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On the 40th Anniversary of Polyus Research and Development Institute

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In March 2002, the staff of Polyus Research and Development Institute celebrated the 40th anniversary of the institute. This institute was founded almost simultaneously with the advent of the first lasers, and has made a significant contribution to the development of quantum electronics and domestic laser instrumentation. The initiative of creating the first specialised laser institute in the world belongs to M.F.Stel'makh and A.I.Shokin, Chairman of the USSR State Committee on Electronic Technology.

M.F.Stel'makh, the founder and the first director of the institute, paid special attention to the recruitment of its staff, participated in the selection of specialists and personally interviewed each staff member before appointment. Contacts with leading educational institutions of Moscow played a significant role in the establishment of the institute. Students of the Department of Physics of the Moscow State University were the first to work on their degree theses at the Polyus institute. Polyus became the basic chair of the Moscow Physicotechnical Institute as early as in 1970. Later, such chairs were created at Polyus for the Moscow Institute of Radioengineering, Electronics and Automation, as well as the Moscow Institute of Electronic Engineering. Of equal importance were the contacts with several institutes of the USSR Academy of Sciences like the Lebedev Physics Institute, Institute of Crystallography, Institute of Spectroscopy, Institute of Applied Physics, etc. Being a branch of the defence-oriented industry, Polyus was involved from its very inception in the solution of specific research and development problems aimed at designing and industrial production of instruments and laser engineering systems.

The first detailed activity undertaken at the institute concerned the materials and elements of quantum electronics. Many years of labour by technologists on the growth, annealing and processing of crystals, as well as chemists and researchers led to a large-scale production of ruby rods by the end of 1960s. The first Nd^{3+} : YAG crystals were grown in 1966 by the Czochralski method, and their pilot-plant production was started. Later, such crystals were also grown at the plants of the Research and Industrial Association 'Polyus' in Bogoroditsk and Sergach.

At about the same time, active research was carried out for creating nonlinear and electrooptical materials, technology was developed for the production of lithium niobate and tantalite crystals, a persistent quest was aimed at finding more efficient crystals, and production of electrooptical shutters, modulators and frequency converters was set up. Simultaneously, the research activity was aimed at the creation of water-soluble crystals of ADP, KDP, DKDP, TGS, CDA, DCDA, etc., and elements based on them. A little later, technology was developed for the commercial production of KTP crystals, which made it possible to create highly efficient frequency converters of laser radiation.

M.F.Stel'makh (1918 – 1993) – founder and first director of Polyus

The first lasers were used at the Polyus Institute to design the equipment based on laser technology, including the K-3 setup (more than 100 such units were manufactured), the equipment in the series 'Kvant' intended for drilling holes in diamond draw plates and spot welding of relays (the total number of such units was more than 1100), the setup 'Katun' based on a high-power CO_2 laser, etc.

By the beginning of 1980s, the laser technology equipment of the Polyus Institute was produced commercially by four plants of the Ministry of Electronic Industry, and a total of 7000 units were delivered. The total number of laser devices used in the USSR constituted about 50 % of the total production of such devices in the world.

One of the most important fields of activity at the Polyus Institute was the development of semiconductor lasers, which was started in 1962 at the initiative of M.F.Stel'makh and V.I.Shveikin. The first semiconductor laser was built at Polyus as early as in 1963, and the study of heterojunctions in $A^{III}B^{V}$ compounds carried out during the years 1966 – 1971 led to the creation of highly efficient low-threshold cw semiconductor lasers that do not require any cooling. The

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semiconductor lasers developed at the Polyus Institute were used at the beginning of 1980s to produce the first fibreoptic communication systems in our country, which are being used successfully even today. Semiconductor lasers produced by Polyus have been used successfully in space research and in systems for recording and reading information. At present, we produce about 100 types of semiconductor laser emitters and transmitting modules using the latest MOCVD technology of growing high-quality semiconducting structures. Investigations have been started for the production of superluminous LEDs which are being used widely in many instruments and systems of civil and special engineering.

Laser rangefinders were among the first laser instruments to be fabricated at the Polyus Institute. Lasers produced by Polyus Research and Development Institute were used successfully by the Space Instrumentation Research and Development Institute for locating moon rovers at the surface of the Moon in 1972–1973. Among the well-known devices manufactured by Polyus Research and Development Institute are the binocular rangefinders in the series LDI-3, LDI-3-1M, having a mass smaller than 1.3 kg, as well as the KTD-3 topographic tachometer, which does not have analogues in the world and is a combination of a laser rangefinder, an electronic theodolite and a microcomputer. Laser rangefinders operating at an eye-safe wavelength (1.5 μm) have been produced in recent years.

The development of laser range-finding and targeting devices for high-precision artillery is one of the most important fields of activity at the Polyus Institute. Laser targeters 1D15, 1D20 and 1D22 were fabricated and produced on large scale during 1970s and 1980s. Investigations are being carried out today with a view to improve their performance and to solve new urgent problems.

The development of laser gyroscopes was started at the Polyus Institute in 1963. In the following year, lasing was obtained in the first experimental model of the T-130 ring laser, and a difference-frequency signal from counterpropagating waves was detected. In 1965–1966, the basic ideas of Zeeman laser-gyroscopic research were formulated and the gyroscopes T-100V, T-50, K-50, K-15, etc., were fabricated. The development of high-precision monoblock prismatic laser gyroscopes of the types KM-11 and KM-43 was started in 1967. These devices have found wide applications in civil aviation and special technologies.

An enormously large number of design and construction problems were solved during the development of laser gyroscopy. These include the conservation of gaseous mixtures, creation of highly reflecting mirrors, precision prisms and piezoelectric drives, elimination of the harmful effect of trapping of counterpropagating waves, development of highly efficient cathodes and optical contact technology, creation of appropriate radioelectronic elements, vacuum-electron technology and the corresponding vacuum-electronic devices. A whole range of new lasing regimes and the methods of improving the accuracy (sensitivity-axis reversal, the four-frequency lasing mode, etc.) were developed.

The main efforts in 1990–2000 were devoted to the development of the production technology for Zeeman laser gyroscopic sensors and constructing small-size three-axis devices based on them (MT-5, MT-4, ZLK-16-1, MT-45, MT-401, 9B-183, 17M-78) for navigation and control systems. At the same time, the production of Zeeman laser gyroscopes (EK-101, EK-104, LGK-200, ZLK-16) was resumed at Polyus. The BINS NSI-2000 navigation system integrated with global GPS and GLONASS navigational systems for equipping the transport planes IL-76 was developed jointly with Lazex Pvt. Ltd. Together with the Nuclear Physics Research Institute of the Moscow State University, a new type of laser gyroscope was fabricated on the basis of a miniature monoblock Nd^{3+}:YAG ring chip laser pumped by a semiconductor laser, and its frequency characteristic was studied for the first time in 2000.

Research on the creation of laser photodetectors (LPD) has been carried out at the Polyus Institute ever since its inception. Way back in 1963, optical superheterodyne detection at the ruby laser wavelength was demonstrated, and the development of semiconductor germanium LPD with an extremely fast response and high quantum efficiency was started. This activity was carried out in close cooperation with units of the Ministry of Electronic Industry like the Pulsar Research Institute and Kaluga Institute of Electronic Technology. Among other things, the germanium avalanche LFD-2 photodiode manufactured by the Ulyanov Electron Tube plant has been used in many systems of special applications. In recent years, several modifications of germanium photodiodes and LPD based on them have been developed at the Polyus Institute, including the avalanche LFD-G photodiode (11 modifications), photodetector modules for fibreoptic communication systems and range finders. A complex of phototdetectors for use in prospective systems is being developed at present.

At the end of 1960s, the development of IR detectors based on pyroelectric crystals of triglycine sulphate and lithium tantalate was started at Polyus Institute under the guidance of M.F.Stel'makh. The technology of growing these crystals was worked out and the necessary technical equipment was constructed. More than 15 types of pyrodetectors in the series PM and PP were created and used in aviation and space technology during 1960–1990, and, later, in medicine for remote temperature monitoring.

M.F.Stel'makh paid special attention to the designing of devices for use in laser medicine, which was started in 1965. As early as in 1967, the staff of the Polyus Institute and Vishnevskii Surgical Institute discovered the antitumor action of laser radiation. From 1969, 'bloodless' operations on organs containing fine blood vessels have been performed at the latter institute using lasers fabricated at the Polyus Institute. Between 1970 and 1975, the first domestic 'laser scalpel' based on the CO_2 laser was developed and produced on large scale. It is still being used in many clinics of Russia and CIS countries. Later, a whole range of surgical equipment like 'Impuls-1' for coagulation of tumours, ophthalmologic devices in the series 'Yatagan', laser scalpels in the series 'Scalpel' and 'Romashka', etc., were designed and fabricated. The plants of the Scientific Industrial Complex Polyus have produced more than 3000 units of laser surgical equipment during 1972 and 1997. The priority of Polyus in this field is asserted by 112 authors certificates, 26 foreign patents, 60 medals from the All-Union exhibition of economic achievements, the grand gold medal of the Leipzig fair, publications in scientific journals, etc. Laser surgery equipment was introduced by the Polyus Institute in wide clinical practice in close collaboration with leading medical organisations like the Central Research Laboratory of the 4th Main Directorate, Ministry of Health, All-Russian Research Institute of Eye Diseases, Ministry of Health, All-Russian Research Centre of the Russian Academy of Medical Sciences, Tuberculosis Research Institute, etc.

Way back in 1962, M.F.Stelmakh, R.V.Khokhlov and I.S.Rez clearly understood the necessity of designing and developing lasers with frequency conversion for industrial applications. In collaboration with the Moscow State University, the Polyus Institute created and tested in 1964 the first Nd : glass laser with second harmonic generation under natural conditions as a constituent of the model of underwater laser vision system. The stage of development was completed by 1967, and the commercial production of the first series of Nd^{3+} : YAG lasers with frequency conversion into second, third and fourth optical harmonics (series LTI and LTIPCh) was started. The plant 'Tantal' in Saratov produced over 1500 such lasers.

Later, laser sources IZ-25, ILTI-401 and ILTI-403 were developed for specialised applications in systems which subsequently led to the creation of a whole series of highly efficient emitters and lasers. A series of LTN-401-403 cw lasers with frequency doubling was later designed and developed for commercial production at the Ulyanovsk Vaccum Tube Plant. These lasers were used in applied science research in communications and information recording systems. The current state of the research and design in the field of nonlinear optics at the Polyus Institute is characterised by the creation and wide-range practical application of highly efficient pulse and cw solid-state lasers with frequency conversion of laser radiation into optical harmonics, optical parametric oscillators, Raman lasers, etc.

The efficiency of conversion of Nd-laser radiation (1064 and 1320 nm) into second harmonic (532 and 660 nm) in new promising KTP crystals achieves 50 % – 70 % for a pulse energy ~ 0.1 J and a pulse repetition rate of up to 500 Hz. Compact, highly efficient optical parametric oscillators have been built, which convert radiation at 1064 nm into radiation at 1500 nm in the eye-safe spectral region. Raman lasers are being developed with the same purpose as efficient radiation sources in rangefinding, illuminating and targeting systems.

Considerable attention is paid to the training of highly qualified personnel in the field of quantum electronics at the Polyus Institute, which serves as the base institute for some of the largest educational institutions of the country, like the Moscow State Institute of Radioengineering, Electronics and Automation, Moscow Institute of Electronic Engineering, and Moscow Physicotechnical Institute. Leading scientists of the Polyus Institute deliver optional courses of general and specialised lectures, and have written several monographs on laser physics, nonlinear optics, and tunable lasers, which have been acclaimed in the former USSR and abroad. They have published hundreds of scientific papers in leading Russian and foreign journals, and have presented a large number of reports at All-Union and International conferences. Scientists of the Institute have defended over forty Ph.D. and many D.Sc. theses, and obtained hundreds of author certificates and patents.

The several-thousand strong collective of scientists, researchers, engineers, technologists and workers of the scientific-industrial complex and Polyus have carried out hundreds of scientific investigations and experimentally worked out and developed designs that formed the basis of laser technologies in many branches of industry and special engineering applications. These designs and developments were used to create several tens of thousand lasers of various types which were used widely in military applications, materials processing technology, medicine, and physical experimental techniques.

A powerful school of scientists and highly qualified specialists has been created. Many of these scientists are known all over the world. Scientists and project leaders of Polyus have been awarded the highest prizes by the government. They won the Lenin and State Awards of the USSR, Prizes of the USSR Council of Ministers and Lenin's Young Communist League, and the Russian State Awards.

It is impossible to name all the scientists and project leaders, designers and technologists, testers and workers of the Polyus Institute, whose selfless efforts have made our institute one of the leading institutions in Russia in the field of high technologies. However, it is impossible to forget the decisive contribution made by its 'old guard' and leading scientists like A.V.Ievskii, G.M.Zverev, V.I.Shveikin, B.V.Rybakov, V.G.Dmitriev, V.A.Pashkov, A.I.Laryushin, A.I.Timofeev, B.N.Malyshev, V.N.Kuryatov, I.S.Rez, V.M.Garmash, L.K.Kovalev, V.M.Vakulenko, V.M.Kan, S.N.Stolyarov, E.R.Aleev, G.M.Romadin, and many more.

It is practically impossible to list all the significant achievements of our institute in a short article. Hence, I have had to confine my report to just a brief review of the main trends of the works undertaken at the Polyus Research and Development Institute.

It is my pleasant duty to thank the management and editorial staff of the journal Quantum Electronics for consenting to release a special issue of the journal to commemorate the 40th anniversary of the Polyus Research and Development Institute, which was named after its founder – director M.F.Stel'makh. Naturally, the articles published in this issue cover by no means the entire range of pure and applied science research, and the projects undertaken at the Polyus Institute, but reflect just a 'momentary glance' at the activity of our institute.

The author would like to take this opportunity to express through the journal Quantum Electronics his deep sense of gratitude to all the staff members of Polyus for the many years of untiring labour, as well as to all the scientists of the Russian Academy of Sciences, higher school and research institutions of the country, with whom we had the privilege of working together for the advancement of quantum electronics and laser technology in our country.