

CONFERENCES AND SYMPOSIA

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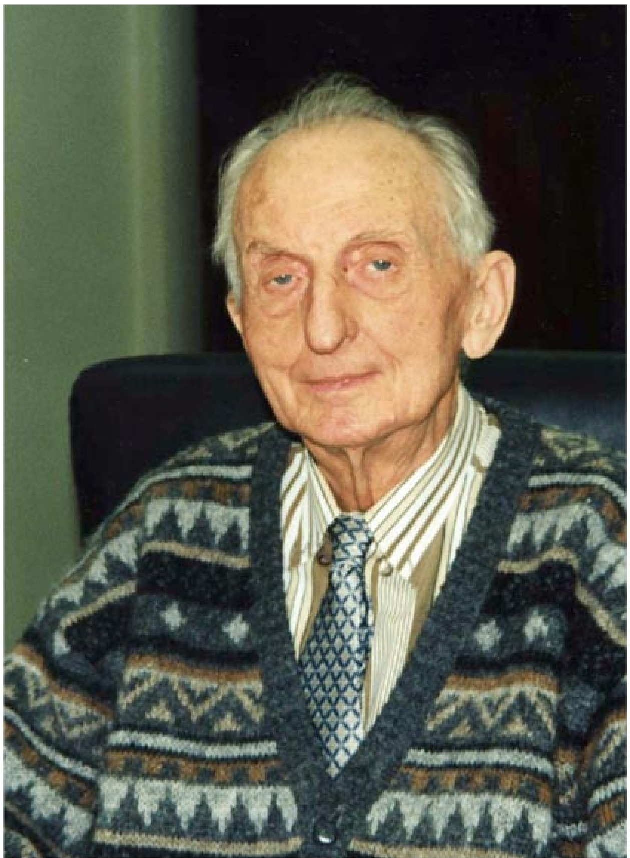
Scientific session of the Physical Sciences Division of the Russian Academy of Sciences dedicated to the ninetieth anniversary of Academician A M Prokhorov (25 October 2006)

A scientific session of the Physical Sciences Division of the Russian Academy of Sciences (RAS) dedicated to the ninetieth birthday of Academician Aleksandr Mikhailovich Prokhorov was held in the Conference Hall of the P N Lebedev Physics Institute, RAS on 25 October 2006. The following reports were presented at the session:

(1) **Dianov E M** (Fiber Optics Research Center, RAS, Moscow). "A M Prokhorov and quantum electronics";

(2) **Karlov N V, Konov V I, Osiko V V, Shcherbakov I A** (A M Prokhorov General Physics Institute, RAS, Moscow). "A M Prokhorov: founder of the General Physics Institute".

An abridge version of the reports is given below.



11.07.1916 (Australia) – 08.01.2002 (Moscow)

Aleksandr Mikhailovich Prokhorov in 2001

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A M Prokhorov and quantum electronics

E M Dianov

1. Introduction

To speak of the role which the eminent physical scientist, outstanding organizer of science, and true patriot of his country Academician Aleksandr Mikhailovich Prokhorov played in the development of quantum electronics is simultaneously easy and difficult. Easy — because he is one of the creators of this scientific area and the results of his scientific activity are brilliant and well known to the Russian and international scientific communities. Difficult — because his accomplishments are numerous and nearly impossible to be covered in one report.

The physical principles of quantum electronics, approaches to the creation of quantum oscillators and amplifiers, and prospects for the development of quantum electronics are magnificently outlined in A M Prokhorov's Nobel lecture "Quantum electronics" [1].

That is why in this report I enlarge primarily on the works of 1954 – 1958, which laid the foundations of quantum electronics. This research was carried out simultaneously and independently by A M Prokhorov's group at the P N Lebedev Physics Institute of the USSR Academy of Sciences (FIAN) and Charles Townes's group at Columbia University in the USA.

I believe that a brief review and comparison of these works are of great interest, because they clearly show the virtually similar train of thought of the participants and the synchronous progress of research undertaken by the two groups. This is quite surprising for that cold war era, when contacts between scientists were severely limited.

Next I briefly touch on A M Prokhorov's contribution to the development of laser physics and related areas. By the example of fiber optics I will demonstrate his approach to the solution of complex scientific and technical problems.

In concluding, I will dwell on the Australian period of A M Prokhorov's life.

Uspekhi Fizicheskikh Nauk **177** (6) 677 – 689 (2007)
Translated by E N Ragozin; edited by A Radzig

2. Birth of quantum electronics and the onset of the laser era

The basis for quantum electronics is the phenomenon of stimulated emission predicted by Einstein (Albert Einstein, "On the quantum theory of radiation," 1917). The essence of the phenomenon is that an excited atom may give out energy in the form of both spontaneous and induced (stimulated) emission. In the latter case, the excited atom radiates when it interacts with an external photon field. In this case, the emitted and external photons are indistinguishable.

This property of stimulated emission makes it possible to create quantum oscillators of electromagnetic radiation. The observation of stimulated emission requires producing excited atoms. However, when atoms are in thermal equilibrium, their optical levels are not populated and in the excitation of atoms under ordinary conditions they pass to the ground state by spontaneous emission. This is due to the fact that the stimulated emission probability is low under ordinary light intensities. That is why stimulated emission was not considered in optical spectroscopy. The situation in radiospectroscopy is quite different. In the radio-frequency band, where $h\nu \ll kT$, excited molecular levels in thermal equilibrium have higher populations, with the result that stimulated emission should be taken into account. That is why it is no mere chance that the works which led to the advent of quantum electronics were carried out by groups engaged in radio-frequency spectroscopy.

To improve the spectral resolution and sensitivity of radio-frequency spectroscopes, A M Prokhorov and N G Basov used molecular beams as the subjects of research and in so doing employed molecule sorting by energy states. In other words, they obtained excited-state molecules, and this system, in principle, could amplify radiation. Similar research was carried out by Townes's group.

In 1954, Basov and Prokhorov published a paper entitled "Application of molecular beams for radiospectroscopic study of rotational molecular spectra" [2], where they discussed the feasibility of making a quantum oscillator of electromagnetic radiation, which they termed the molecular oscillator. There is good reason to quote a small excerpt of the paper to show how explicitly and clearly they formulated the means of implementing this idea.

"By using a molecular beam in which there are no molecules in the lower state of the radiation transition under consideration, it is possible to make a 'molecular oscillator'. The principle of molecular oscillator operation is as follows.

The sorted molecular beam in which there are no molecules in the lower state of the transition under consideration is passed through a cavity resonator."

That year saw the publication of the paper by Gordon, Zeiger, and Townes, which reported the launch of an NH_3 molecular oscillator utilizing the same principle [3].

In 1955, Basov and Prokhorov published a paper entitled "On the possible methods of obtaining active molecules for a molecular oscillator" [4], where they proposed a technique for producing active molecules (population inversion) through preirradiation of a molecular beam by an auxiliary high-frequency field, which gives rise to resonance transitions between different molecular levels. Figure 1 shows possible versions for employing auxiliary radiation of frequency ν_{aux} to produce population inversion and oscillation at a frequency ν_{osc}. Today, this technique (the 'pumping technique', or the 'three-level technique') is widely used in making lasers of different types.

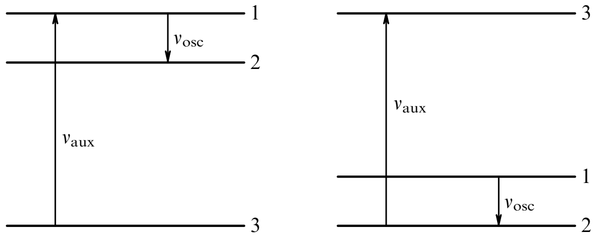


Figure 1. Pumping schemes for the production of population inversion.

In the same year, A A Manenkov and A M Prokhorov published the paper "Fine structure of the paramagnetic resonance spectrum of Cr^{3+} ion in chrome corundum" [5]. That paper signified a passage to radiospectroscopic investigations of solids, of paramagnetic crystals in this case. These investigations led to the creation of quantum microwave amplifiers and their wide application.

The year 1956 saw the publication of Bloembergen's paper dedicated to the production of population inversion by the pumping technique in solid-state masers [6], and a paper by Basov and Prokhorov which gave the theory of a molecular oscillator and a molecular power amplifier [7].

Prokhorov's paper "On the molecular amplifier and oscillator on submillimeter waves" [8] appeared in 1958; in it he discussed the feasibility of creating a molecular amplifier and oscillator at wavelengths shorter than 1 mm. One of the problems encountered in developing a short-wave radiation oscillator was the selection of a resonator. In that paper he proposed and substantiated the use of two plane-parallel mirrors as a resonator (an open cavity). This proposal opened up the way to the development of lasers, and today two plane-parallel mirrors are the resonator type that enjoys the widest application in laser technology.

Later that year, Schawlow and Townes published a comprehensive study on the resonator in the form of two parallel mirrors as applied to the optical wavelength range [9]. In that paper and in his later reports at conferences Townes would note Prokhorov's priority over the proposal of this resonator type.

The physical principles of quantum electronics and the avenues of its subsequent development, including the creation of lasers, were formulated in the above papers.

The launch of a laser in 1960 led to the emergence of a new avenue in science and technology — laser physics. However, as became clear later, this was not the mere emergence of a new field in science and technology. The launch of a laser marked the dawning of the laser era in which lasers came to be indispensable instruments in technological processes, new techniques, medicine, defense technology, scientific investigations, and everyday life. A M Prokhorov realized the enormous potential of lasers. During that period, the range of his interests widened considerably, the number of collaborators in his team increased, and he vigorously sought to engage research, specialized, and industrial organizations in the investigations.

The main results obtained under Prokhorov's supervision over a period of more than forty years have been published in the scientific literature of our country and in international scientific literature and are well known to the scientific communities both in Russia and abroad. In particular, many basic works of the 1953–1995 period were published in A M Prokhorov's book *Kvantovaya Elektronika. Izbrannye Trudy* (*Quantum Electronics. Selected Works*) [10]. There is no way of giving in one report even a brief description of the main results: it is possible to formulate only the main avenues of research:

• the search for new types of active media and methods for producing population inversion;

• broadening the spectral range of lasing and the search for new optical materials transparent in different spectral regions;

• development of methods for controlling the spectral, temporal, energy, and spatial characteristics of laser radiation;

• investigation of laser radiation interaction with different media.

Prokhorov gave much attention to introducing the findings of scientific investigations to practice.

I will mention only a few of the works which he initiated and which were carried out with his direct participation. A M Prokhorov believed that lasers held great promise for application in medicine and devoted much time and effort in this area. One of the first works consisted in developing a laser ophthalmologic facility for treating glaucoma.

A topical problem for modern medicine is rechanneling arteries affected by atherosclerosis (laser angioplastic surgery). Jointly with the Vishnevskii Institute of Surgery, in 1988 the General Physics Institute of the Russian Academy of Sciences (IOFAN) performed 11 operations to rechannel femoral arteries using an excimer laser and an optical fiber of special silica glass.

Aleksandr Mikhailovich Prokhorov devoted much effort to promoting lasers in defense technology. I will mention just one project for the development of an air-defense laser complex executed in accordance with the Resolution of the Central Committee of the Communist Party of the Soviet Union and USSR Council of Ministers (code name 'Omega'). Prokhorov's great erudition and unquestionable authority enabled him to organize research into a wide range of topical problems in the framework of this project in FIAN and other academic and departmental institutes. Undertaken for applied purposes, this research led to the discovery and comprehensive study of numerous new physical phenomena. The main laboratory building of IOFAN was constructed in accordance with this resolution. It is not improbable that some day archeologists will puzzle their brains over the question: Why does the concrete basement of the building contain a stainless steel capsule bearing the Greek letter Ω?

3. A M Prokhorov and fiber optics

As noted in the foregoing, the range of A M Prokhorov's interests was extremely broad. He pioneered and actively supported new research in topical areas of science and technology like microelectronics, solid-state physics, surface physics, hydrophysics, plasma physics, submillimeter spectroscopy, high purity materials, including monoisotopic ones, integrated and fiber optics, and computerization of research.

I would like to enlarge on A M Prokhorov's contribution to fiber optics for the following reasons.

First, his approach to the solution of big and complicated problems may be illustrated more emphatically by this example.

Second, this aspect of his scientific and organization activity is insufficiently known to the scientific community.

Third, among the mass applications of lasers is optical fiber communication, the all-important area of fiber optics. Furthermore, recent outstanding advances in the development of fiber lasers, to which A M Prokhorov made a significant contribution, are, in the view of experts, a new breakthrough in laser physics.

Experiments in optical communication through the free atmosphere were among the first experiments involving the application of lasers. The use of laser light as the carrier radiation in communication systems permitted, in principle, increasing the transmission bit rate by a factor of several dozen thousand in comparison with the transmission bit rate in radio communication. However, before long it turned out that the free atmosphere is not a good transmission medium, primarily because of meteorological conditions. The glass optical fibers produced at that time could not be employed as the transmission medium due to high optical losses (~ 1000 dB km^{-1}). However, in 1966 Kao and Hockham showed that the high optical losses in glass optical fibers arise from impurities in the glass and that the optical losses may be lowered to ~ 20 dB km^{-1} by improving glass fabrication technology. In many countries a start was made on the development of low-loss glass and fiber fabrication technologies.

In 1970, Corning Glass Works produced silica-based optical fibers with losses of 20 dB km^{-1} at a wavelength $\lambda = 0.63$ μm. This lent impetus to the broadening of research in this area, and in the early 1970s in several countries, primarily in the USA, Great Britain, and Japan, intensive research was carried out to produce glass optical fibers with a low attenuation of optical signals.

A M Prokhorov closely followed the progress of this research, questioning collaborators returning from foreign professional business trips about the latest news in this area. He would read all papers on optical fibers which emerged in the literature. As a result, he formed a personal opinion about the state of affairs and ways of solving the low-loss fiber problem. After that he began searching for the person who would like and was able to take up the problem. He chose the author of this report. "Without chemists we will not be able to achieve anything, let us go to Zhavoronkov and find out who can help us,"—these words marked the start of a very difficult and yet absorbing activity aimed at production of low-loss optical glass fibers in the USSR. That dates back to 1973.

The solution to this problem involved four main lines of attack.

(1) Synthesis of the gaseous-phase raw high purity materials.

(2) Development of technology for producing high purity glasses and optical fibers employing high purity raw materials in the gaseous phase.

(3) Development of technological equipment for the production of high purity glasses and optical fibers.

(4) Development of techniques and instrumentation for measuring the main parameters of glasses and optical fibers.

To elucidate the situation regarding the first line, we went to the Academician-Secretary of the Physicochemistry and Inorganic Materials Technology Division of the USSR Academy of Sciences, Academician Nikolai Mikhailovich Zhavoronkov. On hearing out our statement of the problem, he gave us considerable hope. He said that in Gorky, at the Institute of Chemistry of the USSR Academy of Sciences (IKhAN), the Deputy Director, Corresponding Member G G Devyatykh, was engaged in precisely the synthesis and deep purification of volatile hydrides and chlorides of several elements, including those of silicon, germanium, and boron. These were precisely the elements required in the synthesis of silica-based glasses. Being enthusiastic about the result of the meeting with Academician Zhavoronkov, Prokhorov sent me to Devyatykh.

G G Devyatykh readily agreed to cooperate with us in the area of optical fibers, saying that the Institute of Chemistry was always ready to take on a big job. We agreed that the glass fabrication technology would also be developed in the Institute of Chemistry with the use of the already available volatile compounds. In this case, further purification of the raw compounds would also be pursued to lower the impurity content. The first-generation technical equipment was made in the workshops of IKhAN and FIAN. It was certainly imperfect and yet allowed making a start on the technology work. The methods and measuring equipment were worked out in the Laboratory of Oscillations of FIAN. Experiments were launched early in 1974. A M Prokhorov took an interest in the progress of the work and went to Gorky several times to familiarize himself with it on the spot. The first laboratory samples of optical fibers on the basis of silica glass were made even in 1974. To obtain fiber preform articles, advantage was taken of the modified chemical vapor deposition of glass layers inside a supporting tube of silica glass (the MCVD method). Next, an optical fiber was pulled out of the preform [11].

Once A M Prokhorov had made certain that the technology selected enabled a stable production of optical fibers, he applied to the Defense Department of the Central Committee of the Communist Party of the Soviet Union to convey the information about the successful commencement of work on optical fiber technology. The Deputy Head of the Defense Department N N Detinov showed keen interest in our work and proposed that the Military Industrial Commission (MIC) at the USSR Council of Ministers issue a resolution on this problem. He organized my meeting with the corresponding MIC officials to begin the preparation of this decree. I will never forget this meeting. On hearing my statement about our intent to create low-loss optical fibers, they simultaneously began to laugh and explained to me that the State Optical Institute in Leningrad had already failed to implement two resolutions on this matter and that we physicists did not have a ghost of a chance to solve this extremely complicated technological problem. Being discouraged, I went back to Detinov and informed him of the reception given. He phoned somebody in the MIC, and everything was promptly settled. When I told Aleksandr Mikhailovich Prokhorov about this, he reacted quite calmly and said this was normal.

A M Prokhorov and Academician G G Devyatykh (at the right) (1986).

According to the MIC Resolution, we were to obtain optical fibers with losses below 20 dB km^{-1} at wavelengths of 0.8 – 0.9 μm in a year, and with losses below 10 dB km^{-1} in two years. We accomplished this task well ahead of schedule, thereby making the USSR's first low-loss silica-based optical fibers. Approximately a year later, researchers at the Institute of Radioengineering and Electronics of the USSR Academy of Sciences, who were also engaged in the problem of producing low-loss optical fibers under the supervision of Academician Vladimir Aleksandrovich Kotel'nikov, achieved similar results. In 1977, we obtained optical fiber with attenuation less than 1 dB km^{-1} at a wavelength of 1.5 μm.

In conjunction with industrial organizations, the USSR's first pilot optical fiber telephone communication line was put in operation in Zelenograd near Moscow by the 60th anniversary of the Great October Revolution. The fibers for the optical cable were produced by the FIAN – IKhAN joint team.

This concluded the first development stage of modern fiber optics in the USSR. An efficient cooperation of academic institutions was established, which had solved the main problems associated with the creation of low-loss optical fibers, including the production of the raw materials of requisite purity, the development of optical fiber production technology, and the development of the technique for measuring the main fiber parameters. To state it in different terms, the scientific and technical foundations were laid for the industrial mastering of this technology. It should be emphasized once again that this was made possible primarily due to A M Prokhorov's insistence and deep interest in this problem.

Interestingly, Nikolai Gennadievich Basov also recognized the enormous scientific and technical potential of fiber optics and made attempts to promote this field. In 1996, at a seminar of the Fiber Optics Research Center (FORC) at IOFAN concerned with the state of the art in the area of fiber optics, Basov said that he had had a meeting with the 'power' ministers early in the 1970s and suggested that a start should be made on the joint development of low-loss optical fibers. However, no positive response followed. (In the photograph on p. 653: N G Basov and A M Prokhorov during that discussion.)

The history of the industrial optical fiber production in the USSR, organized by directing bodies, is sad and instructive, as is the continuation of this story in Russia. As a result, today there is no industrial production of optical fibers in this country, with all the ensuing consequences. However, confining myself to the main focus of my report, I will not dwell on this here but will talk briefly about subsequent progress in fiber optics as a scientific branch and of the part played by A M Prokhorov.

As soon as the technology of low-loss optical fiber fabrication was worked out, A M Prokhorov made great efforts to promote optical fibers in engineering. A start was

N G Basov (left) and A M Prokhorov (1996).

made on joint work with Almaz Research and Production Association and Machine-Building Design Office (MBDO) (Kolomna) aimed at introducing optical fibers in the products developed by these enterprises. These organizations began putting together more sophisticated technical equipment, which enabled making pilot batches of optical fibers with improved parameters.

The Machine-Building Design Office at that time was headed by S P Nepobedimyi, who immediately recognized the enormous potential of fiber optics for defense technologies. In particular, optical fibers with improved mechanical strength were developed for the purposes of MBDO. At MBDO, precision machines were made for obtaining preforms for optical fibers, which were employed for many years for producing pilot batches and developing new types of optical fibers.

Another area of applied research was aimed at solving the problem of television (TV) signal transmission in big cities. Landscape irregularities and tall buildings are responsible for the occurrence of zones of unstable reception of TV signals transmitted through the free atmosphere. Such zones also exist in Moscow. In 1984, a system for transmitting TV signals via a fiber-optic cable with the help of laser radiation was developed jointly with organizations of the Ministry of Communication and the Ministry of Communication Facilities. The development work was successfully completed by bringing the 2-km long television fiber-optic cable to one of the buildings in the unstable reception zone on Altaiskaya Street. Next (1987), an 8.5-km long fiber-optic line was laid between the Ostankino transmission tower and Bezbozhnyi Lane, and several other such lines were also laid in Moscow. Moreover, several fiber-optic telephone lines were laid in Leningrad and Gorky.

In parallel with applied work, A M Prokhorov vigorously pioneered and supported basic research into optical glass fibers. In 1980, a Fiber Optics Sector was set up at FIAN; in 1983, after the establishment of IOFAN, a Fiber Optics Laboratory was set up there, and in 1985 there appeared a Fiber Optics Department. In 1993, a Fiber Optics Research Center at IOFAN was organized. This allowed making a start on extensive basic research, including the development of optical fiber technology, the studies of new waveguide structures and of mechanical, optical, and radiation fiber properties, and the search for new fields of optical fiber applications. All these investigations were conducted in close contact with IKhAN.

Investigations of nonlinear optical effects turned out to hold the greatest promise. Although glass is not a good nonlinear material, the small core dimensions (~ 10 μm) and the long interaction length (1 – 1000 m) lead to a high efficiency of nonlinear processes in optical fibers. As a consequence, several new basic results have been obtained. Among them are the generation of femtosecond solitons in optical fibers, the discovery of electrostriction mechanism of soliton interaction, the generation of a sequence of noninteracting solitons in optical fibers with length-varying dispersion, the proposal and experimental confirmation of a photogalvanic model of second harmonic generation in glass optical fibers, and the discovery of the shift of the femtosecond soliton carrier frequency in optical fibers due to stimulated Raman scattering (SRS) [12].

The study of SRS in optical fibers made of glass of various compositions led to the development of high-efficiency medium-power SRS fiber lasers [13].

Until the very last days of his life, A M Prokhorov would not lose his lively interest in fiber optics.

Recent years have seen remarkable achievements in the area of fiber optics, like the development of fiber-optics communication lines with a transmission bit rate of ~ 10 Terabit s^{-1}, the development of single-mode cw fiber lasers with an output power of 1 – 2 kW [14], and the extensive use of distributed fiber-optic sensory systems for monitoring the temperature, strain, and pressure for various objects (buildings, ships, bridges, etc.). These achievements impel us to be surprised at A M Prokhorov's astonishing intuition when we recall the vigor and persistence with which he developed fiber optics in our country.

4. Australian period of A M Prokhorov's life

In connection with the jubilee I would like to address myself to the very beginning — Aleksandr Mikhailovich Prokhorov's birth in distant Australia and the first seven years of his life spent there.

It is a widespread opinion that the personality of a child is largely formed during the first five – six years of life. As attested to by his spouse Galina Alekseevna, Aleksandr Mikhailovich always believed that his birth and the first years of his life in Australia had predestined his entire life. Unfortunately, information of any detail about this period of his life is lacking.

From official sources it is known that he was born in Atherton in the State of Queensland located in the northeast of Australia (Fig. 2). But this is not quite so.

In July 2005, after the conference on fiber optics held in Sydney, I succeeded in visiting the State of Queensland and seeing the place related to the birth and the first years of A M Prokhorov's life in Australia. Professor Petr Georgievich Kazanskii, formerly a staff member of FORC at IOFAN, who now is with Southampton University in England, kept me company.

Prior to describing this journey, I will briefly enlarge on the circumstances which brought Aleksandr Mikhailovich Prokhorov's parents to Australia.

His father Mikhail Ivanovich Prokhorov, born in 1880, was a professional revolutionary and in 1911 was exiled to Siberia for life. His mother Mariya Ivanovna (maiden name

Figure 2. Detail of the State of Queensland, in northeast Australia, where A M Prokhorov was born. The inset shows an Australia map.

Mikhailova) followed him to Siberia. In 1912, the Prokhorovs, together with their very young daughter Klavdiya, fled Russia for Australia. They arrived in the State of Queensland, whose Government favored the arrival of migrants from all over the world to develop unused lands, which were virgin rainforests. On favorable terms the migrants were offered 150-acre lots with an access road with the understanding that they agreed to live on the farm for at least 5 years and cultivate the land. On coming to Australia, at first Mikhail Ivanovich Prokhorov changed several jobs: he was a carpenter and a pattern maker. Meanwhile, two more daughters, Valentina and Evgeniya, were born to the family, and the parents decided to become farmers.

The Prokhorovs chose a lot in the Gadgarra district in the southeast of the Atherton tableland, where a small Russian colony comprising political emigrants already existed at that time. There, Aleksandr Mikhailovich Prokhorov was born on 11th July 1916. The Prokhorovs' farm was located near Butchers Creek, where there was a school. Aleksandr Mikhailovich Prokhorov went to that school with his sisters.

Different sources suggest that the life of Russian settlers was extremely hard and quite unlike their life in Russia. The settlers, among whom there were professors, lawyers, and workers, endeavored to survive in the unfamiliar tropical climate by cutting down woods, sowing the soil, and raising domestic animals. There is little doubt that these life conditions were to have a profound impact on the formation of young Prokhorov's character.

In 1923, the elder daughter Klavdiya unexpectedly died of pneumonia and the family returned to the homeland.

So, upon the conclusion of the conference in Sydney, we arrived by air in the town of Cairns, rented a car, and went to Atherton. The small town of Atherton is located on a tableland of the same name, at an altitude of 700 m above sea level. I would like to note the scenic nature of the Atherton tableland, which is of volcanic origin. This is an open, thinly populated hilly area, with low mountains in the distance. Lakes and waterfalls are numerous, among them being the well-known Millaa Millaa waterfall. There remain picturesque areas of rainforest with trees of unusual shapes like, for instance, the Curtain Fig Tree. By the way, we encountered a farm where rare animals and birds were bred, including crocodiles and koala bears.

By evening we reached Atherton and stayed in a motel of the same name. We already knew that on the territory of the Tropical Forest Research Center in Atherton there was a memorial plaque dedicated to Aleksandr Mikhailovich Prokhorov. That is why in the morning we went there. We had given notice of our arrival and they were waiting for us. The scientific staff members of the Center displayed considerable interest in our visit to Atherton: we had a feeling that they took pride in the fact that the Nobel Laureate Prokhorov was born in their part of the world and the memorial plaque was located in their center. Near the administrative building there is a relatively small rock to which the memorial plaque is attached.

Kept at the Center is a copy of Aleksandr Mikhailovich Prokhorov's birth certificate, whence it follows that Aleksandr Mikhailovich was born in Peeramon, Russel Road.

From the Center staff members we received the valuable information that Prokhorovs' farm had been located not in Peeramon but near Butchers Creek, in which there was a school. And Peeramon was merely the nearest administrative center.

With this information in our possession we went to Peeramon.

Peeramon consists of only several houses; the most famous of them is the building which accommodates Australia's oldest pub (Historic PUB, 1908) and a hotel. The

Tropical Forest Research Center, which is the site of A M Prokhorov's memorial plaque.

picturesque interior of the pub includes, in particular, a large collection of old-fashioned telephone sets.

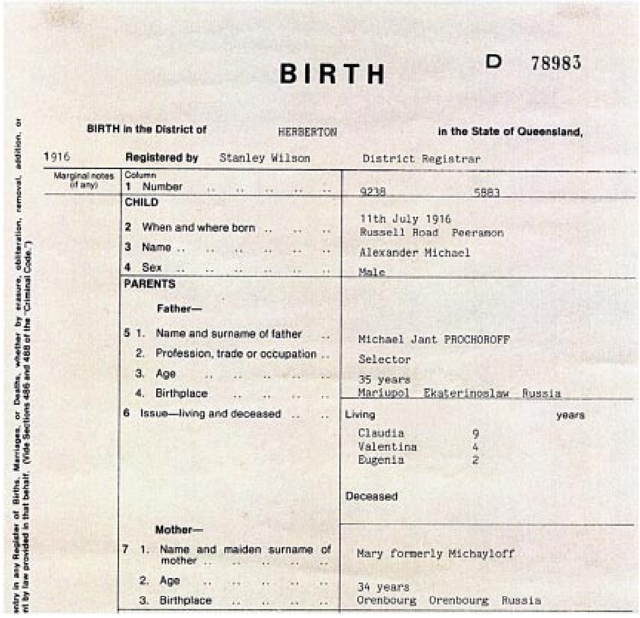
From Peeramon we set off in search of Butchers Creek, located near the small town of Malanda. We found the school in which Aleksandr Mikhailovich Prokhorov began studying. The school director Sandra Cameron displayed keen interest in our visit to the school and confirmed that the Prokhorovs' farm (Gadaloff Road, Butchers Creek) had indeed been located several kilometers away from the school and that Aleksandr Mikhailovich Prokhorov had gone to school there. The school in Butchers Creek was opened in 1913 as evidenced by the plaque on a stone by the school entrance.

Unfortunately, no written evidence that Aleksandr Mikhailovich Prokhorov had attended the school has survived because of a fire which occurred there.

Sandra Cameron told us that there is a history museum in Malanda, which also keeps information about Aleksandr Mikhailovich Prokhorov. Unfortunately, the museum was closed already, and we had to fly to Sydney that day.

We left Queensland with a feeling that we had come into contact with the extraordinary life of our great Australian-born compatriot Aleksandr Mikhailovich Prokhorov.

The author expresses his sincere gratitude to F V Bunkin, A A Manenkov, and P P Pashinin for valuable discussions during the preparation of the report.



BIRTH D 78983

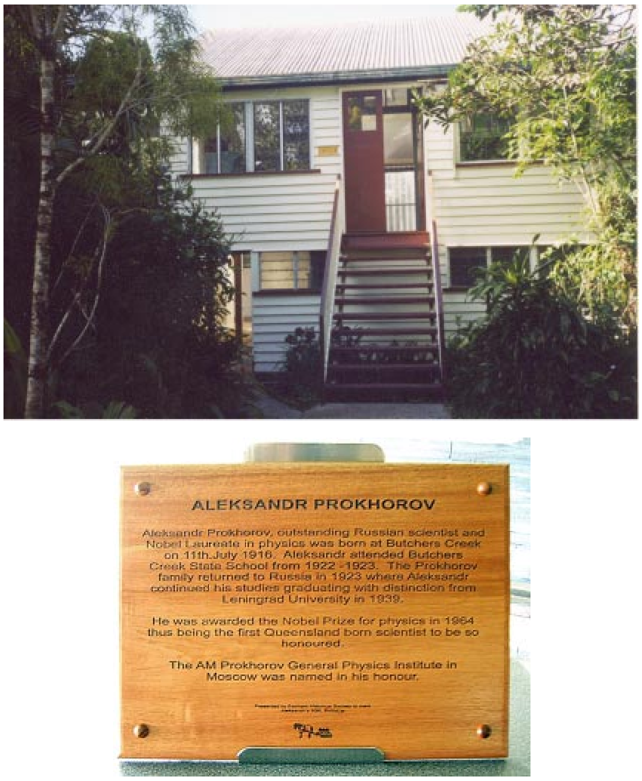
BIRTH in the District of HERBERTON in the State of Queensland,

1916 Registered by Stanley Wilson District Registrar

Marginal notes (if any)	Column	
	1 Number	9238 5883
	CHILD	
	2 When and where born	11th July 1916 Russell Road Peeramon
	3 Name	Alexander Michael
	4 Sex	Male
	PARENTS	
	Father—	
	5 1. Name and surname of father	Michael Jant PROCHOROFF
	2. Profession, trade or occupation	Selector
	3. Age	35 years
	4. Birthplace	Mariupol Ekaterinoslaw Russia
	6 Issue—living and deceased	Living years Claudia 9 Valentina 4 Eugenia 2 Deceased
	Mother—	
	7 1. Name and maiden surname of mother	Mary formerly Michayloff
	2. Age	34 years
	3. Birthplace	Orenbourg Orenbourg Russia

...entry in any Register of Births, Marriages, or Deaths, whether by erasure, obliteration, removal, addition, or ...nt by law provided in that behalf. (Vide Sections 486 and 488 of the "Criminal Code.")

A M Prokhorov's birth certificate.



School in Butchers Creek, where A M Prokhorov began studying (at the top). Memorial plaque dedicated to A M Prokhorov, which was mounted in the school on 12 July 2006.

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A M Prokhorov: founder of the General Physics Institute

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On 30 July 1982, the Council of Ministers of the USSR issued a decree adopting a proposal by the USSR Academy of Sciences to transform the A Division of the P N Lebedev Physics Institute of the USSR Academy of Sciences to the General Physics Institute of the USSR Academy of Sciences.

The General Physics Institute of the USSR Academy of Sciences (IOFAN) was formally established under a resolution of the Presidium of the Academy of Sciences on 30 September 1982. The General Physics and Astronomy Division of the USSR Academy of Sciences was entrusted with the scientific and scientific-methodical direction of the Institute.

However, resolutions and decrees alone, even those ranking the highest in priority, would not suffice for the genuine creation of an institute. This is merely a necessary condition but far from a sufficient one. There has to be a charismatic leader. Aleksandr Mikhailovich Prokhorov was such a charismatic leader.

He always and everywhere satisfied the requirements of the post he filled, whether it was commanding the reconnaissance platoon of a regiment during the hard times of the Great Patriotic war, heading the Chair of Laser Physics of the Moscow Institute of Physics and Technology (MIPT), being Editor-in-Chief of the Great Soviet Encyclopedia Publ., and Academician-Secretary of the General Physics and Astronomy Division, or being a member of the Presidium of the USSR Academy of Sciences. Nevertheless, the life's cause of the outstanding physicist and science organizer, one of the founders of quantum electronics and laser physics, Nobel Laureate in Physics, Lenin Prize and State Prizes Laureate, and two-time Hero of Socialist Labor Academician A M Prokhorov was the formation of the General Physics Institute, which now bears his name.

Everything in this man was extraordinary. In personal contact with him, one was always amazed by the incredible quickness, perfect clarity, and astonishing exactness of his concrete thinking. His capacity for work, and the breadth, depth, and volume of his erudition compelled admiration.

A M Prokhorov was born into a family of Russian political emigrants in Australia on 11th July 1916. In the early 1920s his family returned from the forced exile to their native land, to Russia. From 1934 to 1939, Aleksandr Mikhailovich Prokhorov was a student in the Physics Department of Leningrad State University; in 1939–1941, a postgraduate of the P N Lebedev Physics Institute (FIAN) of the USSR Academy of Sciences; and in 1941–1944, a participant in the Great Patriotic war, the commander of a regiment reconnaissance platoon. Due to serious injuries, in 1944 he was demobilized. As he later told his close friends, it was his wife Galina Alekseevna who saved his life despite the severe injuries. He owed her his life and his return to scientific activity.

From 1944 to 1946, A M Prokhorov continued his postgraduate studies at FIAN. The central idea which determined the thrust of Prokhorov's scientific life for several decades to come was the idea of monochromatic oscillations in nonlinear systems with a resonance feedback. He passed the milestones which mark the formation of the personality of a scientist, like the work on his Candidate (1939–1941 and 1944–1946) and Doctorate (1946–1951) theses, in the Laboratory of Oscillations at FIAN in the atmosphere of a radiophysical approach and 'oscillatory' mutual aid.

A M Prokhorov (11.07.1916–08.01.2002)

It was precisely this laboratory, which was officially headed by the young Doctor of Physicomathematical Sciences A M Prokhorov in 1954, that gave birth to quantum electronics.

This very laboratory comprised the skeleton of the scientific organism of Division A of the P N Lebedev Physics Institute of the USSR Academy of Sciences.

It was on the basis of this laboratory that Aleksandr Mikhailovich Prokhorov in 1982 established the General Physics Institute of the USSR Academy of Sciences — his main offspring — and became its first Director.

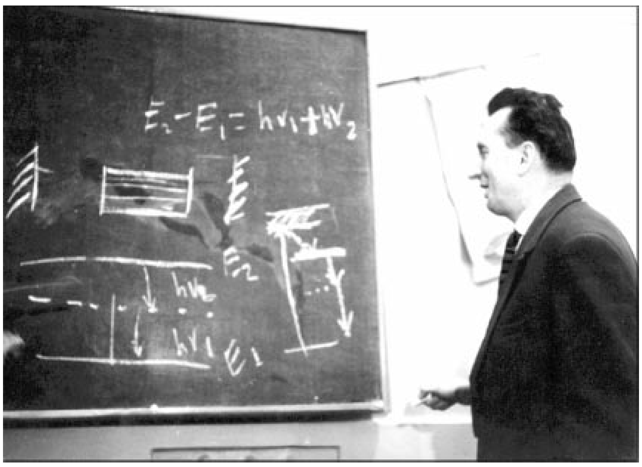
For several years the Laboratory of Oscillations was the only laboratory in the USSR, whose team would actively and purposefully develop quantum electronics. In the West, investigations in the same area were equally vigorously pursued by only one laboratory — the Radiation Laboratory of Columbia University. This research was headed by Charles H Townes.

Quantum electronics was in reality born at the moment an excited quantum system (a beam of appropriately sorted molecules) was placed in a resonator. Molecular monochromatic microwave oscillators (masers) — the first quantum electronic devices — were made in late 1954 – early 1955 in the Radiation Laboratory of Columbia University (J Gordon, H Zeiger, C Townes) in the USA and in the Laboratory of Oscillations of FIAN (N G Basov and A M Prokhorov) in the USSR. The masers operated on a beam of ammonia molecules, the radiation wavelength being equal to 1.25 cm.

In 1959, A M Prokhorov and N G Basov were awarded a Lenin Prize for the development of a new principle of generation and amplification of radio waves.

In 1960, A M Prokhorov was elected a Corresponding Member of the USSR Academy of Sciences.

The 1954 – 1960 time interval is marked by at least two of Prokhorov's considerable scientific achievements. Shortly after the launch of the molecular oscillator with electrostatic sorting of unexcited and excited molecules in a thermally equilibrium beam of ammonia molecules, Basov and Prokhorov came up with a general method for producing nonequilibrium media in quantum electronics. This is the famous three-level technique. All solid-state masers and virtually all high-power lasers operate on the basis of this technique.



A M Prokhorov at a seminar at the Laboratory of Oscillations (1964).

The successes of quantum electronics of the radiofrequency band naturally raised the question as to whether its achievements could be extended to much shorter-wavelength ranges. For radiophysics and the theory of oscillations, the aspiration of increasing the frequency of controllable monochromatic radiation was caused by the logic of the development of these sciences and was quite natural. However, when moving to shorter wavelengths, of basic importance was the problem of resonators, without which there is no way of obtaining monochromatic oscillations. In 1958, Aleksandr Mikhailovich Prokhorov proposed the use of an open resonator for this purpose. In essence, this was an analog of the Fabry – Perot interferometer, well known in optics. A radiophysical, purely 'oscillatory' approach enabled Prokhorov to advance the well-known instrument as a resonator for submillimeter masers and for lasers. Both suggestions — the three-level scheme and the open resonator — came to be the cornerstones of quantum electronics.

Late in October 1964 it was announced that the founders of quantum electronics, Nikolai Gennadievich Basov, Aleksandr Mikhailovich Prokhorov, and Charles Hard Townes, were awarded the Nobel Prize in Physics 1964 for fundamental work in the field of quantum electronics which has led to the construction of oscillators and amplifiers based on the maser – laser principle.

On the first of July 1966, ten days prior to his fiftieth birthday, Aleksandr Mikhailovich Prokhorov was elected Full Member (Academician) of the USSR Academy of Sciences to the General and Applied Physics Division. The academic status had no effect on his attitude to his associates. The democracy, benevolence, and sociability inherent in him would continue to surprise all his acquaintances.

Lasers, laser radiation, the interaction of laser radiation with matter, and their applications in science and technologies constitute the objective basis of Academician A M Prokhorov's world-wide fame. The main point is that lasers, owing to the high oscillation monochromaticity and coherence, have the capacity to ultimately concentrate in space, time, and the spectral interval virtually all radiation energy which attains, as a rule, quite high magnitudes.

The advent of lasers was prepared by the entire progress of quantum electronics which introduced radiophysical and oscillation theory methods into optics, gave rise to its second birth, imparted dynamism to it, and speeded up its development. Nonlinear optics made its appearance; there emerged coherent optical radiation sources to find wide use in technologies and medicine. Conventional optics started a new life.

The fundamental advances in the area of laser physics led A M Prokhorov and the Designer-in-Chief of the KB-1 Design Office (subsequently the Strela Moscow Design Office, more recently the Almaz Central Design Office), Academician A A Raspletin, to apply to the Central Committee of the Communist Party of the Soviet Union (CPSU) and the USSR Council of Ministers with a proposal to undertake research, with broad cooperation between co-executives, aimed at developing a laser air-defense. This proposal was supported in the Defense Department of the Central Committee of the CPSU and in the Military Industrial Commission (MIC) attached to the USSR Council of Ministers. On February 23, 1967, the Central Committee of the CPSU and the USSR Council of Ministers adopted their resolution, as did the MIC on 26th June of that year. These documents defined the line of work, the list of

1964 Nobel Laureates (left to right): Charles Townes, A M Prokhorov, N G Basov (the Prize in Physics); the English chemist Dorothy Crowfoot Hodgkin (the Prize in Chemistry); the American biochemist Konrad Bloch and the German biochemist Feodor Lynen (the Prize in Physiology or Medicine).

executives, and the terms of laser complex development, which received the code name 'Omega'. In accordance with this Resolution, a laboratory building with an area of 11,000 m^2 was constructed for the P N Lebedev Physics Institute of the USSR Academy of Sciences.

The foundation of the building was laid in 1969; it was completed and introduced into service in 1973. At present it is the main building of the General Physics Institute of the Russian Academy of Sciences (RAS) and its front appropriately bears a memorial plaque with the bas-relief of Aleksandr Mikhailovich Prokhorov — the founder and first Director of the Institute.

Two stainless steel capsules are concealed in the foundation of this building. One of them contains the capital Greek letter Ω. In this way, the IOFAN building retains the memory of the purpose-oriented work to which it owes its existence.

The second capsule contains a handful of 'fianits' — beautiful crystals synthesized on the basis of zirconium and hafnium oxides, which have no natural analogs. Their high hardness, high refractive index, and wide variety of coloring — from colorless to dark-violet — make fianits excellent jewels, which are conquering the world market. More recently, different and much more important applications have been found for them.

These crystals were developed at FIAN, in the Solid-State Physics Laboratory of Division A, which accounts for the presence of the second capsule in the IOFAN building foundation.

The 'Omega' series of applied investigations led to the discovery and comprehensive study of new physical phenomena, new materials, and technologies. This was quite typical for Aleksandr Mikhailovich Prokhorov. The very formulation of the 'Omega' research and the diversity of its findings illustrate his favorite thesis about the interdependence and interpenetration of applied and basic research as the necessary prerequisites for technical progress.

The 1980s was marked by a rapid growth of the Institute and its recognition as the world leader in several avenues of

IOFAN main building.

President of the USSR Academy of Sciences A P Aleksandrov (left) wishes A M Prokhorov happy 60th birthday (1976).

scientific research. Apart from the main building, three more buildings were built on the territory of the Institute owing to Aleksandr Mikhailovich Prokhorov's efforts: for the Research Center for Laser Materials and Technologies, Fiber Optics Research Center, and Natural Science Center of IOFAN. In these parts of the Institute, research on topical problems of science and technology was set up.

Of the investigations performed during the 1980 – 1990 period, mention should be made of solid-state laser research. Two classes of new active materials were developed. Basic investigations into the transfer, migration, and degradation of impurity-ion electron excitation energy in glasses and crystals led to the development of laser phosphate glasses with a high neodymium concentration and of a new class of crystal materials of the gadolinium – scandium – gallium garnet type. This crystal is remarkable in that it permits an isomorphic introduction into its volume of the donor impurity of chromium ions, along with an active rare-earth impurity ion. Furthermore, these active media possess enhanced resistance to laser and radiation damage. Lasers which utilize these crystals exhibit higher efficiencies and are highly reliable in operation.

Construction of lasers with semiconductor laser pumping should also be placed among the works in this area. Requirements imposed on the active media of such lasers were formulated, and materials meeting these requirements were made, around which solid-state lasers with unique properties were developed. Today, solid-state lasers with semiconductor laser pumping have triumphantly come to the forefront in quantum electronics. In this case, A M Prokhorov's foresight again proved to be correct.

In the area of new laser creation, indubitably of interest is the development of color center lasers utilizing alkali-halide crystals at room temperature, as well as lasers utilizing stimulated Raman scattering.

In the field of laser applications, special mention should be made of Prokhorov's works pertaining to medicine. Among them are the world's first laser ophthalmologic facilities, new surgery in gynecology and urology, and the development of photodynamic therapy — a radically new medical technique in oncology. Interesting results have been obtained with the use of excimer lasers for the treatment of destructive forms of tuberculosis, as well as laser urological complexes, including a laser lithotriptor (a medical device for eliminating calculi in the human body). This last device utilizes a new effect discovered at the Institute, which consists in the disruption of dielectrics under two-frequency irradiation.

Aleksandr Mikhailovich Prokhorov pioneered investigations in several areas of nanophysics and nanotechnology at the Natural Science Center, which are being successfully pursued at the present time.

The 1980s – 1990s saw fiber optics triumphantly become a part of everyday life. Investigations in this field were also pioneered by A M Prokhorov already in the early 1970s. Optical communication and the Internet have become necessary attributes of the modern person. The Fiber Optics Research Center attached to IOFAN has made a substantial contribution to the solution of several problems encountered on the way to these truly revolutionary transformations.

Such was the case until the onset of the 1990s, when the Institute, like all Soviet science and all our country, experienced the results of the disintegration of the Great Power. Nevertheless, the potential laid by A M Prokhorov afforded not only safety for the Institute as such, but also the retention of its position in world science.

What is the A M Prokhorov General Physics Institute of the RAS today?

The institute has a staff of 1028, of which 508 are research workers, 122 Doctors of Sciences, 281 Candidates of Sciences, and 48 postgraduates.

In the Institute there are three doctoral dissertation councils with specializations in radiophysics, acoustics, laser physics, condensed-state physics, theoretical physics, plasma physics, optics, and technology and equipment for the fabrication of semiconductors, materials, and devices of electronic engineering. Beginning in 2000, 56 candidate's and 38 doctoral theses have been defended at the Institute.

Six chairs of leading Russian universities are affiliated with the Institute: four chairs of the Moscow Institute of Physics and Technology, a chair of the Moscow State Institute of Radioengineering, Electronics, and Automation, and a chair of the D I Mendeleev Moscow Academy of Chemical Technology.

Since 2000, staff members of the Institute have published 24 monographs. In 2005 alone they published 951 papers, 311 of which in foreign publications.

According to the editors of the *Kvantovaya Elektronika* (*Quantum Electronics*) journal, the Institute is the main contributor of articles: in 2004 and 2005, staff members of

A M Prokhorov (right), after reporting to the Presidium of the RAS, and Yu S Osipov, President of the Russian Academy of Sciences (1996).

the Institute published in this journal 50 and 35 papers, respectively.

Total financing rose from 111 million rubles in 2000 to 368 million rubles in 2005. In 2005, the budgetary financing was 91.2 million rubles and the out-of-budget one was 276.8 million. In 2005, the out-of-budget financing comprised 120 projects supported by the Russian Foundation for Basic Research, 19 projects of the Russian Federation Ministry of Education and Science, and 130 different contracts. Work on 14 grants from the International Science and Technology Center (ISTC) and 3 grants from the American Civil Research and Development Foundation (CRDF) is presently underway at IOFAN.

Cooperation with research organizations from 15 countries is underway in the framework of bilateral and academic agreements. Joint laboratories have been set up with scientific institutions from Canada, Italy, and France. Up to 300 foreign scientists and specialists visit the Institute annually.

The Institute organizes the annual international conferences on Advanced Laser Technologies, the International Laser Physics Workshop, and the Zvenigorod Conference on Plasma Physics and Controlled Thermonuclear Fusion. The Institute is one of the organizers of the International Quantum Electronics Conference/Lasers, Applications, and Technologies (IQEC/LAT).

The main lines of basic research conducted at the Institute are defined by the Regulation of the Presidium of the RAS: condensed-matter physics, optics and laser physics, radiophysics and electronics, acoustics, and plasma physics. A more detailed description of these areas consists of 27 appellations which embrace virtually all modern areas of the above lines of research.

To exemplify the most important scientific results, mention should be made of the following.

The effect of selective adsorption of a spin modification of water molecules was discovered. For the first time in world practice, it was possible to separate water into spin-modified fractions — ortho and para water.

By the example of chromium-doped germanium cuprate, a new magnetooptic effect was discovered: violation of spin precession in a doped quantum chain.

Phase conjugation in acoustics was theoretically substantiated and experimentally realized in magnetoelastic media.

Methods were developed for the synthesis and processing of carbon nanotubes, around which new unique photonics elements were produced.

A new type of magnetic resonance due to orbital ordering was discovered.

The characteristic features of electrodynamics were revealed for composite media possessing a negative effective refractive index.

The existence of new quasiparticles was theoretically predicted and experimentally borne out: these quasiparticles — waveguide-plasmon polaritons — are formed in photonic-crystal layers with metallic nanostructures.

A radically new method was elaborated for the detection and determination of extremely low concentrations of organic compounds, which relies on the laser desorption of ions from the nanostructurally irregular surface of silicon.

Several new laser materials were proposed, around which new types of solid-state lasers with unique parameters were constructed.

Work is in progress on the hot plasma confinement in the toroidal magnetic field of the L-2M stellarator.

Work is underway to investigate the formation dynamics of the pico- and femtosecond laser microplasma of multiply ionized gases and solids.

Image-converter tubes, streak cameras, and diffractometers are being investigated and elaborated. A temporal resolution of 160 fs has been attained.

An ultrahigh-vacuum (10^{-10} Torr) scanning tunnel microscope GPI-300 was developed.

Infrared imagers were developed on the basis of 2D platinum-silicide infrared radiation detector arrays. These imagers are applied in medicine and for thermal audits to monitor electrical and heat power engineering units. In the Central Hospital of the RAS, a room equipped with a medical infrared imager has been set up for thermographic examinations.

Equipment was made for photodynamic therapy, including the autofluorescent diagnostics of early forms of cancer.

Fundamental research in the field of diode laser spectroscopy led to the development of a technique for detecting *Helicobacter pylori* bacteria by way of spectral analysis of the air exhaled by a patient.

The Physics Instrumentation Center, which was organized by A M Prokhorov and which now is a branch of the IOFAN, is operating successfully. The center sets itself the task of bringing the Institute's developments to small-batch output. In particular, the center produces the ophthalmologic excimer laser facility Mikroskan TsFP for refraction surgery. The facility enables correcting hypermetropia, myopia, and astigmatism by means of a laser flying spot.

The laser facility Mariya for the therapy of destructive forms of tuberculosis was awarded a Gold Medal at the 51st Brussels-Eureka Salon.

Crystals made on the basis of partially stabilized zirconium dioxide, which were developed by Institute staff members back in the 1970s, have been modified to find use in the development of unique medical instruments, multipurpose biological prosthetic appliances, and biologically inert implants with a high fatigue strength for dental and orthopedic surgery.

The word 'innovation' is highly popular nowadays. We are not sure whether Aleksandr Mikhailovich Prokhorov used this word, but he fostered innovations throughout all his life.

The above, by no means complete, list of basic and applied scientific results is, in our opinion, a prominent example of the realization of Aleksandr Mikhailovich Prokhorov's idea that there is no way of dividing investigations into basic and applied. Only their indissoluble bonds and interpenetration ensure the progress of modern science and the prosperity of society as a whole.

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