30th anniversary of the Institute of Optical Monitoring: milestones of the formation and development of the research field

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Introduction

Formation of the research fields and teams inside any research institute is a result of a complex effect of the objective and subjective factors. Objective factors are motivated by the practical needs in a given research field and its readiness to response adequately to this need. Subjective factors, which play a particular role in science, depend on the intellectual potential of a leader and his/her scientific school. Finally, it is just a combination of these factors that determines both the progress of the research field and its life.

Below we present a brief historical sketch about the Institute of Optical Monitoring, which illustrates the way of the development of one of the research fields, whose origination in Tomsk may be dated to the 1960s and which was officially recognized for the new academic institution on January 1 of 1972. It is just this date that opens the official history of the institute organized by the initiative and with the leading role of Academician V.E. Zuev, at that time director of the Institute of Atmospheric Optics. The new academic institution was organized as an Special Design Office of Scientific Instrumentation “Optika.” It was founded as an independent self-supporting organization under the scientific and methodical supervision provided by the Institute of Atmospheric Optics. The high level of organization readiness and the need in SDO “Optika” is evidenced by the fact that its staff was 270 already by the end of 1972.

Then the Institute developed rather rapidly as far as concerned both the staff (up to 900 in 1989) and the material and technical basis (up to 30 000 m^2 of premises in 1991). The illustrated description of this development can be found in the V.E. Zuev book *History of Creation and Development of Academic Science in Tomsk* (SB RAS Publishing House, Novosibirsk, 1999). We would like to emphasize only

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that in the first two decades the nomenclature of devices produced at the Institute also grew extensively. The main achievement was the development (in cooperation with the IAO) of the first Russian space-based lidar BALKAN, which was then (in 1995) installed aboard the MIR space station and operated there for two years.

The 1990s, which were hard for Russia as a whole, led to a fast decrease in the staff and drastic change in the internal policy in the Institute. In 1992, in accordance with the decision of SB RAS, all design bureaus were rearranged into the design and technology institutes, which were ordered not only to conduct test and design, but also the research. The rearranged institute was headed by one of the former deputy directors of the IAO, Corresponding Member of RAS M.V. Kabanov. Simultaneously, some scientists were moved from the IAO to the Institute to reinforce the research. A new stage in the development of the Institute began.

Due to successful formation of the research sector, in 1997 the Design and Technology Institute "Optika" was renamed the Institute of Optical Monitoring in accordance with the decision of the Siberian Branch of the Russian Academy of Sciences and the Division of Oceanology, Atmospheric Physics, and Geography RAS. Thus, the Institute acquired the academic status. Its nominal staff was restricted to 230, and the scientific supervision in the SB RAS passed from the Joint Academic Council on Physical and Technical Sciences to the Council of the Earth Sciences.

In spite of the seeming complexity of the organizational peripetias the Institute sustained for the past three decades, some logic is seen in its development. Actually, beginning its activity as a manufacturer of optical devices and opto-mechanical parts, the Institute passes gradually to the development (in cooperation with the IAO) and production of optical-meteorological systems and their operation under field conditions. The experience in obtaining long-term observation series favors not only competent modernization of new equipment, but also rising skills in processing and analysis of the obtained optical and meteorological information. The systematic monitoring of the optical and meteorological state of the atmosphere is an important element of atmospheric monitoring. Therefore, additional "injection" of scientists, experts in theory and methodology of monitoring, from the IAO to the IOM made the Institute all-sufficient for solution of almost all problems on the optical and meteorological monitoring of the atmosphere and the surface.

At this new stage of the Institute's development, it became possible to define its independent research field, which is formulated in the Institute's Regulations as: *Scientific, methodical, and technological aspects of monitoring and prediction of changes in the atmosphere and ecosystems under the effect of natural and anthropogenic factors.*

Thus, the history and logic of the development of the Institute of Optical Monitoring SB RAS under the effect of objective and subjective factors turn out to be rather interesting and preceptive. We in this paper present our own point of view on the development of the Institute's research field and do not pretend to present thorough description of its activities. A more detailed idea of this activity can be got from the papers included in this topical issue.

1. Prehistory of the research field

The retrospective analysis shows that two institutes of the Tomsk Research Center, SB RAS (IOA and IOM) have common background research field, and the first step in the formation of this field is dated by 1955. It happened just in this year, that Professor N.A. Prilezhaeva the head of the optics and spectroscopy chair at Tomsk State University was charged with the job on organizing the research into propagation of infrared radiation through the Earth's atmosphere. Solution of particular problems was entrusted to V.E. Zuev, assistant professor, who formed the research team and organized building of a testing area. Two principally important problems were solved simultaneously: development and production of emitting and receiving devices operating in the infrared wavelength region (standard devices were absent at that time) and organization of the group on meteorological provision of optical measurements (atmospheric transmission depends on weather conditions). This, in fact, had laid the basis for the research field, which was new in Tomsk and only some its problems were present in the research scope of R&D teams in other cities of the former USSR and foreign countries. The new field dealing with atmospheric transmission for the visible and infrared radiation was quickly filled with new problems. The need in the staff (postgraduate students, engineers, technicians) grew. Zuev's group, which initially was a part of the laboratory of optics and spectroscopy at the SPhTI, became an independent Laboratory of Infrared Radiation of the SPhTI, postgraduates (M.V. Kabanov, S.D. Tvorogov, S.S. Khmelevtsov) defended their candidate's theses, and V.E. Zuev defended his doctor's thesis. It should be noted here that already at that years the research was conducted in close combination of theory and experiment, and experimental solution of the problems was based on new devices produced in the laboratory.

The advent of lasers caused a radical turn in the subject of studies of the Laboratory. Continuing to follow the principle of self-provision with experimental devices, the Laboratory organized its own laser group, which produced stably operating He–Ne lasers. With the use of these lasers, as well as the first commercially available solid-state lasers, the Laboratory conducted pioneering research into propagation of laser radiation through the atmosphere and under laboratory conditions (in model media). The results obtained on scattering of laser beams in disperse media and on laser spectroscopy of atmospheric gases gained international fame and recognition to the research team of the laboratory, whose staff has grown up to 100 by the late 1960s. Meanwhile, the idea on laser sensing of the atmosphere was ripening ...

New scientific problems and new research fields turned out to be within "tight" bounds of the university laboratory. A new critical event was the formation of the academic Institute of Atmospheric Optics based on this laboratory in 1969. New possibilities opened for the development of all studies of the former laboratory and for new studies, including scientific instrument-making. The history of the first years of the scientific and production life of the IAO, as well as its not simple development in the next years is a subject for a separate consideration. Here we only note that from the very beginning the problems of scientific instrument-making were paramount for the IAO not only for conducting research works, but also for realization of the technological potential in practical applications. Therefore, by the initiative of V.E. Zuev, the IAO director, the Corresponding Member of AS USSR since 1970, on January 1 of 1972 the Presidium of the Siberian Branch of the Russian Academy of Sciences decided to organize the Special Design Office of Scientific Instrumentation named "Optika" under the scientific supervision of the IAO.

2. Scientific and engineering problems solved in Special Design Office "Optika"

The critical need in experimental equipment for basic and applied research motivated the priority problems of the Special Design Office "Optika" under the scientific supervision of the IAO: to produce devices and opto-mechanical elements by request from IAO scientists. As the production basis of the SDO "Optika" grew, production of currently designed items grew to the level of a planned production of scientific instruments meeting required specifications. Already in 1974 the first scientific device (optical nephelometer) was produced in such a way under the leadership of Dr. B.A. Savel'ev, former researcher of the IAO and director of the SDO "Optika" since 1973. In spite of the fact that some efforts in the first years of the SDO "Optika" history were directed toward creation of the production basis, the schedule of research works in collaboration with the IAO became increasingly stable. In the process of such research works on some opto-electronic devices and systems, the SDO "Optika" found new technical solutions, which required solution of scientific problems (mostly in the field of technology).

Laser sources of optical radiation became the basic elements of new opto-electronic devices produced in the 1970s and 1980s. The absence of commercially available lasers needed for multifrequency sensing of the atmosphere and multicolored navigation devices stimulated the development of metal-vapor lasers, which, in principle, are suitable for achieving these tasks. For these purposes, a subdivision for the development of technical means for multiparameter diagnostics of active media with vapors of copper, gold, and other metals was organized. Simultaneously, the problems of technical provision for reliability of lasers when operated in the sealed-off mode were solved. The results of this research have formed the basis for A.N. Soldatov's and G.S. Evtushenko's doctor's theses, which were then successfully defended.

Another basic element of optical devices is a receiver of optical radiation. As far as concerned these elements, the primary task was to use commercial photodetectors, improving their technical characteristics, in new devices. The specificity of using photodiodes and photomultipliers in devices operating through the atmosphere under field conditions consisted in high requirements to their mechanical and climate resistance at the large dynamic range of recorded optical signals. Therefore, the main scientific and engineering problems were connected with seeking new technical solutions on power supply modes and stabilization of sensitivity of photodetectors. For example, some methods for tuning the PMT gain by varying the voltage across the dynodes were proposed. For the detectors based on avalanche photodiodes, a system of engineering, design, and technical problems connected with the use of optimal filtering of synchronous detection and temperature stabilization was solved (the results were included in the N.P. Soldatkin's doctor's thesis).

When developing various-type lidars, a number of scientific and engineering problems connected with optimization of the lidar transmitting/receiving system were solved. In particular, the methods for calculation of the lidar sensing range and estimation of the dynamic range of lidar signals, which is bounded below by external (background radiation) and internal noise and above due to vignetting fluxes of scattered radiation by spatial filters, were developed. Optimal spatial filters were proposed and produced with the allowance for the process of imaging in the hyperfocal space of the receiving system at recording a laser pulse. The basic design was developed for synthesis of the transmitting and receiving systems for polarization lidars providing for measurement of the scattering phase matrix when sensing disperse media.

The photo-acoustic effect was employed successfully in the development of laser spectrometers for studying weak spectral lines of the molecular absorption. Based on the results of experiments and metrological tests conducted in cooperation with the IAO, a series of laser spectrophones was produced, which found then their utility in laser spectrometers and high-sensitivity gas analyzers. The frequency characteristic of a spectrophone was studied, as well as the pressure dependence of the sensitivity of a photo-acoustic cell, and a number of other problems were solved.

The development of opto-mechanical production in the SDO "Optika" was accompanied by creation of testing and measuring instrumentation for such production. As a result, precision interferometric methods were developed along with the corresponding interferometers for real-time quality control of various-size optical elements. Several such interferometers were produced for leading Soviet opto-mechanical plants.

The results obtained were used for production of new devices and optical-meteorological systems, as well as in unique measurement systems, most of them still functioning at the IAO. It should be noted that these results were obtained in the period from 1976 to 1992 under the leadership of A.F. Kutelev as a chief designer.

3. Formation of the research field in the DTI "Optika"

Under the new social and economic conditions in Russia in 1992 with the new role of the academic science, reorganization of the SDO "Optika" into the Design and Technology Institute "Optika" meant not only the transition to the new problems, but also revision of the strategy of design works. In fact, formation of the independent research field started.

The first step in this direction was made in late 1992: Academician V.E. Zuev, Corresponding Member of RAS M.V. Kabanov, President of the Presidium of SB RAS Academician V.A. Koptyug, and Tomsk governor V.M. Kress discussed the proposals on organization of the basic center of climate and ecological monitoring in Tomsk. The result of this discussion was the approved (in March 1993) Agreement between the Presidium of SB RAS and Administration of the Tomsk Region on the joint support of the Regional Research and Technological Problem "Climate and Ecological Monitoring of Siberia" on the territory of Tomsk Region. Corresponding Member of RAS M.V. Kabanov was appointed scientific leader of this program.

The second step that positively affected the formation of the Institute's research field was approval of the Interdepartmental Project "Climate and Ecological Monitoring of Siberia" by the Scientific Council of the Program "Siberia" and its inclusion into the Program. Co-executors of this Project were several academic institutes: DTI "Optika" (Tomsk), Institute of Solar and Terrestrial Physics (Irkutsk), Institute of Computational Mathematics and Mathematical Geophysics (Novosibirsk), Buryat Institute of Natural Sciences (Ulan-Ude) and universities: Tomsk State University and Tomsk Polytechnic University with their research institutes. Simultaneously, a meteorological station was opened at the DTI "Optika" with the technical and methodical help of the Western Siberian Division of the Russian Hydrology and Meteorology Committee (headed by V.I. Zinenko). The station was opened in October 1994 on the territory of Tomsk Akademgorodok and it was the first part of the Climate and Ecological Observatory of the DTI "Optika."

Along with the above measures, the formation of the Institute's research field was also affected by the extending subjects of research. Publication of papers on scientific and methodical principles of climate and ecological monitoring was begun at that time under the scientific supervision of M.V. Kabanov. These papers were generalized and the subject received further development in the Kabanov's monograph *Regional Monitoring of the Atmosphere.* Part 1. *Scientific and Methodical Bases* (SB RAS Publishing House, Tomsk, 1997). By the initiative of Academician V.A. Koptyug, the research team headed by Dr. A.V. Pozdnyakov was moved from the Institute of Ecology of Natural Complexes to the DTI "Optika" and this team developed new approaches to solving the problems of sustainable development and made an impact upon the formation of the Institute's research field. Of significant importance were also research works on UV radiation field in Siberia, which started in 1995 in Tomsk Akademgorodok under the leadership of Dr. I.I. Ippolitov, now the head of the Climate and Ecological Observatory.

Meanwhile, the Institute's priorities in design works also changed. If in the SDO the preference was given to the development of unique optical-meteorological systems, then the Design and Technology Institute was oriented at the development, with the following production, of small series and at the use of its own experimental base. The priority remained on the development of devices for climate and ecological monitoring, and the nomenclature extended up to teaching and demonstration devices (UMOG-1 system for physical practicum, Laser-Show laser light-dynamic system, etc.), as well as medical devices (laser treatment devices Lazter-01, Lazter-03, Lazter-05, LT-92, dental mirrors, etc.). The list of the main devices developed in these years at the Institute included:

– mobile ecological-meteorological station "Ecolid" mounted on ZIL-131 truck and delivered in 1993 to Ust'-Kamenogorsk;

– RGA-11 mercury gas analyzer included in the State Measuring Technique Register and produced in a small series; six analyzers in this series were produced in 1994 by request for institutes of SB RAS;

– space lidar BALKAN developed in cooperation with the IAO based on the laser geodesic range finder of the Russian Scientific Research Institute for Space Device Engineering; the lidar BALKAN has passed prelaunch tests and was mounted on the MIR space station in 1995;

– the system for automation of technological processes on railway transport (monitoring of trucking) implemented at Tomsk-Gruzovoi station in 1996;

– the precision automated system for photometric control of rails straightforwardness at rolling (monitoring of rolling); this system was certified and mounted at the Kuznetsk Metallurgical Plant in 1996.

As is seen from the above discussion, the initially common subject of the two institutes (IAO and DTI "Optika") has evolved and became different by 1997. Therefore, after acute discussions the institutes separated. For the DTI "Optika" renamed the Institute of Optical Monitoring (IOM SB RAS), the new stage began. This stage was also stimulated by the new international situation with Earth sciences, which even gave rise to the new strategy in Earth studies [see, for example, G.A. Zavarzin, V.M. Kotlyakov, "*Strategy of Earth studies in view of global changes*," Vestnik RAN, No. 1 (1998)].

4. Development of the research in IOM

Global scales and the increasing rates of the observed environment and climate changes became so marked in the second half of the 20th century that they are now considered as very important components of further development of human civilization. Due to discussion of these problems at the level of state leaders (the United Nations Conference on Environment and Development, Rio de Janeiro, 1992), a set of declarations was issued and this has led to the formation of the corresponding international and local research programs. Already in the process of formation of such programs and in analyzing the results of research within them for the first years, some key features were revealed, which should be taken into account in further research into the observed geospheric and biospheric changes in all regions of our planet and which were taken into account in the development of the IOM research.

One of the key features is the need in justified separation of leading natural and anthropogenic factors in every region. The results of statistical analysis of instrumental observations (according to the data of Russian Hydrology and Meteorology Committee) showed, for example, that the warming in Siberia has the higher rate in the last half-century and is irregular, and the observed seats of accelerated warming (up to 0.5°/10 years) have a scale of several hundreds of kilometers. This analysis revealed particular requirements to organization of a network of climate and ecological monitoring and to the nomenclature of measurement instruments for regional monitoring aimed at isolating the main factors in a region. Thus, the strategy of the IOM research with the priority study of mesoscale natural and climate processes and following generalization of the results for developing regional and global models of natural and climate changes was justified.

Another one key feature is connected with the revealed need in monitoring of not only the state of the environment and climate, but also the dynamic characteristics of the environment- and weather-forming processes. In particular, from the studies within the framework of the Project "Climate and Ecological Monitoring of Siberia" (with UV radiation fluxes, parameters of atmospheric electricity, and some others taken as an example) it follows that important indicators of observed changes are not only mean parameters of natural and climate systems, but also the rate of change of these parameters. Principal conclusions on the technique of monitoring follow herefrom, and this is especially important for the development of scientific instrument-making in the IOM. Modern geoinformation technologies providing for the correct selection of the format of an information database and the access to this database acquire particular importance.

The next key peculiarity of the geospheric and biospheric changes is connected with the complex interaction of natural and climate systems on the global, regional, and local scales. Unrevealed cause-and-effect relations in the interaction of natural, technogenic, and climate systems at different levels stimulated the development of the systematic-evolution approach to monitoring and simulation of climate changes. The interdisciplinary character of such studies determined the IOM staff including scientists with a diverse specialization and obligations on coordination of the integration (multidisciplinary) Project "Complex Monitoring of Great Vasyugan Bog: Study of the Current State and the Processes of Development under the Effect of Natural and Anthropogenic Factors" (executors of this three-year project are 18 academic institutes and 6 organizations).

Thus, in accordance with the logic of development of scientific research into regional environment and climate changes, the IOM under the leadership of Corresponding Member of RAS M.V. Kabanov has now the field of research, which covers problems of theory and methodology of regional monitoring and which can be called "Physics of natural and climate changes." Within the framework of this field, the climate and ecological monitoring conducted at the IOM is the key method of the research, which does not exclude also the methods of mathematical and physical simulation under laboratory and field conditions. The studies of many problems are conducted in the close contact with Russian and foreign scientists.

Conclusion

The rather long and successful work of the IOM as a subdivision of the Joint Institute of Atmospheric Optics responsible for the development of new devices under the scientific supervision of the IAO naturally left a mark on the Institute's structure and its international relations at the new status of an independent institute.

Engineering laboratories dealing with the development of new optical, acoustic, and radio devices for monitoring of various components of the environment, including technogenic ecosystems, are now kept in the IOM structure. Three such laboratories: Laboratory of Ecological Instrument-Making (headed by Dr. N.P. Soldatkin), Laboratory of Remote Sensing (headed by Dr. N.P. Krasnenko), and the Laboratory of Optical Crystals (headed by Dr. A.I. Gribenyukov), as well as the Design Bureau (headed by A.N. Levchenko) are united in the Engineering and Design Department headed by Dr. A.A. Tikhomirov. Four research laboratories: Climate and Ecological Observatory (headed by Dr. I.I. Ippolitov), Laboratory of Geoinformation Technologies (headed by Dr. V.A. Krutikov), Laboratory of Self-Organization of Geosystems (headed by Dr. A.V. Pozdnyakov), and the laboratory of Optical Methods and Technologies (headed by Dr. V.A. Tartakovskii) are united in the Department of Geophysical Research headed by Dr. V.A. Krutikov. All laboratories now have no strict functional restrictions on conducting individual or joint research or design works.

Earlier the IOM took part in international relations only through the IAO, but now it develops its international contacts independently. Among these contacts, to be mentioned are contracts of the IOM with the Defense Evaluation and Research Agency (UK) on the joint development of new technologies for synthesis of nonlinear optical crystals. Further development of these contracts is the contract with the European Bureau of Aerospace Research and Development (EOARD), London, UK, active since 2001. Among the promising contracts there is the contract with the Schlumberger transnational company with the central Bureau in the United Kingdom; this contract implies study of the nature and geography of radio pulse emission of the lithosphere. Scientific problems of this contract since 2000 complement the complex monitoring of the environment and are being solved by the group headed by Dr. Yu.P. Malyshkov (this group was moved from the Tomsk Polytechnic University).

For developing the main research field of the Institute, the cooperation with European institutes within the framework of the INCO-Copernicus Program is of great importance. This cooperation concerns the problems of monitoring and simulation of natural and climate changes of the global and regional scale. For the IOM, the principle importance of this international cooperation sponsored since 2001 is that it is developed from the Russian part by both the IAO and the IOM on equal terms. Such joining of the scientific and technical potential of two institutes (IAO and IOM) seems promising not only for the development of international relations, but also for scientific research within national and regional programs. Moreover, in spite of the fact that monitoring of atmospheric processes and phenomena remains the priority method of research in both institutes, the monitored parameters are different, and such data can serve a basis for organization of joint research in the main and related areas.