Image Processing Systems Institute of the RAS: New Challenges

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Abstract. I summed up twenty-five years of work of the Image Processing Systems Institute RAS. I celebrated achievements of the team; the people who contributed to the establishment and development of the Institute; also outlining current trends in scientific research and new challenges the Institute’s scientists face in modern conditions.

1. Introduction
The Image Processing Systems Institute of the RAS (IPSI RAS) marks a jubilee in 2018. I intend to show how its research team went from strength to strength. I also sum up landmark accomplishments the Institute has made and outline topical research issues the Institute’s scientists are set to address in the modern world.

2. History of establishment
In the late 70s of the last century, a group of researchers of Kuibyshev Aviation Institute headed by Professor (currently, academician) Victor Alexandrovich Soifer [1] actively collaborated with researchers at the Institute of Information Transmission Problems of the USSR Academy of Sciences and Department A of P. N. Lebedev Physical Institute of the USSR Academy of Sciences. Thanks to that collaboration, the Kuibyshev (currently, Samara) scientists made fundamental research findings in the areas of digital image processing, laser beam mode shaping, synthesis of Bessel beams, tailored wavefront shaping, and mathematical modeling in diffractive optics [2-12].

In the 80s of the last century, V. A. Soifer, A. M. Prokhorov, I. N. Sisakian and their disciples published a series of joint research papers in leading Soviet scientific journals [3-12], having established a new research direction, which has been given the name “Computer (Diffractive) Optics”. This interdisciplinary research direction emerged at the interface of such fields of science as cybernetics, quantum electronics, and microelectronics.

To further develop research in the emerging scientific field, in 1988 the Presidium of the USSR Academy of Sciences established a Kuibyshev Branch of the Central Design Bureau of Unique Instrumentation (KB CDB UI) of the USSR Academy of Sciences with 60 employees on the staff. The Presidium of the USSR Academy of Sciences designated Computer (Diffractive) Optics as a key research direction for the newly set up academic Institute.

3. Kuibyshev Branch of the CDB of Unique Instrumentation of the RAS
The core of the research body of the KB CDB UI of the USSR Academy of Sciences was composed of young scientists with Candidate degrees in Science, including Ye. Yu. Arefiev, M. A. Golub, N. L. Kazanskiy, V. V. Kotlyar, O. V. Prisekina, A. G. Khramov, with V. A. Soifer (Doctor of Engineering)
appointed as Director. The credit for great efforts associated with the organization of the Branch goes to Yu. N. Boyarkin (the Deputy Director for General Affairs), L. F. Egorova, Yu. A. Runkov, L. P. Chepurnova, G. G. Yamovich. Following its establishment, the KB CDB UI of the USSR Academy of Sciences operated on a self-supporting basis, with its budget depending on a search for customers and implementation of applied research projects under commercial contracts. While remaining a self-sustained organization, the research team of the Branch was also actively involved in the basic research, in the first place, thanks to participating in the state scientific-and-research programs, such as “Advanced Information Technology”, “Science-Intensive Technologies”, “Conversion in Samara”, (the last two programs came to life with academician Shorin’s assistance). Partaking in these programs enabled the research team in the harsh 90s to obtain and publish a number of ground-breaking research findings in laser technology [14-15] and generation of light beams with novel properties [16-18]. With the leading researchers (V. A. Soifer, V. V. Kotlyar, M. A. Golub, N. L. Kazanskiy, L. L. Dokolovich, S. N. Khonina) making it their priority to publish their findings in the leading international optical journals, V. Soifer’s scientific school soon began to be recognized internationally, which brought in first international contracts and allowed Dr. M. Golub and Dr. V. Kotlyar to defend their Doctoral dissertations with flying colors in Moscow. The scientific and practical significance of the research results jointly obtained by Samara and Moscow scientists (V. P. Shorin, V. A. Soifer, I. N. Sisakian V. A. Barvinok, V. I. Bogdanovich et al.) brought them in 1992 a State Prize of the RF in Science and Technology.

4. Establishment of the Institute
The research achievements of the team enabled V. A. Soifer, with the assistance of academicians S. V. Emelyanov and Yu. I. Zhuravlev, to secure Resolution N 21 of the RAS Presidium of 26 January, 1993 that reorganized the Samara Branch of CDB UI of the RAS into the Image Processing Systems Institute of the RAS. The newly established Institute received new divisions dealing with pattern recognition and image analysis. At the time, the self-supporting principle of operation was retained and was not dropped until 1998.

In the economically hard years of establishment, IPSI RAS managed to survive and later flourish thanks to close integration with a leading Russian university -- S. P. Korolyov Samara National Research University (below, Samara University). Immediately after the establishment of the SB CDB UI of the USSR Academy of Sciences, joint Order N 167 of 14 December, 1988 of the MinVuz of the RSFSR and the USSR Academy of Sciences decreed the organization of a joint Research and Training Center “Spectrum”, which went on to successfully develop over the subsequent 30 years [19]. The collaboration of the IPSI RAS with Samara University provided V. Soifer’s scientific school with a constant inflow of highly skilled specialists, who combine active research with teaching activities. Joint work has led to the establishment of new university sub-departments and centers for collective use of scientific equipment [20-21]. It is due to the joined efforts that many most challenging competitions were won and joint research projects were and have been implemented. Deepening integration with Samara University has proven to be an esC & Pe for the IPSI RAS team under the RAS reform initiated in 2013. In particular, in 2014 five scientists with a Doctoral degree and 14 scientists with a Candidate degree moved from IPSI RAS to Samara University, having chosen to work full-time at the National Research University as fallout of the RAS reform.

In 2016, IPSI RAS enters the Federal Scientific and Research Center “Crystallography and Photonics” of the RAS (FSRC “C & P” of the RAS) as a Branch. Alongside the IPSI RAS, among the organizing institutions of the Center for Crystallography and Photonics are A. V. Shubnikov Institute for Crystallography, Institute of Laser and Information Technology Problems of the RAS, and the Center for Photochemistry of the RAS. The scientific and methodological management of the IPSI RAS -- a Branch of the Center for Crystallography and Photonics of the RAS -- is provided by the division of Nanotechnology and Information Technology of the RAS. The Institute works under the scientific supervision of academician of the RAS, V. A. Soifer.

The IPSI RAS has been doing research in the following research directions (as approved by the RAS Presidium, Resolution N 37 of 12 Feb, 2008):
– Computer (Diffractive) Optics, nanophotonics, optical information technologies and systems;
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– Systems for image analysis and pattern recognition; and
– Geo-Information technology.

The Institute has five successfully operating laboratories of:
– Diffractive Optics (Head: Prof. L. L Doskolovich, Doctor of Phys. & Math. [22]);
– Laser Measurements (Head: Prof. V. V. Kotlyar, Doctor of Phys. & Math. [23]);
– Micrco- and Nanotechnology (Head: Ass. Prof. R. V. Skidanov, Doctor of Phys. & Math.);
– Mathematical Methods for Image Processsing (Head: Prof. V. V. Sergeev, Doctor of Eng.); and
– Smart Videodata Analysis (Head: Ass. Prof. A. A. Nikonorov, Doctor of Eng.)

5. Journal of Computer Optics

A significant aspect of the IPSI RAS activity is the publication of a scientific journal *Computer Optics* (cofounders: Samara University and the FRSC for Crystallography and Photonics of the RAS). Publication of the scientific collection *Computer Optics* had began in 1987 on the initiative of academicians Ye. P. Velikhov and A. M. Prokhorov, and Professor I. N. Sisakian to provide the information support of a complex program for the scientific and technical progress of member-countries of the Council for Mutual Economic Assistance. Starting with issue 16 -- commemorating I. N. Sisakian’s death (1996) -- the collection issues began to be exclusively published in Samara. Note that the credit for further development and success of the edition should mainly go to the contribution from members of V. Soifer’s scientific school [24-25]. In 2007, the collection was upgraded to a scientific journal published quarterly (since the second half of 2015 -- bimonthly). The Editorial Board includes five members of the RAS (S. Yu. Zheltov, Yu. I. Zhuravlev, V. Ya. Panchenko, V. A. Soifer, I. A. Scherbakov), a corresponding member of the RAS (B. V. Kryzhanovsky), seven Doctors of Science (N. L. Kazanskiy, V. V. Kotlyar, A. V. Kupriyanov, V. S. Pavelyev, V. V. Sergeev, S. N. Khonina, V. M. Chernov), scientists from the Republic of Ireland (Dr. Liam O’Faolain, Tyndall National Institute, Cork, Ireland), Germany (Professor Rihard Kowarzik, Friedrich Shiller University, Jena), India (Professor Kehar Singh), China (academician Jin GuoFan, Singhua University, Beijing), USA (Dr. Olga Korotkova, the University of Miami; Sos Agayan, Doctor of Phys. & Math, Texas University in San Antonio) and Finland (Professor Jari Turunen, Joensuu University). The journal is intended for researchers and specialists active in the areas of research such as diffractive optics; optical information technology; nanophotonics and nanostructure optics; image analysis and understanding, pattern recognition; geoinformation technologies; digital image/signal processing, information coding and protection; Earth remote sensing techniques; hyperspectral data analysis; numerical methods of computer-generated diffractive optics; and smart video stream analysis.

The Journal’s development strategy is worked out by Editor-in-Chief, academician V. A. Soifer [26], while a key role in the Editorial Board’s every-day operation belongs to the Issuing editor, Ye. Ya. Tkhtarov. A supreme IPSI RAS’ achievement is the fact that the Journal of Computer Optics is indexed by the most authoritative bibliometric scientific publication databases: since 2012 -- by Scopus and since 2017 -- by the Web of Science Core Collection (Emerging Source Citation Index). To date, all the articles starting with the first 2009 issue have been indexed by Scopus and starting with the first 2015 issue -- by the Web of Science Core Collection. According to Scopus statistics, the most cited articles of the Journal were penned by the IPSI RAS scientists [27-43].

6. Research Achievements

The IPSI RAS researchers have made an essential contribution to the development of research areas such as diffractive computer-generated optics and digital image processing & recognition.

The IPSI scientists have proposed and studied new classes of diffractive optical elements intended to address both fundamental and practical problems [33-36, 43-54]:
– Generation of light beams with unique properties,
– Laser micromanipulation,
– Laser engineering,
– Illuminating devices,
– Ultra-tight focusing,
– Optical sensors, to name just few.
To be able to design and characterize the diffractive optical elements, the IPSI RAS researchers have proposed a theory and techniques of the computing experiment in diffractive optics [55-62], also proposing procedures for synthesizing diffractive micro- and nanoreliefs and bringing them to a mature level [63-73].

The IPSI RAS researchers have developed software packages for image processing and mathematical tools for computer vision systems [31-32, 36-42, 74-80]. These software-hardware complexes are based on (i) in-house methods and algorithms, such as a directional field method; hierarchical data representation and compression, and transmission and distributed storage of large-volume images; and (ii) methods for analysis and understanding of hyperspectral data obtained from Earth remote sensing. The IPSI engineers and programmers have created geo-information technologies and systems to address problems in agriculture and regional management.

These results were published in leading international scientific journals and summarized in fundamental monographs published by renowned publishing houses all over the world in the Russian, English [81-87] and Chinese languages.

Figure 1 depicts publication dynamics at the IPSI RAS. Publications are seen to grow particularly over the last five years. Such a growth may be credited to RAS’ and University’s programs for support of publications and the implementation of Russian Science Foundation programs. Notably increasing is the number of publications in prestigious journals with the Web-of-Science impact-factor 3+: NeuroImage [88], Physics Review Letters [89-90], Nature Communications [91], ACS Applied Materials & Interfaces [92], Scientific Reports [93], Applied Physics Letters [94-95], Optics Letters [48, 53, 96-97], Optics Express [98-104], Photonics Research [105], and the like. In particular, in the journals indexed by the international databases Scopus and Web of Science Core Collection, published by the IPSI RAS researchers are, respectively, 187 and 146 papers in the year 2016, and 187 and 155 papers in the year 2017.

Active publication and world-class research findings have led to an increase in the personal bibliometric indices of the IPSI employees both in the Russian Scientific Citation Index and in international databases (see Table 1). Of particular significance is the fact that not only venerable scientists, such as V. A. Soifer, N. L. Kazansky, V. V. Kotlyar, S. N. Khonina, and L. L. Doskolovich, but also a younger generation of scientists in their thirties (A. A. Kovalev, Ye. A. Bezus, D. A. Bykov) have made it to the top. It is worth noting that the leading IPSI RAS scientists have been doing fairly well according to the Web of Science Core Collection database:

- V. A. Soifer, ResearcherID C-3088-2017, publications: 247, citations: 2644, Hirsh: 29;
- V. V. Kotlyar, ResearcherID A-5830-2014, publications: 232, citations: 2413, Hirsh: 28;
- S. N. Khonina, ResearcherID E-2467-2014, publications: 259, citations: 2374, Hirsh: 26;
- N. L. Kazanskiy, ResearcherID Q-2349-2015, publications: 148, citations: 1406, Hirsh: 26;
- L. L. Doskolovich, ResearcherID B-1600-2014, publications: 77, citations: 1139, Hirsh: 21.

Achievements of the IPSI RAS scientists have been marked with a variety of state, regional, and international awards:

- 1992 - State Prize of the RF in Science and Technology - V. A. Soifer awarded jointly with other Samara University’s scientists (V. A. Barvinok, V. I. Bogdanovich, P. A. Bordakov, V. I. Mordasov, A. G. Tzidulko, V. P. Shorin), I. N. Sisakian and industry specialists;
1993 - The First Prize of the German Society of Assistance for Applied Information Science for the best research work in the area of image processing and pattern recognition - V. A. Soifer and S. N. Khonina;
1995 - The Order of Honor (V. A. Soifer);
1998-2017 - Regional Prizes in Science and Technology - N. L. Kazanskiy, V. V. Kotlyar, V. V. Sergeev (1998); V. M. Chernov (1999); V. A. Soifer, V. A. Fursov, V. V. Kravchuk (2001); N. I. Glumov, N. Yu. Ilyasova, A. G. Khramov (2003); A. V. Volkov (2007); S. V. Karpeev (2008); L. L. Doskolovich (2009); S. N. Khonina (2010); R. V. Skidanov (2011); V. V. Myasnikov (2012); S. I. Kharitonov (2013); S. B. Popov (2014); A. A. Kovalev (2015); D. L. Golovashkin (2016); D. A. Bykov, and A. V. Kupriyanov (2017);
1999 - Title of the “Honored Scientist of the RF” (V. A. Soifer);
1999 - Medal of the Order “For the Services to the Fatherland” of the II degree (N. L. Kazanskiy);
2000 - V. A. Soifer was awarded a title of the corresponding member of the Russian Academy of Sciences, on the division of Information Technology and Computing Systems of the RAS;
2004 - State Prize of the RF for Young Scientists (D. L. Golovashkin and V. S. Pavelyev);
2004 - Order for the “For the Services to the Fatherland”, IV degree (V. A. Soifer);
2007-2018 годы - Samara Region Governor’s Prize for the Outstanding Achievements in Science and Technology - V. A. Soifer (2007), V. V. Kotlyar (2013), S. N. Khonina (2015), N. L. Kazanskiy (2016), L. L. Doskolovich and V. V. Sergeev (2017), R. V. Skidanov and V. A. Fursov (2018);
2008 - Prize of the RF government for the Outstanding Achievements in Science and Technology (V. A. Soifer);
2008 - Title the “Honored Worker of the RF Higher School” (V. A. Fursov);
2010 - the Order “For the Services to the Fatherland”, III degree (V. A. Soifer);
2010 - The RF government Prize in Education (V. A. Soifer awarded jointly with academician V. P. Shorin and faculty members of other universities);
2011 - Medal of the Russian Academy of Sciences with the Prize for Young Scientists of the RAS awarded by the results of the 2010 competition (V. A. Kolpakov);
2012 - Golden Medal of the Geneva International Invention Exhibition (Swiss) - A. G. Khramov, awarded jointly with scientists from Samara State Medical University;
2014 - Medal of the Russian Academy of Sciences with Prizes to young scientists, awarded by the results of the 2013 competition (D. A. Bykov and A. V. Gavrilov);
2014 - Prize “Scopus Award Russia” from the Elsevier Publishing House in the nomination “For Contribution to Science” - V. A. Soifer (joint award with the Russian Foundation for Basic Research);
2014 - Title of the “Honored Scientist of Samara Region” (N. L. Kazanskiy);
2015 - Medals of the RAS with Prizes to university students, awarded by the results of the 2014 competition (Ye. V. Byzov and S. V. Kravchenko);
2015 - the Order of Honor from the European Academy of Natural Science of the city of Hanover for the “Great Contribution to Scientific Research” (V. A. Soifer);
2015 - L. L. Doskolovich elected a Professor of the RAS on the division of Nanotechnology and Information Technology;
2016 - Prize “Scopus Award Russia” from the “Elsevier” Publishing House in the nomination “For Contribution to Science” - N. L. Kazanskiy (a joint award with the Ministry of Education and Science of the RF);
2016 - V. A. Soifer elected a member of the Russian Academy of Sciences on the division of Nanotechnology and Information Technology of the RAS;
2017 - Title of the “Honored Scientist of Samara Region” (V. V. Kotlyar).

7. New Tasks and Plans
Among fresh organizational issues facing the IPSI RAS, of topical priority are establishing effective liaison with the parent organization (FSRC “C&P” of the RAS) and actively partaking in the work of reorganized Samara University and Samara Scientific Center of the RAS, which is now in the process
of reorganization. For the Journal of Computer Optics, the key goal is getting into the main, journal part of the Web of Science Core Collection -- Science Citation Index Expanded, as well as awarding to the Journal an impact-factor Journal Citation Reports (JCR).

| Name                | Publications | Citations | Hirsch Index |
|---------------------|--------------|-----------|--------------|
| V. A. Soifer        | 568          | 8366      | 44           |
| S. N. Khonina       | 564          | 6498      | 38           |
| V. V. Kotlyar       | 591          | 5547      | 33           |
| N. L. Kazanskiy     | 428          | 6484      | 45           |
| L. L. Doskolovich   | 321          | 4390      | 33           |
| V. S. Paveliev      | 235          | 1959      | 17           |
| R. V. Skidanov      | 217          | 2356      | 20           |
| A. A. Kovalev       | 229          | 1600      | 21           |
| S. I. Kharitonov    | 152          | 2009      | 20           |
| S. V. Karpeev       | 142          | 1105      | 19           |
| D. A. Bykov         | 80           | 869       | 18           |
| E. A. Bezus         | 77           | 813       | 17           |
| S. G. Volotovsky    | 71           | 1029      | 16           |
| P. G. Serafimovich  | 69           | 687       | 14           |
| S. S. Stafeev       | 80           | 428       | 11           |
| A. P. Porfirev      | 100          | 358       | 10           |
| A. V. Ustinov       | 124          | 674       | 13           |

Table 1. Bibliometric indices of the leading IPSI RAS scientists (RSCI and Scopus).

In the area of scientific research, the scientific supervisor and the Academic Board of the IPSI RAS on a regular basis propose topical research problems to be addressed by the research team. The advanced research topics include analysis and understanding of nanoscale imagery, smart video stream analysis, the use of techniques of virtual and augmented reality when solving medical and engineering problems, a gradual transfer from diffractive optics to the fundamental problems of diffractive nanophotonics and optical data processing, as well as combining efforts of experts in optics and image processing in designing the airborne hyperspectral equipment and ultralight computer vision systems. In a number of these areas, significant advances have already been made and research findings have been obtained and published [32, 75-80, 87-109], attracting interest of the international research community.

8. Conclusion

I wish the IPSI RAS research team to stay in sound health, possess boundless energy and unceasing scientific curiosity, as well as making new creative accomplishments for the benefit of our Motherland and Russian Science!

9. References

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