

## **Analysis of the scientific and organizational results of the Image Processing Systems Institute of the RAS**

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**Abstract.** This work summarizes milestones of research activity of the Image Processing Systems Institute of the Russian Academy of Sciences. Key research achievements of the Institute's team are depicted, staff members who have made an essential contribution to the Institute's success are acknowledged, and research areas of the Institute has been working in are outlined.

**Keywords:** scientific results, research institute, computer optics, image processing, diffractive nanophotonics, research directions, Russian Academy of Sciences

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### **Introduction**

This year we celebrate the 40th anniversary of the Computer Science Faculty of Samara State Aerospace University (National Research University) (SSAU) and the 70th anniversary of corresponding member of the Russian Academy of Sciences (RAS) Professor Victor A. Soifer. Presidium of the USSR Academy of Sciences (USSR AS) organized Kuibyshev branch of the Central Design Bureau of Unique Instrumentation (KB CDB UI) of the USSR AS on the basis of the research group headed by Professor Victor Soifer in 1988. This research group worked at the Computer Science Faculty of the Kuibyshev Aviation Institute (now - Samara State Aerospace University). KB CDB UI of the RAS was reorganized into the Image Processing Systems Institute of the RAS (IPSI RAS) five years later. Prof. Victor Soifer was director of the Institute since 1988 until January 2015. Now he is scientific leader of IPSI RAS. 2015 is the last year of the IPSI RAS work as an independent institution. At the end of 2015 IPSI RAS will become part of the Federal Research Center "Crystallography and Photonics". Looking back at the milestones of the Institute history, I would like to summarize key achievements of the Institute's team over the years passed.

## 1. The origins

Late in the 70s of the last century, a research team at Kuibyshev Aviation Institute headed by professor V.A. Soifer actively collaborated with partners from the Institute of Information Transmission Problems of the RAS and P.N. Lebedev Physical Institute of the RAS. Those years were marked by obtaining basic research findings in areas such as digital image processing [1], focusing of light [2 – 5], generation of laser modes with desired transverse mode content [6 – 7], Bessel beams [8], and desired radiation directivity diagrams [9]; basics of computing experiment and asymptotic analysis in optics [10 – 13]. Following a host of articles jointly published in leading scientific Russian periodicals by V.A. Soifer, academician A.M. Prokhorov, professor I.N. Sisakyan, and their disciples [2 – 13], it became evident that at the interface of the research fields of cybernetics, quantum electronics, and microelectronics, a new research field was emerging, which became known as Computer, or Diffractive, Optics. In 1988, with the task to pursue research in the emerging area, the Kuibyshev branch of the Central Design Bureau of Unique Instrumentation of the USSR AS was established, with 60 people on the staff.

## 2. Kuibyshev branch of the CDB of unique instrumentation

The core of the KB CDB UI of the USSR Academy of Sciences was formed by young Candidates of Science: Ye.Yu. Arefiev, M.A. Golub, N.L. Kazanskiy, V.V. Kotlyar, O.V. Prisekina, and A.G. Khrarov, with V.A. Soifer, Dr. of Eng., appointed director. Large organizational efforts associated with establishing the Branch were contributed by vice-director in charge of general issues Yu.N. Boyarkin and staff members L.P. Chepurnova, L.F. Egorova, Yu.A. Runkov, G.V. Uspleniev, Ye.D. Vasil'ev, D.M. Yakunenkova, and G.G. Yamovich. The newly established KB CDB UI of the USSR Academy of Sciences was run as a self-sustained organization, with financing largely depending on the hunt for customers and commercial contracts for implementation of applied research projects. Notwithstanding the self-financing status, the basic research also stayed high on the list of priorities, which mainly became possible due to participation in the state-funded scientific & technical programs, such as 'Advanced Information Technologies', 'High Technologies', and 'Samara's Conversion'. In the arduous 90s, taking part in the above-mentioned programs enabled the KB's research team to obtain and publish a number of cutting-edge research findings in the field of laser technology [14 – 16] and generation of laser beams with novel properties [17 – 19]. With the KB's key researchers (V.A. Soifer, V.V. Kotlyar, M.A. Golub, N.L. Kazanskiy, L.L. Doskolovich, S.N. Khonina) steering a course toward extensively publishing in leading foreign journals from the very beginning, the scientific school soon acquired the international recognition, which brought along first foreign contracts, also enabling M.A. Golub and V.V. Kotlyar to defend dissertations for Advanced Doctor's Degrees with flying colors in Moscow. Scientific and practical significance of the results obtained by Samara research team in collaboration with colleagues from Moscow (V.P. Shorin, V.A. Soifer, I.N. Sisakyan, V.A. Barvinok) brought them the 1992 RF State Prize for achievements in science and technology.

### 3. IPSI of the RAS

Building on the success of the research team, V.A. Soifer – while enlisting the support of academicians S.V. Emelyanov, Yu.I. Zhuravlyev, and V.P. Shorin – initiated the adoption of RAS Presidium's Resolution N 21 of January 26, 1993 by which the Samara branch of the CDB UI of the RAS was reorganized into the Image Processing Systems Institute of the RAS. Divisions on pattern recognition and image analysis were organized in the newly established Institute. Unfortunately, the Institute continued to be run on the self-support basis, which survived till 1998.

Nowadays, the IPSI RAS has 44 budget-funded positions, with the general number of employees (including part-timers) having reached 100 people. The Institute boasts 16 holders of Dr. of Sc. degree and 19 holders of Candidates of Sc. degree on the staff. The researchers with Doctor's Degree are 50 year-old on average, with Candidate's Degree – 35 year-old. All in all, there are 63 young researchers under 35 (including part-time workers, graduate and postgraduate students). 48 per cent of the total wage fund accounts for the salary of young scientists (under 35).

During the challenging formative years, the IPSI RAS managed to survive, later growing into a successful research institution, which was largely due to close integration with a leading Russian university – S.P. Korolyov Samara State Aerospace University (National Research University), below referred to as SSAU. Just after the KB CDB UI of the USSR AS was established, a joint Scientific & Training Center (STC) 'Spectrum' was set up by the joint order N 167 (December 14, 1988) of the RSFSR Ministry of Higher Education and USSR AS. In the course of 25 years passed, the STC 'Spectrum' has been making rapid progress, making use of the opportunities offered by the RAS and federal programs aiming to promote the integration of basic research and higher education:

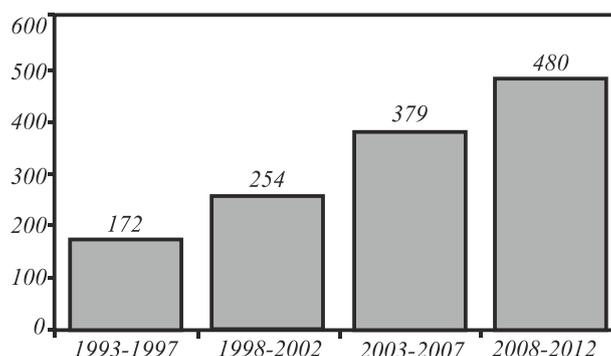
- 1997-2004: Participation, jointly with SSAU, in the federal program 'Integration of Basic Research and Higher Education';
- 2002-2012: Establishment and development of a Research & Education Center of Mathematical Principles of Diffractive Optics and Image Processing as part of the Russian-American program 'Basic Research and Higher Education';
- 2006-2007: Participation in the SSAU Innovative Education program;
- since 2009: Taking part in the program of development of SSAU as a National Research University;
- since 2013: Taking part in the "5-100" program for improving the SSAU competitiveness.

The partnership between the IPSI RAS and SSAU has provided a stable influx of aspiring young researchers and professionals. The fruits of the collaboration include the establishment of new University subdepartments and joint Centers for collective use of research equipment [20], with highly challenging competitions won by joined effort and collaborative projects being under way currently. Further integration with SSAU may prove to be one of the ways to preserve the IPSI RAS research team now that the RAS has been reformed since 2013.

#### 4. Research achievements

The effectiveness of IPSI RAS' research activity can be evaluated in terms of the number of scientific articles published, the amount of grants won, and commercial contracts awarded.

Ever since its establishment, the number of publications by the Institute's researchers has exhibited a steady growth (Fig. 1). Noteworthy is not only the number of publications but also the journal titles where the articles have been published. Recent years have seen an increase in publications in the journals that have the Web-of-Science impact-factor exceeding 3: Physics Review Letters [21], Applied Physics Letters [22], Optics Express [23 – 26], and Optics Letters [27 – 30]. In 2013, the journal Nature Communications published an article by D.A. Bykov and L.L. Doskolovich prepared by an international team of researchers with the participation of Moscow State University's scientists [31]. The IPSI researchers published 81 scientific articles in 2013 and 136 scientific articles in 2014 in the Editions indexed in the international database SCOPUS.



**Fig. 1.** – IPSI RAS: Publications dynamics

The interest in the research findings obtained by the IPSI RAS researchers is reflected in a high level of the articles' citation data. While Table 1 shows data according to the Russian Scientific Citation Index (RSCI), it should be noted that data on citations and Hirsh-indexes in Web of Science at V.A. Soifer, V.V. Kotlyar, and S.N. Khonina are not much different from those.

The research findings made by the IPSI scientists have also been summarized in a number of fundamental monographs published by recognized Publishing Houses around the world in the Russian, English [32-37], and Chinese languages [38]. Research topics covered by the monographs embrace all major IPSI's research areas - from diffractive nanophotonics to medical imagery processing.

The research achievements widely recognized in the research community have enabled the IPSI's RAS scientists to win a host of Russian Foundation for Basic Research (RFBR) grants and RF Presidential grants (Fig. 2). For instance, out of three RF Presidential grants for Young Doctors of Science awarded in the field of information and telecommunication technologies in 2003, two grants were awarded to the IPSI researchers (L.L. Doskolovich and S.N. Khonina). Three young researchers of the IPSI

RAS (D.A. Bykov, Ye.A. Bezus, A.V. Kuznetsov) get Russian President's Fellowships now. In 2014, three scientists of the IPSI RAS (L.L. Doskolovich, N.L. Kazanskiy, and R.V. Skidanov) won the Russian Science Foundation grants (2014-2016) for supporting research groups.

The bar charts in Fig. 3 present the number of Russian and international commercial contracts that IPSI RAS researchers have implemented over the last 15 years. Unfortunately, the world finance crisis has removed the international contracts from the agenda. However, thanks to active efforts undertaken at the domestic market the Institute landed two major Russian commercial contracts. One of them is to be implemented jointly with SSAU and aims to develop equipment for hyperspectral remote sensing [39–42] and tools for hyperspectral information processing [43–44] in the frame of the order of the space-missile center 'Progress' following RF Government's Resolution N 218. The other is concerned with the creation of compact vision systems for unmanned aircraft commissioned by the Research Institute for Applied Problems (Saint-Petersburg) [45–46].

**Table 1.** Citation indices of IPSI RAS leading researchers

N	Name	RSCI	Hirsh index
1	V. A. Soifer	4814	29
2	N. L. Kazanskiy	3036	26
3	V. V. Kotlyar	2805	24
4	S. N. Khonina	2775	24
5	L. L. Doskolovich	2045	21
6	R. V. Skidanov	1118	14
7	S. I. Kharitonov	931	14
8	A. V. Volkov	969	13
9	S. G. Volotovskiy	449	13
10	V. S. Pavelyev	938	11
11	A.A. Kovalev	508	11
12	D. L. Golovashkin	647	10
13	V. V. Sergeev	827	9
14	N. I. Glumov	726	9
15	S. V. Karpeev	412	9
16	D. A. Bykov	277	9
17	Ye. A. Bezus	269	9
18	V. A. Kolpakov	291	8
19	A. V. Ustinov	282	8
20	O. Yu. Moiseev	254	8
21	P.G. Serafimovich	219	8
22	N. Yu. Ilyasova	672	7
23	A. G. Khramov	629	7
24	S.B. Popov	613	7
25	A.V. Kupriyanov	171	7
26	M. A. Moiseev	170	7

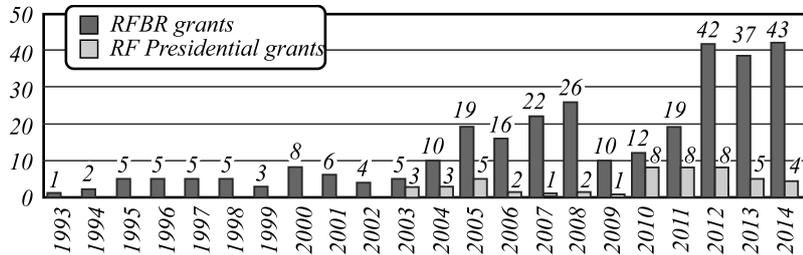


Fig. 2. – RFBR grants and RF President's grants

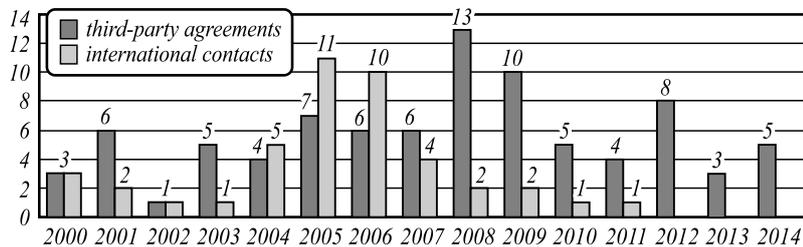


Fig. 3. – The bar chart shows successfully completed domestic and foreign commercial contracts

## 5. Modern day

Entering the RAS' division of Nano- and Information Technologies, the IPSI has been conducting research in the following fields, as approved by the RAS' Presidium Resolution N 37 of February 12, 2008:

- Computer/diffractive optics, nanophotonics, optical information technologies and systems;
- Systems for image analysis and pattern recognition;
- Geoinformation technologies.

In accordance with the Order of the Federal Agency of Scientific Organizations Professor N.L. Kazanskiy is temporarily working as acting director of the IPSI RAS since January 20, 2015. The IPSI RAS has four successful laboratories:

- Diffractive Optics (headed by Professor L.L. Doskolovich, Dr. of Phys. & Math);
- Laser Measurements (headed by Professor V.V. Kotlyar, Dr. of Phys. & Math);
- Micro- and Nanotechnologies (headed by Professor R.V. Skidanov, Dr. of Phys. & Math);
- Mathematical Methods of Image Processing (headed by Professor V.V. Sergeev, Dr. of Eng.).

The scientific leader of IPSI RAS V.A. Soifer makes a point of encouraging his research team to always be involved in the cutting-edge research, with new areas including such subjects as, understanding and analysis of nanoscale object images [47–

48], intelligent analysis of the Earth's remote sensing data [49–50], optical computing [24, 28, 29], chip-aided nanophotonic data processing [51–52], and so on.

Research work concerned with further development of methods and technologies for diffractive optics and image processing has also been successfully continued. Topics that have been actively developed include methods for designing diffractive focusing elements [53–59], methods for synthesizing the diffractive microrelief on various optical materials [60–67], computer-aided simulation technologies [68–74], and asymptotic diffraction research methods [75]. Methods for designing optical antennae have been put in practice for designing lighting devices [76–79], multi-order [80–81] and spectral [82–83] optical elements. Facilities and techniques for conducting optical experiments have been persistently improved [83–85], with the range of industrial application of laser light focusers considerably expanded [86]. New optical devices and machine vision systems have been created [87–92], the dedicated software for diffractive optics purposes has been developed [93], and methods for image processing and recognition proposed [94–97].

Annually, a number of research findings by the IPSI RAS researchers have been included into the list of achievements of the Russian Academy of Sciences (see Table 2). Among topics worthy of noting here are sharp focusing of laser light [98–100], new types of diffraction conditioners beams with unique properties [101–102], hyper-resonant magneto-optic effects in periodic nanoheterostructures [21, 31, 103], focusing of the surface electromagnetic waves [22–23, 58–59], nanolithography techniques based on evanescent electromagnetic waves [63–64], new methods for image processing [43–50, 91–92, 94–97, 104–106], and others.

**Table 2.** Number of IPSI RAS research findings included in the annual list of the Russian Academy of Sciences research achievements (RAS Reports)

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	1	1	4	7	5	9	3	4	3

As collaboration with SSAU, IPSI RAS publishes a journal of *Computer Optics*, which contains two major sections -- on optical technologies and image processing. The quarterly journal is peer-reviewed and indexed in international databases Scopus and Compendex. The most frequently cited journal articles [107–114] have been prepared mainly by the Institute's researchers. Now *Computer Optics* will be published every two months [115].

On a regular basis, the Institute hosts major regional international scientific conferences:

- “The IV-th workshop on Computer Optics”, (February 19-24, 1990, Togliatti);
- 5th International Workshop on digital image processing and computer graphics "Image Processing and Computer Optics", (August 22-26, 1994. - Samara);
- 5<sup>th</sup> international conference on “Pattern Recognition and Image Analysis” (“PRIA-2000”, October 16-22, 2000, Samara);
- International conference “Mathematical Modeling-2001”, Chaired by academician A. A. Samarsky (June 13-16, 2001, Samara);

- Fourth international scientific and practical seminar and All-Russian youth school “High-performance parallel computing using clusters” (September 30 - October 2, 2004, Samara);
- Seminar on “Computer Optics and Image Processing” to mark the 30-th anniversary of SSAU’s Technical Cybernetics subdepartment and 20-th anniversary of IPSI RAS (June 20, 2008, Samara);
- Third international conference on Physics of Metals and Mechanics of Materials, Nanostructures, and Deformation Processes (June 3-5, 2009, Samara);
- International conference with taught courses for young researchers “Advanced Technologies for Aviation and Space” (“PIT-2010”, September 29 – October 1, 2010, Samara);
- Asia-Pacific Conference on Fundamental Problems of Opto- and Microelectronics (Москва-Самара, July 4-8, 2011, Moscow-Samara);
- 20th International Symposium “Nanostructures: Physics and Technology” (June 24-30, 2012, Nizhny Novgorod-Kazan-Saratov-Samara);
- 11<sup>th</sup> International conference “Pattern recognition and Image Analysis: New Information Technologies” (“PRIA-11-2013», September 23-28, 2013, Samara).

Active research activity, organizing and hosting big international scientific events have been attracting an interest that prominent Russian and foreign scientists take in IPSI RAS researchers’ works (as illustrated by Figs. 4–9).

## 6. Public recognition

As recognition of the successful research and economic activities, many IPSI RAS workers have been awarded various state and public awards.

In 1993, V.A. Soifer and S.N. Khonina were awarded the First Prize of the German Society for Support of Applied Informatics for the best research paper in image processing and pattern recognition. IPSI RAS director, V.A. Soifer was awarded the Honor Order (1995), the Orders for ‘Services to Motherland’ of IV-th (2004) and III-rd (2010) degrees, RF Government’s prizes for outstanding achievements in science and technology (2007) and in education (2010). In 2003, D.L. Golovashkin and V.S. Pavelyev were awarded the RF State Prize for Young Scientists. V.A. Soifer (2007), V.V. Kotlyar (2012), and S.N. Khonina (2014) were awarded the Governor’s Prize of Samara region, 18 researchers (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; and S.B. Popov, 2014) become laureates of the Regional Prize in science and technology. V.A. Kolpakov (2011), D.A. Bykov and A.V. Gavrilov (2014) were awarded a RAS medal for young researchers, Ye.V. Byzov and S.V. Kravchenko were awarded a RAS medal for students in 2015. A.G. Khramov with colleagues from Samara Medical University was awarded the 2012 Gold medal of the International Inventions Exhibition in Geneva, Switzerland. V.A. Soifer was awarded the Scopus Award Russia 2014 and the title of "Honorary citizen of Samara Region".



**Fig. 4.** – Presiding over the international conference “Mathematical Modeling-2001” are our illustrious contemporaries, academicians A.A. Samarsky (left) and Yu.I. Zhuravlev



**Fig. 5.** – Vice-President of the International Commission in Optics (ICO), Prof. Jin Guofan of Tsinghua University delivers a lecture on “Binary Optics” at a seminar held at IPSI RAS on 8 September, 2006



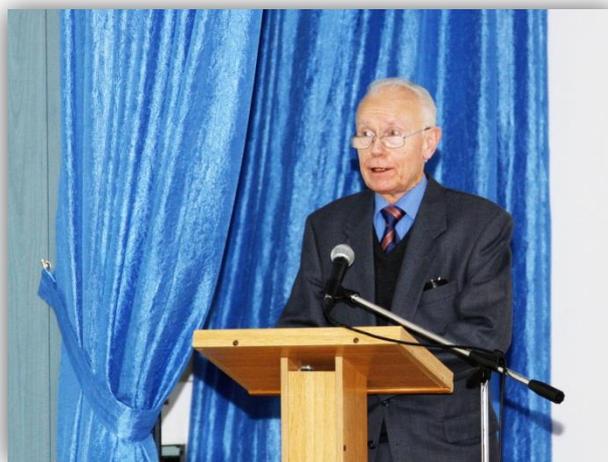
**Fig. 6.** – Prof. R.V. Skidanov presents a diffractive optical element for laser micromanipulation to academician J.I. Alferov (center) and the corresponding member of the RAS V.A. Soifer



**Fig. 7.** – At the laboratory of Micro- and Nano-technologies (left to right): N.L. Kazanskiy, Yu.N. Boyarkin, academician Yu.V. Gulyaev, A.V. Volkov, SSAU Rector, Prof. Ye.V. Shakhmatov, academician G.V. Novozhilov, and the corresponding member of the RAS V.A. Soifer



**Fig. 8.** – Chief Academic Secretary of the RAS Presidium, academician I.A. Sokolov (left) is discussing problems of steganography at the laboratory of Mathematical Methods of Image Processing with N.L. Kazanskiy (center) and V.V. Sergeev



**Fig. 9.** – Professor Heinrich Niemann of the University of Erlangen-Nuremberg is greeting the IPSI RAS scientists at the 25<sup>th</sup> anniversary celebration session of the International conference “PRIA-11-2013” on September 26, 2013

## 7. Conclusion

IPSI RAS is now the largest Russian scientific team working in the field of image processing and diffractive computer optics. IPSI RAS results largely determine the success of Russia in these scientific areas. Summing up, I wish the IPSI RAS

researchers to stay in good health, showing inexhaustible energy, insatiable scientific curiosity and new creative accomplishments for the benefit of our Motherland and Russian science!

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