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SERGEĬ IVANOVICH VAVILOV

(On the Seventieth Anniversary of his Birth)

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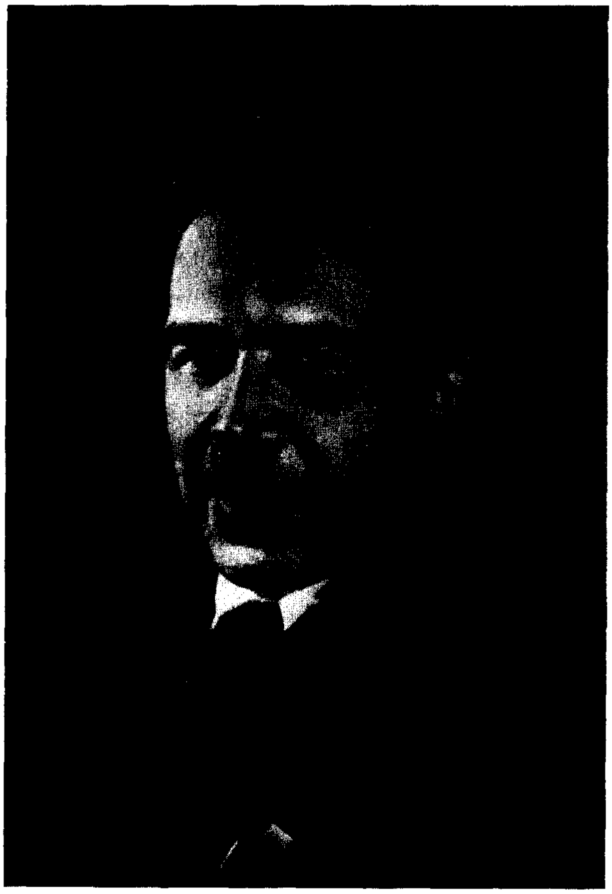
THE 24th of March, 1961 marks the seventieth anniversary of the birth of the outstanding Soviet optical physicist, Sergeĭ Ivanovich Vavilov.

The life of Sergeĭ Ivanovich was cut short ten years ago (January 25, 1951), at a time when he was full of creative ideas and plans.

S. I. Vavilov's life coincided with the time of radical reconstruction of social relationships, with the unprecedented upsurge of the national economy, and with the technological progress, all set off by the Great October Revolution. He devoted all his forces to the service of his Fatherland and was among those who, at the price of extreme exertion, brought about the irresistible development of Soviet science.



Sergeĭ Ivanovich Vavilov was born in the family of a mercantile clerk on the 24th of March, 1891. He obtained an excellent secondary education at the Moscow Commercial School. In this school special attention was devoted to the teaching of natural sciences and languages. Professors and instructors from universities taught the basic subjects. In addition to studying the required subjects, Sergeĭ Ivanovich studied Italian and Latin thoroughly, obtained a complete mastery of German, and got a good knowledge of English, French, and Polish; he was thus easily able to follow the foreign literature. During these school years he stood out among his comrades for his beautiful execution of classical compositions, which were the forerunners of his brilliant popular scientific works. His interest in natural science and philosophy appeared likewise in his early years. He carried out various experiments independently in his home, and he founded a society for the study of philosophical matters in which he was the constant main speaker. It must be observed that he thoroughly studied Lenin's celebrated "Materialism and Empirico-criticism" in its first edition during these very early years.

In 1909 Vavilov started work at the physics-mathematics faculty of Moscow State University. At this time Petr Nikolaevich Lebedev, having created the first Russian school of physics, was working in Moscow University. Even as a freshman student, Vavilov began to take an active part in the work of this school; in his second year he began scientific work under the direction of P. N. Lebedev's assistant, lecturer P. P. Lazarev. Soon, however, in 1911, the normal development of work was interrupted. Lebedev, as a sign of protest against the arbitrariness of the Tsar's minister Kasso, left the university and founded with great difficulty the laboratory in Mertvyĭ Pereulok (now Ostrovskii Pereulok). Here, after the death of Lebedev in 1912, Vavilov completed his first scientific work on the thermal bleaching of dyes. The work won a gold medal from the Society of Lovers of Natural Science, Anthropology and Ethnography at the Moscow University.

Upon graduation, Vavilov turned down an offer to remain at the university and was inducted into the army. The First World War began in July of 1914. Vavilov was continuously at the front, first in the engineers and then in the radio sections. There was a radio laboratory available to him in Lutsk, where he could carry out some experiments. It is to this period that his theoretical and experimental work "The Frequency of a Loaded Antenna" belongs.

In 1918 Vavilov returned to Moscow and began work in the Physics Laboratories of the People's Commissariat for Public Health, which was directed by his former teacher, Academician Lazarev. In these laboratories, which were soon transformed into the Institute of Physics and Biophysics of the People's Commissariat for Public Health, Vavilov worked until 1929.

During this period he carried out several investigations into the nature of light as well as very important classical studies on the luminescence of solutions. On the occasion of the 200th anniversary of the death of Isaac Newton, he translated Newton's Optics, adding a large number of commentaries; he also wrote several excellent popular books.

In 1926, on a foreign mission, Vavilov worked in the laboratory of Prof. Pringsheim in Berlin. The development of his pedagogical activity can be attributed to this period. He gave lectures on photochemistry and the absorption of light and later on physical optics at Moscow University; he taught in the Moscow Engineering School where, in particular, he gave a course in theoretical illumination engineering; he was a physics professor at the Moscow Higher Institute of Zootechnology.

In 1929, he transferred his basic activity to the Moscow State University, where he established a department of general physics and did much to improve the teaching of physics. At the university Vavilov attracted upper-class students to scientific work; soon a school of physics began to form around him. Here in his laboratory the following began their work: E. M. Brumberg, B. Ya. Sveshnikov, I. M. Frank, V. S. Fursov and A. A. Shishlovskii. The work at the university was of short duration, however; soon Vavilov was chosen, first as Associate Member of the U.S.S.R. Academy of Sciences, and then as Academician with appointment as Assistant Director of the State Optical Institute's scientific section. He moved to Leningrad in the spring of 1932.

With the move to Leningrad began a new period in Vavilov's activity, characterized by much scientific organizational work. He had to direct the enormous scientific-research institute of the State Optical Institute, which dealt with all questions of theoretical and applied optics. He organized there a new laboratory of luminescence, to which came some of his Moscow students and a number of young Leningrad physicists. Simultaneously Vavilov was entrusted with the reorganization, in essence the creation, of the Physics Institute of the Academy of Sciences, taking as a base the physics section of the Physics-Mathematics Institute. At that time the section included only a small group of scientific workers, chiefly theoreticians, from which it was necessary to create a strong scientific center.

Vavilov turned his attention to the development of experimental work, to which the following young scientists were attracted: B. M. Vul, P. D. Dankov, N. A. Dobrotin, L. V. Groshev, A. N. Sevchenko, I. M. Frank, P. A. Cerenkov, and others.

Vavilov's own scientific interests were then chiefly concentrated on developing methods of observing the action of individual light quanta, i.e., on a direct proof of the quantum nature of light phenomena. This work, carried out by Sergeĭ Ivanovich in conjunction with a number of his Leningrad collaborators, lasted for a considerable period of time and was one of the important phases of his scientific activity.

Following the 1934 governmental decision to transfer the Academy of Sciences to Moscow, the newly organized Physics Institute (which was named after P. N. Lebedev at Vavilov's initiative) was one of the first to move from Leningrad to Moscow, where it began to develop rapidly. Vavilov believed that all the most important trends of modern physics should be represented at the Institute. Laboratories for optics, radiophysics, luminescence, acoustics, molecular physics, the physics of dielectrics, and the atomic nucleus were created, as well as a theoretical section. Vavilov paid special attention to the development of new trends and attached great importance to the study of cosmic rays and nuclear processes. At first he himself directed the young physicists working in this area (N. A. Dobrotin, S. N. Vernov, P. A. Cerenkov, etc.); later the greatest specialists were attracted to the direction of this work — Lev Vladimorovich Mysovskii and Dmitrii Vladimorovich Skobel'tsyn.

In 1935 Vavilov visited a number of European countries to become acquainted with the optical industry.

The 1934-1941 period was one of exceptional strain in his life. He had to direct two large institutions, one in Leningrad and the other in Moscow. He regularly traveled to Moscow to work in the Physics Institute and in the Presidium of the Academy of Sciences, of which he had been made a member. At this time he also held public office as a deputy of the Supreme Soviet of the RSFSR.

During World War II Vavilov continued to direct both institutes, which were evacuated to different cities; he also worked as representative of the State Committee on Defense, which necessitated frequent trips to Moscow. He supervised much defense work. To this same period can be attributed his creation of a generalized theory of luminescence phenomena in solutions, in which the first successful attempt was made to unify the diverse phenomena of luminescence, namely the variation of the luminescence yield and the duration and polarization of luminescence with the concentration of the solution.

In 1943 the Physics Institute of the Academy of Sciences moved back to Moscow. Somewhat later the State Optical Institute also returned to Leningrad. Resumption of the functioning of both institutes required considerable efforts.

In 1945 Vavilov was chosen President of the Academy of Sciences. His outstanding organizational abilities were especially displayed in this last period of activity. He strove to organize a wide network of scientific-research institutions in the country and to attract new personnel in the local areas to science. With these goals, he aided in every way the organization of the republic academies (of the Azerbaĭdzhan, Kazakh, Latvian, and Estonian S.S.R.'s) and the creation of new bases and affiliates for the U.S.S.R. Academy of Sciences, as well as of a number of other scientific institutions.

Vavilov devoted a great deal of attention to the popularization of knowledge. He was one of the organizers and first chairmen of the Society for the Propagation of Political and Scientific Knowledge; until his death he was an editor of the second edition of the Great Soviet Encyclopedia; he was also a chairman of the Editorial-Publishing Council of the Academy of Sciences of the U.S.S.R. and an active member of the editorial board of the journal Uspekhi Fizicheskikh Nauk. At the same time he carried out a great public task as a deputy of the Supreme Soviet of the U.S.S.R. and as a member of the Moscow Soviet of Workers' Deputies, and he was an active fighter for peace.

In Leningrad and in Moscow he continued actively to direct the work of his pupils. He had many doctoral candidates under him at this time: V. V. Antonov-Romanovskii, B. Ya. Sveshnikov, A. N. Sevchenko, N. A. Tolstoĭ, P. P. Feofilov, M. D. Galanin, and A. M. Bonch-Bruevich. He continued to work on the theory of light and on luminescence, as well as on philosophical problems. The particularly significant monograph "The Microstructure of Light" belongs to this very last period of his life. In this work he unified and examined from a new point of view his works on the theory of light and on luminescence.

Vavilov suffered a severe heart attack in November, 1950 in Leningrad, after which he was directed for treatment to the Barvikhu Sanitorium. His health continued to deteriorate, but, in spite of this, interrupting his treatment, he departed for Moscow and began to work intensely. During the night of January 24th, 1951 another violent heart attack brought about his death from a myocardial infarctus.

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As a scientist, S. I. Vavilov was characterized by a striving to pose problems of central and philosophic significance, a striving towards drawing general conclusions. He was deeply interested in the theory of relativity, the nature of light, the structure of matter, and atomic physics. In addition, all of Vavilov's activity was involved with the transformation of theoretical results into practical applications.

Vavilov began his scientific work at the time of the widespread development of the quantum theory of light. In his first studies of the absorption coefficient he set up the task of verifying quantum descriptions of light by detecting changes in the index of absorption under a wide variation in the intensity of absorbed light. In spite of an enormous variation in intensity (factor of 10^{20}), he did not find indications of discontinuity of absorption, i.e., of the quantum properties of light, from which he inferred the incorrectness of the quantum descriptions. However, the successes of quantum theory stimulated Vavilov to re-examine his point of view. He did not stop meditating and setting up experiments to verify the quantum theory. In particular, he carried out a great series of works in conjunction with his Leningrad collaborators (E. M. Brumberg, Z. I. Sverdlov, and T. V. Timofeeva). These works dealt with the direct detection of the action of individual light quanta at limitingly low intensities of light flux, tens of quanta per second. Subsequently the quantum nature was demonstrated, even of such "purely wave" phenomena as the interference of light.

Vavilov developed a great interest in the study of elementary radiators, to determine the character of which he proposed two methods of research, one consisting of the interference of widely diverging beams, and one of polarization diagrams. The first makes use of the inhomogeneous spatial distribution of electromagnetic radiation from dipoles, quadrupoles, magnetic dipoles, etc., which causes great diversity in the interference of widely diverging beams, thus permitting one to establish the nature of the radiator. The method of polarization diagrams consists of investigating the dependence of the degree of polarization of luminescence on the angle between the direction of the light beam exciting the luminescence and the direction of observation, and also on the angle between the light vector of the exciting light and the observation plane. The curves obtained from such investigations (showing the dependence of degree of polarization on the indicated angles) can serve both to determine the nature of the elementary radiator and to investigate the spatial position of the radiator. Vavilov's polarization diagram method gained wide use. In recent years one of his pupils, P. P. Feofilov, solved by such a method the problem of the nature of the elementary radiators which serve as glow centers in crystals with cubic lattices, and also the problem of their position relative to the symmetry axes.

A. N. Sevchenko and G. P. Gurinovich carried out further calculations of polarization diagrams for more complex cases of radiation, and investigated with the aid of these diagrams the nature of the absorption and radiation of porphyrin solutions. N. D. Zhevandrov used them to determine the orientation of molecules in a lattice and to study exciton processes in molecular crystals.

An especially important position in Vavilov's series of works on the nature of radiation is held by his part in the discovery of a new form of radiation, known under the name of the Vavilov-Cerenkov effect. The Curies had already observed the weak glow of solutions under the action of radioactive radiations; but they considered this glow to be luminescence. P. A.

Cerenkov, who had studied under Vavilov's direction the luminescence of uranyl compound solutions under the action of gamma rays, observed a weak glow in all the pure solvents he used. A further thorough study of the properties of this glow established their utter non-conformity with the properties of luminescence. It became evident that a new form of radiation had been discovered. Its nature was revealed by I. M. Frank and I. E. Tamm of the Physics Institute of the U.S.S.R. Academy of Sciences. The radiation turned out to be the glow from electrons moving with a velocity greater than the velocity of light in the given medium. In 1946 these investigations were awarded a first-class Stalin prize.

The weak glow observed by Cerenkov upon the passage of gamma rays through a liquid becomes pronounced under certain conditions. It is the cause of large energy losses by elementary particles given enormous velocities in present-day accelerators. This phenomenon has gained not only theoretical but also practical significance. A large number of papers and whole monographs have been devoted to it. Special "Cerenkov" radiation counters were developed to determine the velocities, energies and characters of elementary particles. In 1959 Cerenkov, Tamm, and Frank were awarded the Nobel prize.

Vavilov's greatest series of works is associated with problems of luminescence. He is the founder of the Soviet school of luminescence. He concentrated basically on the energetics of luminescence. As early as 1924, in one of his first works, he showed that the efficiency for transforming absorbed light energy into luminescence light in luminescent dye solutions can be as high as 80%. This result demonstrated the possibility of the very effective conversion of one form of light energy into another, Sergeĭ Ivanovich called the conversion coefficient the "luminescence yield." In succeeding works Vavilov studied in detail the nature of losses in excitation energy occurring during its conversion and examined several different forms of luminescence quenching, such as the extinction due to the concentration of molecules of the luminescent material itself and the extinction due to impurities. Initially Vavilov thought that extinction occurred at the moment of a collision between an excited molecule and an unexcited molecule of the same substance or with a quencher molecule; later he became a proponent of the theory of the resonance transfer of energy from excited to unexcited molecules, assuming at the same time that a fraction of the transfers are accompanied by extinction.

Studying the relation between the size of the luminescence yield and the wavelength of the exciting light, Vavilov found a direct proportionality between these quantities over a wide range of wavelengths. This was an indication of the constancy of the quantum yield, i.e., of the proportionality of the number of emitted quanta of luminescence to the number of absorbed quanta of exciting light. This relation is violated, according to Vavilov, only in the long-wave region, where the frequency of the radiated light becomes greater than the frequency of the absorbed light. This relationship between wavelength of exciting light and luminescence energy yield bears the name of "Vavilov's Law." Subsequently Vavilov pointed out the possibility of two or more quanta of radiation appearing for one high-energy quantum, i.e., of a quantum luminescence yield greater than unity. Such processes are observed in gamma scintillations; they have also been found by V. A. Fabrikant and F. A. Butaeva in the optical frequency region, and recently by Vavilov's son, V. S. Vavilov in the photoionization of semiconductors.

The principal questions raised by Vavilov as to the possible significance of the yield are extremely important and continue to be discussed in the literature. These are such matters as the possibility of a yield greater than unity, and the causes of the sharp fall-off in yield for excitation in the anti-Stokes region which has been observed by M. N. Alentsev, V. V. Antonov-Romanovskii, B. I. Stepanov, M. V. Fock and a number of other scientists.

Vavilov paid great attention to the study of excited states of molecules and also to the laws of attenuation of glow. In a number of investigations carried out in conjunction with V. L. Levshin, A. N. Sevchenko, A. A. Shishlovskii, M. D. Galanin and others, he studied the duration of glow and the connection between the duration and other characteristics of luminescence. The considerable length of the glow (greater than 10^{-10} sec) associated with the considerable stability of the excited states of the luminescent molecules was considered by Vavilov as a characteristic indication of luminescence; he used it to define the concept of luminescence as distinguished from processes of light scattering. The law of glow attenuation was used by Vavilov to characterize the kinetics of luminescence and differentiate the various forms of luminescence.

Numerous investigations were undertaken by Vavilov in the field of polarized luminescence.

During the forties, both in the papers of Vavilov himself and in the papers of other authors, there were already accumulating voluminous data on the yield, duration, and polarization of the glow. It turned out that these quantities, to a certain degree, are related to one another: the decrease in yield observed during extinction is accompanied by a decrease in duration, and an increase in concentration leads to depolarization of the glow.

Vavilov first attempted to relate these diverse phenomena by a general theory based on an assumption about the inductive transfer of energy from one molecule to another. Such transfers naturally lead to glow depolarization and may also explain extinction if we hypothesize that some of them are accompanied by the transition of energy into heat. These works of Vavilov, together with works on the quantum fluctuations of light, were awarded a Stalin prize in 1942.

The influence of the migration of energy on the attenuation, extinction, and depolarization of glow, and, in particular, the role of particle diffusion, were subsequently examined by his pupils M. D. Galanin, B. Ya. Sveshnikov, and other scientists. On the one hand, these works showed the important role of energy migration in a wide circle of phenomena, and on the other they gave considerable impetus to developing the theory of these phenomena.

Vavilov was the founder and organizer of the Soviet school of luminescence, which was due not only to his own pupils but also to the influence of his work. Working himself in the region of molecular luminescence, he also assisted greatly in developing the study of crystal-phosphor glow. New centers of luminescence research appeared in a number of cities in the Soviet Union. To coordinate the work on luminescence, Vavilov organized at the Department of Physico-Mathematical Sciences of the U.S.S.R. Academy of Sciences, a Commission on Luminescence; this was afterwards transformed into the Council on Luminescence. The Commission called general meetings of workers in the region of luminescence. The first two meetings, conducted by Vavilov, were of very great importance.

At the present time almost all types of luminescence and its applications are being developed in the Soviet Union. New fields have arisen — electroluminescence, glow under the action of fast particles, the study of individual scintillations — and are being studied in detail by Soviet scientists. Besides the large luminescence research centers in Moscow and Leningrad, new centers have been created in Kiev, Tartu and other U.S.S.R. cities. In a number of cases Vavilov's students are playing a leading role in the new centers.

Vavilov's optical works, both in the area of the theory of light and in the area of luminescence, were incorporated by him into the monograph "The Microstructure of Light," which was written in the last year of his life. In this monograph Vavilov notes the fact that certain characteristic properties of light phenomena associated with their quantum nature and their radiator features begin to appear only under the following special conditions: when a limitingly small light flux (a small number of quanta) is applied, when light phenomena are observed during limitingly small time intervals (about 10^{-9} sec), or, finally, when processes taking place at very short distances from radiation sources are studied. Vavilov refers all these phenomena to the region of "microoptics." "The Microstructure of Light," together with another, very popular little book of Vavilov's "Eye and Sun," was awarded a first-class Stalin prize in 1952.

Vavilov, attempting to solve general problems about the nature of light, naturally turned to previous eras and took an active interest in the history of the development of representations of light, substance, and matter. He made a superb translation, with numerous annotations, of Newton's "Optics" and "Lectures on Optics." He wrote a voluminous biography of Newton and made a number of studies of the work of M. V. Lomonosov, Academician V. V. Petrov, Leonard Euler, and others.

Vavilov's interest in philosophical questions was reflected in a series of articles aimed at confirming the materialistic philosophical outlook and giving a correct materialistic interpretation of the most recent discoveries and theories. His works "The New Physics and Dialectical Materialism" and "Lenin and Contemporary Physics" are especially important. These and a number of other works were of great value in the development of philosophical thought in the Soviet Union and in the establishment of a correct understanding of the development of contemporary physics.

Vavilov continually strove for a fuller practical use of the results of scientific achievements. Foremost among his works in the practical direction must be noted the development under his general leadership of fluorescent lamps, a development carried out in the Physics Institute of the Academy of Sciences, in the State Optical Institute, and in the All-Union Electrical Engineering Institute. Along with V. L. Levshin, M. A. Konstantinov, V. A. Fabrikant, F. A. Butaeva and V. I. Dolgopolov, Vavilov was (posthumously) awarded a Stalin prize for this work.

This highly economical form of lighting makes feasible extensive illumination with the requisite spectral composition in industrial enterprises, on the streets, and in the home; it improves working conditions and raises the productivity of labor. It is becoming more and more widely used and will become the principal form of illumination in the near future.

Vavilov's guiding influence on the development and introduction of qualitative and quantitative luminescence analysis has been of extremely great value, leading to the wide application of this analysis to biology, medicine, geology, and various branches of industry.

It is evident from what has been said how many-sided and intense has been the work of S. I. Vavilov. In this era of Communism under construction it is difficult to say what we should prefer: the new facts and laws discovered by Vavilov, his enormous scientific organizational and practical activity, or his work in the area of the popularization of knowledge and in nurturing scientific personnel. Vavilov worked tirelessly in all these areas of activity and achieved large-scale successes. He did not spare himself for the good of the Fatherland.

The Soviet people valued highly the working achievement of S. I. Vavilov. In life he was awarded two Orders of Lenin and the Order of the Worker's Red Banner. After his death a collection of his works was published by a decree of the Government. The Institute of Physical Problems of the U.S.S.R. Academy of Sciences and the State Optical Institute were named for him, as well as the luminescence laboratory in the Physics Institute of the Academy of Sciences. A gold medal to be awarded by the Academy of Sciences for the best works in physics, and fellowships, were established in his name, and memorial plaques were put up in buildings of the Physics Institute and the Optical Institute in which Vavilov worked. The Soviet people will long retain a bright memory of S. I. Vavilov.

Translated by Mrs. J. D. Ullman