Seventieth anniversary of Soviet physics

The Editorial Board

Usp. Fiz. Nauk **153**, 369–378 (November 1987)

This year the Soviet people celebrate a glorious anniversary—the seventieth anniversary of the Great October Socialist Revolution. The October Revolution gave a powerful impetus to the economic and cultural development of our country. During the years of Soviet rule our country has been transformed into a powerful industrial state. Science was developing at a rapid rate. At the present time in our country there are more than 5 thousand scientific organizations, in which approximately 4.5 million persons are working. Five percent of the national income—approximately 30 billion rubles are devoted to the development of science.

On the eve of the anniversary it is natural to look back on the road that has been traversed, and to note the achievements. There is reason for the Soviet physicists to be proud. They have made discoveries of world significance, their work has made an important contribution to strengthening the economic and the defence might of our country.

In this article we give a brief review of the development of Soviet physics during the last decade. The preceding period of this development has been dealt with in articles published in the October issues of our journal in 1967 and 1977.

The last decade brought new achievements in the study of cosmic space. An important role in such studies is played by artificial earth satellites and space stations; their utilization began with the launching of the first Soviet sputnik thirty years ago.

The most impressive event in this field during the last few years is the success of the "Vega" project. The space stations "Vega-1" and "Vega-2" have approached to a very close—on a cosmic scale—distance of 8 thousand kilometers to the mysterious heavenly object—the Halley comet. The nucleus of the comet was photographed, the electromagnetic processes and the fluxes of particles in the neighborhood of the comet have been studied, the chemical composition of its material was determined. Numerous technical difficulties have been successfully surmounted, including the problem of the precise aiming of the cameras at the nucleus of the comet and the problem of shielding the apparatus from the impact of meteorite particles in the vicinity of the comet.

The "Vega" project is a shining example of international scientific collaboration. The "Vega" vehicles contain scientific apparatus belonging to nine countries. The data which were obtained by these pieces of equipment in the course of the flight towards the nucleus of the comet were used for aiming the European space probe "Giotto."

Soviet science occupies a leading position in the investigation of the planet Venus. The data obtained by the space stations "Venera," including those obtained with the aid of apparatus descending to the planet, made it possible to determine the climatic conditions on Venus, and its chemical composition. The space stations "Venera-15 and 16" by using a radio-ranging method determined with a high degree of accuracy the relief of the planet's surface. During the first stage of the flight of the space vehicles "Vega" a balloon was lowered to the planet the motion of which through the atmosphere was followed by stations in many countries of the world.

In the "Konus" experiment detectors of γ-radiation were installed on the space vehicle which discovered bursts of this radiation, which are of cosmic origin. Lines were discovered which apparently correspond to cyclotron radiation in the neighborhood of neutron stars.

The "Relikt" installation produced a map of the luminance of the sky in the relic radiation at a wave length of 8 mm. The velocity of the earth's motion with respect to this radiation has been measured and estimates have been given of the magnitude of its fluctuations.

The first results have been obtained from the international observatory "Roentgen" in the "Kvant" module forming a part of the orbital station "Mir" which, in addition to Soviet scientific equipment, also contains apparatus from England, Holland, FRG and the European Space Agency. An x-ray map of the Great Magellanic Cloud has been produced and observation is continuing of the region where recently a flareup of a very powerful supernova occurred.

In the joint Soviet-Czech "Intershok" project collisionless shock waves in the plasma in space near the earth have been studied.

Plans of very interesting future investigations are already being discussed. Among them is the flight of an unmanned probe to Mars bringing samples of Martian matter back to earth, and even a manned flight to this planet.

Great possibilities for further conquest of cosmic space are provided by the contribution of a powerful rocket system "Energiya" which has recently undergone successful tests.

The achievements of astrophysical investigations conducted in space by no means signify a reduction in the role played by astronomical observations made from the earth. For such observations there have been constructed in our country the largest-in-the-world optical telescope BTA and the "RATAN-600" radio-telescope. In 1984 the Siberian solar radio-telescope with a resolution down to 20″ at a wavelength of 5.2 cm has been put into operation. In recent years important progress has been achieved in our understanding of the process of the evolution of the universe. The hypothesis concerning cellular-network distribution of galaxies with the characteristic size of the empty regions of the order of 30–35 Mpc has been confirmed.

The principal achievement in elementary-particle physics of the last decade is the discovery of W and Z bosons made at CERN in 1983. This discovery became possible because of the construction of a proton-antiproton collider the idea of which was put forward in our country 20 years ago. A similar collider of an even greater energy has begun operation in the USA. This year the first Z bosons will be produced by the electron-positron collider in the USA, and two years later at CERN. No such machines capable of producing W and Z bosons will be available in our country until the end of this decade. And this is undoubtedly a lagging behind

0038-5670/87/110921-06$01.80

which it is necessary to liquidate.

Soviet physicists carried out experiments in high-energy physics primarily using the Serpukhov accelerator, where, in particular, a number of new mesons have been discovered. Of particular interest is the discovery of a meson holding the record for the highest value of spin, equal to 6, and of mesons which apparently are exotic ones, i.e., consist not of a quark and an antiquark, but of two quarks and two antiquarks or (in another case) of two gluons.

Record precision has been achieved in the measurement of masses of upsilon mesons using colliding electron beams in Novosibirsk with the aid of the method of resonance depolarization.

Several Soviet experimental groups carried out research at high energy accelerators abroad as members of large international teams. Of the results obtained by them we should first of all note the discovery of mutual transformation of B and $\overline{\text{B}}$ mesons taking place in vacuum. This discovery was made at the ARGUS installation in the laboratory using the colliding electron-positron beams of DESI (FRG). We should also note the measurement of the cross section for neutral neutrino currents carried out using the CHARM installation at CERN which enabled one to determine with record precision the important parameter of the electroweak theory—the Weinberg angle. Complete agreement with theory was provided by an experiment on measuring the lepton decays of Σ hyperons carried out in Batavia (USA) by means of an original installation produced by Soviet physicists.

A number of important discoveries with reference to weak processes with nonconservation of spatial parity was made in several institutes of our country in experiments at low energies. In particular, the resonance amplification of nonconservation of parity in the interaction of fast neutrons with nuclei and the P-odd asymmetry of separation of fragments in the fission of uranium and thorium nuclei initiated by polarized neutrons have been discovered. The rotation of the plane of polarization of light in passage of a laser beam through vapour of atomic bismuth was discovered, and this proved the existence of a weak neutral electron current. A record low value for the upper limit on the magnitude of the electric dipole moment of the neutron was obtained with the aid of ultracold neutrons.

In 1980 a report that a careful measurement of the electron spectrum from β decay of tritium gives an indication that the neutrino has a nonzero mass of the order of several tens of electron volts caused a sensation. At the present time similar experiments are in progress in a couple of dozen of institutes of different countries. However, until now there is no final confirmation or rejection of this result. Two groups in Rovno and in Moscow have measured neutrino fluxes from reactors and have refuted the communication made earlier by French physicists of the existence of neutrino oscillations.

Significant progress was achieved in realizing fusion of light nuclei with the aid of muon catalysis. Work was continued on the synthesis of new elements, in particular an isotope of element 108 and element 110 have been synthesized.

A number of important results were obtained in underground low-background laboratories (at Baksan, in Artemovsk and in a joint Soviet-Italian detector in a tunnel under Mont Blanc). New upper limits have been established in the search of such exotic objects and phenomena as the reaction with nonconservation of electric charge, oscillations of neutrino passing through the earth's sphere, magnetic monopoles, and double β decay. Of particular interest were reports on the observation of several neutrino events preceding the flareup of a supernova on 23 February 1987. The construction of a gallium-germanium detector for recording the main flux of solar neutrinos is nearing successful completion. This program is of particular interest because of the theoretical prediction made in 1985 by Soviet theoreticians according to which electron neutrinos coming from the central region of the sun can experience in solar matter resonance transformations into other types of neutrinos (for example, into muon neutrinos).

In the field of theory the last decade was marked by the final establishment of the so-called standard model of strong and electroweak interactions based on the gauge group $SU(3)\times SU(2)\times U(1)$.

In the theory of the strong interaction—quantum chromodynamics—the main unsolved problem is the elucidation of the mechanism of nonemergence of quarks and gluons and the creation of quantitative methods of calculating the properties of hadrons and the cross sections for their interactions. The static properties of hadrons (their masses, magnetic moments, etc.) can be calculated on the basis of quantum chromodynamics sum rules evolved by Soviet theoretical physicists. An important role in this and other approaches is played by the quadratic vacuum average of the gluon field introduced by them—the so-called gluon condensate.

The grand unification models of strong and electroweak interactions so far have not been confirmed experimentally, but Soviet theoreticians have made a significant contribution to the development of these models. They have predicted that within the framework of these models there must exist superheavy magnetic monopoles, which in collisions with protons must effectively catalyze the transformation of protons into positrons.

Great hopes are associated with supersymmetry which was for the first time proposed in our country and which is now being developed all over the world. On the basis of supersymmetry it is proposed to realize the superunification of the electroweak and strong interactions with gravity. Particularly great effort in recent years has been directed towards the development of so-called superstrings with characteristic dimensions of the order of a Planck length (10^{-33} cm). Superstring models indicate that at such small distances six additional spatial dimensions must be significantly manifested, which, in contrast to the usual four dimensions: t, x, y, z are compactified. Superstring models were first proposed abroad, and are now actively being developed in a number of institutes of our country. In connection with superstrings of additional interest are investigations by Soviet theoreticians of two-dimensional exactly solvable quantum field-theoretical models.

In connection with the central role played in contemporary theoretical investigations by the Planck scales of length and energy during the last decade of a very clear indication has become evident of the very close connection and interdependence of elementary particle physics and cosmology. A number of pioneering ideas at the interface of these two fields of science belong to Soviet theoreticians, particularly those relating to the theory of the inflationary stage of the early universe.

Investigations of the properties of plasma associated primarily with the program of controlled thermonuclear reactions are being carried out on a broad front in the Soviet Union. Soviet scientists have carried out investigations on developing optimal variants of realizing controlled thermonuclear fusion. These efforts have led to the development of "Tokamaks"—the most promising approach to the construction of a thermonuclear reactor. Already for more than a decade investigations of hot plasma have been carried on at the largest Soviet Tokamak T10. By using the powerful sources of electromagnetic radiation-gyrotrons developed by Soviet radiophysicists, it has been possible to achieve on this installation electron temperatures of one hundred million degrees.

The successful operation of the first in the world Tokamak with superconducting windings T-7 made it possible to go on to the next step—the construction of a large superconducting installation "Tokamak-15" with a plasma volume of approximately 25 m^3. It is expected that in this installation it will be possible to attain a temperature and a density of plasma required for a thermonuclear reactor.

In parallel with T-15 an installation TSP using a strong magnetic field is under construction at which it will be possible to conduct experiments with a deuterium-tritium plasma.

The "Tokamak" program which is being successfully developed over the whole world, provides a scientific basis for developing thermonuclear reactors of this type. In our country a design is in progress of the experimental reactor OTR. In this connection the international collaboration within the framework of IAEA has turned out to be very useful. Such a unification of efforts directed towards mastering a new—practically inexhaustible—source of energy for the benefit of all peoples was realized on the initiative of the Soviet Union.

Exploratory research is being conducted on a number of other promising directions for achieving control of thermonuclear fusion. Of work on systems with magnetic confinement of plasma we should mention stellarators and mirror magnetic traps.

Soviet scientists are also actively developing the problem of inertial confinement of plasma. A most important direction in this regard is laser thermonuclear fusion. Its idea was put forward by Soviet scientists. They also carried out the pioneering theoretical and experimental work which indicated the possibility of successful development in this direction.

Another system of inertial confinement of plasma has been realized on the installation of "Angara-5," where it is possible to realize rapid heating of small dense targets by a direct application of electrical power of up to 12 terawatts.

Broadbased investigations on controlled thermonuclear fusion have led to the birth of a new branch of physics—the physics of high-temperature plasma. Soviet scientists developed the theory of collisionless plasma based on describing oscillations and noise in such plasma as collective processes in selfcoordinated electromagnetic fields. As a result it was possible to give a qualitative, and in many cases a quantitative, explanation of phenomena observed experimentally, including phenomena occurring in cosmic plasma. Many ideas, concepts and methods which had been first developed in plasma physics, often in connection with quite specific plasma installations, have subsequently attained significance in general physics. It suffices to recall the idea of weak turbulence and its description by a chain of kinetic equations, the concept of a collisionless shock wave, the diffusion of electrons in a magnetic field with ruptured magnetic surfaces. Plasma physics provided a strong impulse towards the development of the theory of solitons and the theory of dynamic chaos. These theories have become transformed in the past decade into independent divisions of theoretical and mathematical physics. A large contribution to the creation of these divisions was made by Soviet scientists.

The extension of ideas of collective interactions to gravitating systems led, also involving the active participation of Soviet scientists, to the appearance of new concepts concerning the dynamics of stellar systems and galaxies.

The development of the fundamental physics of plasma and the improvement of experimental techniques have significantly advanced applied plasma investigations. At the present time a number of plasma and plasma-chemical technologies for metallurgy and petroleum chemistry have been developed. In our country powerful MHD-generators have been constructed and are being utilized, both pulsed-explosive ones, and steady-state ones. Soviet scientists have developed reliable plasma reactive propelling devices which utilize a plasma flux as a reactive jet. These propelling devices are being used in space vehicles and for technological applications.

Contemporary plasma physics is a many-branched and rapidly developing field of the physics of our days. Soviet science occupies strong positions both in fundamental investigations, and also in many types of applications.

The largest and broadest field of modern physics is possibly solid-state physics. To it is devoted from 50 to 70 percent of personnel and material resources apportioned to physics in our country. It has applications to all fields of technology.

Important and unexpected results were obtained in investigating quantum corrections to the usual theory of electrical conductivity. It turned out that the interference of electron waves leads to a number of new phenomena, in particular to quantum oscillations of resistance as a function of the value of magnetic flux. This effect has been experimentally observed also in our country. It turned out that taking these effects into account the fluctuations of resistance of a sample do not decrease with an increase in its dimensions, which has led to the recognition of a new branch of solid-state physics—"mesoscopics"—the physics of objects with dimensions of the order of 100–1000 Å, the properties of which are sensitive to a detailed distribution of defects.

Significant progress has been achieved in the study of hopping conductivity in semiconductors, particularly in connection with the role played by the Coulomb gap and the transport of carriers along negative donor and positive acceptor centers.

New types of heterostructures have been produced including quantum wells and superlattices on the basis of $A^{III}B^{V}$ and $A^{IV}B^{VI}$ semiconductors and also high quality silicon MDS (metal-dielectric-semiconductor) structures. They have formed the basis for design of numerous physics experiments, and also for technological applications.

One of the most important events in solid state physics during recent years has been the discovery of the quantum Hall effect. This discovery was made abroad, but Soviet scientists have made an important contribution to its investigation. The quantization of Faraday rotation was predicted and observed, and a fractional quantum Hall effect was discovered in silicon MDS structures.

The spectroscopy of excitons and of electron complexes is a traditional field of activity of Soviet scientists. In recent years the existence of new quasiparticles—phonoritons—has been proved in the excited region of the spectrum in the case of strong pumping. Additional light waves have been studied. The boundary for the existence of electron-hole liquid in crystals has been extended into the region of higher temperatures. Biexcitons have been discovered in silicon. Multielectron impurity complexes have been investigated, and the shell model of their structure has been confirmed.

The bistability near the edge of exciton absorption has been investigated and high rates of "switching" in such systems have been observed associated with the rapid rate of scattering of band electrons and de-excitation of impurity electrons.

A new phenomenon has been discovered—magnetic-impurity oscillations of photoconductivity of semiconductors which has become a method for the spectroscopy of impurity centers and the measurement of relaxation time in them.

Significant progress has been achieved in the physics of hot electrons. The study of the behavior of holes in crossed electric and magnetic fields demonstrated the existence for them of "traps" in momentum space, where population inversion can appear. On the basis of this effect lasers in the far IR range have been produced.

Of fundamental significance is the discovery of cooling of carriers in a strong electric field associated with the simultaneous action of several scattering mechanisms.

Investigations of optical orientation of electrons and excitons in semiconductors have been pursued. Among the achievements in this field are the deep cooling of nuclear spins as a result of the interaction with oriented electron spins and the momentum ordering of electrons. The luminescence of ordered hot carriers has made it possible to measure the relaxation times in the femtosecond range.

Another method of measuring the energy and intervalley relaxation times has been developed based on anisotropic dimension effects. The study of these effects made it possible to produce new types of sensitive semiconductor detectors. Significant successes were achieved in the understanding of the strong electron-phonon interaction. It was established that in materials of the polyacetylene type there exist quasiparticles of new type—topological solitons which can be carriers of charge, including fractional charge, with the statistics of the quasiparticle not being determined by spin. The theory based on this concept describes extensive experimental material. A theory of radiationless capture of electrons and excitons with the emission of a large number of phonons has been developed. It has been established experimentally that in a number of semiconductors where the coupling of band electrons with phonons is weak electrons in deep levels are strongly coupled to the lattice.

Great success was achieved in the study of dislocations in semiconductors. The energy spectrum of electrons on a dislocation has been found. The experimental discovery of combined resonance at dislocations has made it possible to demonstrate convincingly the band mechanism for the transport of electrons along reconstructed dislocations.

A fundamental achievement was the discovery of photogalvanic effect in ferroelectric materials and semiconductors and a development of the theory of the effect. The phenomenon consists of the appearance of photocurrents under spatially-homogeneous absorption of light. These currents depend on the polarization of the light. The effect has found an application in the study of band structure and in holography.

In the field of amorphous systems of interest is the construction of a model of "soft" potentials which provide a description of glasses over a wide temperature range.

Soviet physicists participate actively in the construction of a theory of the recently discovered "quasicrystals" which have a symmetry inadmissible from the point of view of "classical" crystallography.

Of great interest is also the question of the existence of magnetic bodies in which at a transition point neither a ferromagnetic nor an antiferromagnetic moment arises but a so called "toroidal" moment.

At the end of 1986 and beginning of 1987 an important discovery was made in the field of superconductivity, possibly the most important discovery in physics in recent years. Superconductors have been produced with a high temperature of the superconducting transition—at first near 40 K, and later near 90 K.[1)] This meant the surmounting of the "nitrogen barrier"—superconductivity now exists at temperatures above the boiling point of liquid nitrogen. This opens up broad—and until now not yet completely assimilated—prospects of applying superconductors in science and technology. Soviet scientists have devoted much attention to the problem of high temperature superconductivity, but the discovery was made abroad. At the present time our physicists have actively entered the theoretical and experimental study of the new superconductors, the properties of which until the present time do not yet have a full explanation.

Soviet theoretical physicists have made an important contribution to the study of properties with carriers of the "heavy fermion" type. Superconductivity of such materials apparently is of a special nature.

Research at ultralow temperatures—of the order of 1 mK—has been highly developed recently in many countries. A very important object of such research is superfluid ^{3}He which simultaneously has the properties of a superfluid, of a magnetic substance and of a liquid crystal. The lagging behind in this field that existed in our country has by now been overcome. Superfluid ^{3}He has been obtained and its magnetic properties have been investigated with an interesting effect being discovered of a discontinuity in the phase of magnetic precession. Theoretical investigations of superfluid ^{3}He are being carried out in our country at a high level. The use of topological methods has made it possible to study the singularities and the order parameter and to construct a theory of rotation of ^{3}He which has been confirmed in joint Soviet-Finnish experiments.

Research on low-temperature quantum crystals has been continuing. The phenomenon of atomic roughness of crystals of super fluid ^{4}He has been discovered. Interesting results were obtained in the study of quantum diffusion in these crystals.

The last decade is characterized by a very rapid tempo of fundamental and applied research in the field of quantum electronics, laser physics and optics.

Research and development on lasers of new types has undergone rapid growth. Priority in the development of a new generation of solid state lasers (based on activated crystals in glasses), of high efficiency and able to cover previously inaccessible regions of the spectrum (in particular in the middle infrared range) and continuously tunable in frequency belongs to Soviet scientists.

Original work on semiconductor lasers (lasers using new heterostructures, injection lasers), excimer lasers, powerful high pressure gas lasers, and chemical lasers using chain reactions has been successfully advanced. Work carried out in the USSR on laser frequency standards makes it possible to approach the realization of frequency stability $\sim 10^{-16}$–10^{-17}.[2]

During the past decade the fruitfulness of new methods, new approaches, introduced by quantum electronics and laser physics into other divisions of physics, and into neighboring fields of science and technology has been particularly vividly demonstrated.

The aspect of optics has undergone radical change: a broad spectrum of new problems has appeared, many of which go far outside the framework of physical and applied optics in their traditional sense.

The physics of action of a strong light field on matter has undergone rapid progress.

Work on multiphoton excitation and dissociation of polyatomic molecules has led to significant new physics and applied results. An understanding has been achieved of the mechanisms of randomization of forced oscillations in highly excited multiatomic molecules; the results obtained have made it possible to have a new insight into the prospects of laser chemistry and laser synthesis of materials.

Soviet physicists have carried out pioneering work on laser annealing of semiconductors—a rapid and high quality laser recrystallization of near-surface layers of semiconductors made amorphous as a result of ion implantation or other causes.

These investigations stimulated work leading to many results on laser-induced phase transitions in semiconductors occurring in nano, pico and even subpicosecond time scales, and in the physics of rapid relaxation processes in semiconductors. Together with the work on the action of powerful laser radiation on metals (in recent years important new results have been obtained here in investigating the interaction of radiation with periodic surface structures, including structures induced by the laser field itself) that has been successfully developed in our country already during approximately 20 years, the investigations enumerated above provide the physical basis for laser technology—undoubtedly one of the most important applications of lasers. The last decade is marked by a number of serious achievements in this field. Work on nonlinear optics has undergone further development. Highly efficient nonlinear-optic frequency converters (frequency multipliers, parametric generators, etc.) covering the range from vacuum ultraviolet to the far infrared region that have been widely used in physics and applied work have been produced in our country by the efforts of many teams. Soviet physicists have also achieved important results in developing nonlinear materials (rapid growth of water-soluble crystals, production of highly efficient crystals grown from melt).

The nonlinear optics of fiber light-guides has been successfully developed in our country; new results were obtained in the physics and technology of forming pico and femtosecond laser pulses. The basic principles of wave front reversal (utilizing stimulated scattering and four-wave mixing) were formulated for the first time in papers by Soviet physicists; during the last decade this work has undergone rapid development. New methods have been developed for controlling the structure of light beams, and holography. Significant results are associated with the utilization of new nonlinear materials—photorefractive and liquid crystals—in systems of wave front reversal, and nonlinear-optics information processing, and dynamic holography. At the same time investigations of the nonlinear response of these unusual materials has brought many new physical results.

The investigation of the physics of nonlinear response continues to be an important division of nonlinear optics.

In recent years the achievements in the technology of generating powerful ultrashort light pulses with field intensities of $\sim 10^{10}$–10^{11} V/cm have put on the agenda the experimental verification of the basic tenents of nonlinear quantum electrodynamics.

It has to be said that a significant theoretical advance in this important field has been made by the efforts of several theoretical groups in our country.

The work on laser spectroscopy, in particular on nonlinear laser spectroscopy, carried out in our country during the last decade is at the forefront of research. In work on active laser spectroscopy of light scattering Soviet scientists have formulated the basic variants of this new method, having demonstrated its fundamental advantages in ultrahigh-resolution spectroscopy and particularly in the investigation of non-steady-state and nonequilibrium media (discharges, plasma, highly excited molecules, semiconductors). The development of the method of resonance photoionization spectroscopy has been marked by important achievements. It suffices to state that the sensitivity of this method is now at the level of recording individual atoms and molecules. In recent years in our country the photoionization method has been effectively utilized for studying the hyperfine and isotopic structure of spectral lines of atoms with short-lived nuclei.

A method of intraresonator absorption laser spectroscopy which makes it possible to record very small absorption coefficients has been proposed and realized in the USSR. Tuneable semiconductor lasers have been successfully utilized in high resolution molecular vibrational spectroscopy.

Nonlinear laser spectroscopy of surfaces is making rapid progress: the use of nonlinear reflection of light has made it possible to develop effective methods for diagnosing surface modifications. New results have been obtained also in the selective spectroscopy of complex molecules that has been developed for the first time in our country.

New possibilities of recording and processing information based on photoburnout of stable dips in the spectra of complex molecules appear to be promising: in particular, we have in mind a new type of optical memory—spectral memory.

On the whole the modern arsenal of methods of linear and nonlinear laser spectroscopy has tremendously extended the possibility of optical diagnostics of materials. In many cases we have in mind the effective solution of problems which until recently have been regarded as generally inaccessible to optical technology (hot plasma, explosive processes, rapid modification of complex molecules and the recording of individual atoms and molecules, surface monolayers, etc.).

The last decade has been marked by an increase in the interest in quantum optics—the generation of optical fields that do not have classical analogs, the search for methods of decreasing quantum fluctuations of the light field. Significant results in these directions have been obtained by Soviet physicists in the mid 1960's (generation of compressed states and so-called biphotons in parametric processes); in recent years the development of this work has brought new results.

Investigation of phenomena due to the coherence of atomic and molecular states has been successfully developed; this work was begun in our country in the 1960s using atoms and in recent years it has been extended to molecular ensembles.

In recent years essential changes have occurred in such a seemingly mature field of physics as acoustics. Theoretical and experimental investigations of the scattering of sound by sound and other effects in nonlinear acoustics have led to a development of fundamentally new parametric generators and receivers of sound that have numerous practical applications.

The above achievements of Soviet physics cannot serve as a basis for complacency. There are promising scientific fields in which we lag behind and this lagging is not decreasing. The application of the results of fundamental research is meeting with great difficulties. In a number of cases important discoveries were made in our country, but their realization was accomplished in the West. The tragic accident at the Chernobyl atomic energy station has once again emphasized the vital necessity of extremely responsible attitude towards large scale technological utilization of the achievements of science.

The phenomena of stagnation that have become manifest in the period preceding the April 1985 plenary session of the Central Committee of the Communist Party of the Soviet Union (CPSU) had to have an effect on the development of Soviet physics. The development of science to a large extent followed an extensive path. The increase in the number of scientists and the number of published papers did not always correspond to an increase in the significance of the results obtained. The quality of instruments for scientific research produced in our country and the technological infrastructure of many of the scientific research institutes has not attained a modern level.

Our laboratories are equipped with computational technology and the means of automating experiments at a notably lower level than laboratories in the Western countries. These deficiencies can be and must be eliminated in the course of the reconstruction (perestroĭka) taking place in our country in all spheres of life of our society. At the January 1987 plenary session of the Central Committee of the CPSU it was stated that in order "to become an active participant in perestroĭka, science itself must become reconstructed in many respects." A sharp rise in the tempos of fundamental scientific investigations, an increase in their influence on applied science and industrial production is necessary. Naturally the main requirement here is goal-oriented totally devoted effort by each scientist, by all scientific teams, in order that Soviet science in accordance with the Program of the CPSU should occupy leading positions in the main directions of scientific-technological progress.

[1)] For details of this discovery see Usp. Fiz. Nauk **152**, 553 and 575 (1987) [Sov. Phys. Usp. **30** 659,671 (August 1987)].

[2)] The achievements in quantum electronics and laser physics are described in a special issue of this journal Usp. Fiz. Nauk **148** (1) (January 1986) [Sov. Phys. Usp. **29**(1) (January 1986)] and in articles in the February and September numbers published in commemoration of the 25th anniversary of the laser.

Translated by G. M. Volkoff