-2019-43-4-535-543.

[65] Danilov V A and Petrov N I 2016 20 years without Iosif Norairovich Sissakian CEUR Workshop Proceedings 1638 223-235.

[66] Kazanskiy N L 2017 Efficiency of deep integration between a research university and an academic institute Procedia Engineering 201 817-831 DOI: 10.1016/j.proeng.2017.09.604.

[67] Kazanskiy N L and Skidanov R V 2019 Technological line for creation and research of diffractive optical elements Proc. SPIE 11146 111460W DOI: 10.1117/12.2527274.

[68] Soifer V A 2001 Computer processing of images Vestnik Rossiskoj Akademii Nauk 71(2) 119-129.

[69] Soifer V A 2014 Diffractive nanophotonics and advanced information technologies Herald of the Russian Academy of Sciences 84(1) 9-18 DOI: 10.1134/S1019331614010067.