N. D. Papaleksi (100th anniversary of his birth)

V. V. Migulin

Usp. Fiz. Nauk 134, 519–526 (July 1981)

PACS numbers: 01.60. + q, 89.90. + n, 84.40.Cb, 01.30.Cc

A hundred years ago, on December 2, 1880, one of the leading specialists in the field of radiophysics and radiotechnology was born: Nikolaĭ Dmitrievich Papaleksi.

His name and work are well known to the radiophysicists of the whole world, and it is difficult to overrate the contribution made by N. D. Papaleksi personally and in association with L. I. Mandel'shtam in working out the problems of oscillations in nonlinear systems, parametric generation and amplification of oscillations, in developing radiointerferometric methods, and in solving many problems of practical radiotechnology.

It is difficult, and perhaps impossible, to separate the names of these two scientists in the field of radiophysics. Their collaboration continued for forty years, having begun in their student period, and was fueled by warm friendly relations that bound these persons together to the end of their lives. In speaking of Nikolaĭ Dmitrievich's scientific activity, one must turn to the publications that reflect the results of his joint studies with L. I. Mandel'shtam, and only we, as witnesses and participants in a number of the studies that they conducted, recall how the activity of each of them supplemented that of the other, and how much N. D. Papaleksi contributed to their common work.

Nikolaĭ Dmitrievich was born in Simferopol' in a military family. He first studied at Simferopol', and then at Poltava, where he graduated from the gymnasium in 1899 with a gold medal. Then he went abroad, and after a short stay at the University of Berlin, he moved to Strasburg. He continued his education at the University of Strasburg and became acquainted there with L. I. Mandel'shtam, who was studying at the same university. At that time the famous scientist Ferdinand Braun held the chair of experimental physics and headed the Institute of Physics of the University of Strasburg. Under his overall direction the joint studies of the two young scientists developed in the field of electric oscillations associated with problems of radiotelegraphy.

In 1904 N. D. Papaleksi presented his dissertation for the degree of Doctor of Physics (Phil. Nat.), having passed all the required examinations with high honors. In this work he studied theoretically and experimentally the dynamometric principle of high-frequency measuring instruments.

The first joint study of N. D. Papaleksi and L. I. Mandel'shtam was published in 1906, and was devoted to studying the method of obtaining high-frequency oscillations having a specified phase shift. It started the cycle of their studies in the field of physics and technology of electric oscillations and of all the scientific problems that we now lump under the term "radiophysics."

We note in passing that Nikolai Dmitrievich's field of interests was very broad in the Strasburg period of his life. He took up the study of the excitation time of fluorescence, together with L. I. Mandel'shtam set up experiments to study the inertia of electrons in a metal (four years before the well known experiments of R. Tolman and T. Stewart), studied the properties of the high-pressure arc, and much else. All this facilitated N. D. Papaleksi in becoming an erudite scientist, and all the people having contact with him were struck by his fundamental conversance with such fields of science as astronomy, meteorology, gas-discharge physics, vacuum physics, and a number of other branches of physics and technology that extended far outside the framework of the field of science fundamental to him—radiotechnology.

And we add moreover that it was characteristic of N. D. Papaleksi to try to reduce the obtained scientific results to full physical clarity, and if possible, to practical use. He spent much time and effort in application of the advances of science to the technology of radiotelegraphy, 6 measurement technique, and to all that is now called introduction into practice. It is precisely he who, with his inherent perserverance and thoroughness, found the path to realizing the results of their joint studies, freezing L. I. Mandel'shtam from these cares. As early as Strasburg, these sides of their association were manifested very clearly. F. Braun, and later L. I. Mandel'shtam himself served as scientific consultants for the film Telefunken, while N. D. Papaleksi carried out the practical contacts in performing the pertinent studies and developments. The example of the entire creative life of Nikolaĭ Dmitrievich shows that he always sought and found a formulation of a scientific problem warranted by the needs of practice and, after solving the fundamental aspects of the problem, pursued the matter to an actual application of the obtained scientific data.

In 1911 at the 2nd Mendeleev Congress on General and Applied Chemistry and Physics in St. Petersburg, N. D. Papaleksi gave the paper "On New Methods of Measurement in the Field of High-Frequency Currents" in his own name and that of L. I. Mandel'shtam. It contained a presentation of the theory and a description of a set of instruments based on the dynamometric principle.

[1] Papers are published in this section that were read at the Scientific Session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR at the session on Dec. 24, 1980, which was devoted to the 100th anniversary of the birth of Academician N. D. Papaleksi (information on this scientific session is given below in the section "Meetings and Conferences").

 0038-5670/81/070614-05$01.10

In 1912 N. D. Papaleksi published a study on the action of rectifying devices. Many studies were already known on this problem, but Nikolaĭ Dmitrievich's study merits especial attention, because it examined in depth for the first time the behavior of an essentially nonlinear circuit, a circuit with a nonlinear resistance, and it showed the specifics of the processes occurring in such systems. Moreover, in his study N. D. Papaleksi employed for the first time a piecewise-linear approximation of a nonlinear characteristic— a method that has found widespread development and practical application in a large number of studies and methods of calculation.

In 1914, owing to the onset of World War I, N. D. Papaleksi returned home. At this time he was already widely known in scientific circles and in circles of specialists in radio. His papers on the theory and technique of measurements in the high-frequency field, on investigation of circuits having nonlinear elements, and studies on problems of direction finding and on a number of problems of practical radiotechnology won great authority for him. On returning to Russia he was invited as a consultant on physical problems and as head of the experimental laboratory in the Russian Society of Wireless Telegraphy and Telephony (ROBTIT) in Petrograd. Nikolaĭ Dmitrievich directed the development and production of the first domestic radio tubes, which were known as "Papaleksi tubes". He applied for the first time induction heating of the electrodes of the tubes to outgas them during evacuation. He participated in the development and testing of various types of receivers for aviation, and designed direction-finding instruments. In 1915 the first radiotelephone line in Russia was built with his participation from Petrograd to Tsarskoe Selo. A year later he conducted studies on the possibility of radiotelegraphic communication between the shore and a submerged submarine. Characteristically, Nikolaĭ Dmitrievich personally participated both in the tests of aircraft radio apparatus and in the experiments on radiocommunication and direction finding on a submarine, and also experimented with radio remote-control instruments.

In 1918 N. D. Papaleksi moved with his laboratory to Moscow, but, having received an invitation from L. I. Mandel'shtam, went to Odessa in the autumn of the same year, where he actively participated in the organization of the new Polytechnic Institute. In this institute Nikolaĭ Dmitrievich was initially an Assistant Professor and was in charge of the physical practicum, while in 1920 he became Professor in theoretical electrotechnology; he also gave lectures on the theory of electrical oscillations and on meteorology.

At that time radiotechnology was already undergoing the transition from spark transmitters and reception by coherers and crystal detectors to tube technology, while low-frequency tube amplifiers and heterodynes had already become a steady constituent part of the radio instruments of that time. The operation of the network of radio stations existing during those years in Russia was threatened with complete stoppage owing to the lack of French radio tubes. In 1921 under conditions of complete disorder, the materials for preparing radio tubes were only bottle glass and surviving incandescent lamps. Lacking the needed vacuum equipment, the group of young enthusiasts (E. Ya. Shchegolev, K. B. Romanyuk, *et al.*), who later became prominent specialists in radio, undertook in the Polytechnic Institute, with N. D. Papaleksi in charge, to revive the failed radio tubes and to prepare new ones. The experience, perseverance, and inventiveness of Nikolaĭ Dmitrievich and the selfless labor of the whole group led to success. They set up the repair of the failed French tubes and then the production of radio tubes of their own construction. As a result, a low-volume output of amplifier tubes was started at the Odessa radio plant, which had been founded not long before, and they played a great role in ensuring the capability of many radio stations in the south of our country, on the Black Sea fleet, and even in Siberia and in the Far East.

In 1922 Nikolaĭ Dmitrievich published the first part of his study on the theory of the vacuum-tube generator. Unfortunately, the second part of this work did not appear, and the work that he had started even earlier on creating a consistent nonlinear theory of generation of electric oscillations remained incomplete. Yet, upon becoming acquainted with the contents of the published part, one can see how deeply Nikolaĭ Dmitrievich understood the specifics of the operation of this class of nonlinear oscillatory systems, predating all other investigators, who undertook only in later years the creation of a consistent nonlinear theory of the vacuum-tube generator.

In 1922 N. D. Papaleksi and L. I. Mandel'shtam were invited to Moscow as scientific consultants of the radio laboratory of the Communications Plant Trust (CPT). In 1924 the laboratory was moved to Leningrad and converted into the Central Radio Laboratory (CRL) of the CPT. Here the two scientists directed the scientific division.

N. D. Papaleksi carried out a large cycle of studies on the features of operation of high-power radio tubes in radio transmitters, and the results obtained by him and under his direction greatly facilitated the perfection of the production of these tubes, their improvement, and a search for ways to employ them most effectively in radio apparatus. In connection with these studies, the grid modulation of radio transmitters and the specifics of this regime with regard to telephony were investigated. Nikolaĭ Dmitrievich also developed a number of new methods of high-frequency measurements and ways of applying them. He proposed systems for quartz frequency stabilization of radio transmitters and methods of employing the properties of piezoelectric quartz to design highly selective receivers. The study of the methods of modulating high-power self-excited generators led N. D. Papaleksi to design a magnetic manipulator, which was successfully applied at the high-power radio station being built in Teheran on a contract from Persia. As regards the methods of quartz stabilization, they were employed at the same time in the multicascade short-wave transmitter for the Moscow center. The oscillator circuit for frequency stabilization proposed by N. D. Papaleksi and L. I. Mandel'shtam was

applied at the radio station VTsSPS, while the quartz filters for a highly selective receiver were successfully tested and set up in the receiving center near Moscow.

At this same time, jointly with L. I. Mandel'shtam, N. D. Papaleksi started studies of oscillatory processes in nonlinear regenerative systems. They initiated the brilliant cycle of studies on nonlinear oscillations and yielded a series of interesting results for practical applications. Among the first practical results of these studies one can point out the design of an autoparametric filter based on applying the phenomenon of 2nd-order resonance discovered by N. D. Papaleksi and L. I. Mandel'shtam. This instrument, which was designed for attenuating interference in radio receiving, underwent testing in 1928-1929 and was put into service at the radio stations in Tiflis and Baku.

During 1929-1935 N. D. Papaleksi was occupied with problems of the further study and utilization of oscillatory processes in nonlinear systems, developed studies on parametric generation of electric oscillations, and began a set of studies on radiointerferometry. To this period belong the very important results obtained at the CRL under the direction of N. D. Papaleksi and L. I. Mandel'shtam in the field of resonance phenomena in nonlinear regenerative systems and parametric regeneration. The results of these studies, and as is especially important, the fundamentally new nonlinear approach to such phenomena as second-order resonance, asynchronous excitation and damping of oscillations in regenerative systems, parametric regeneration, etc., formed the content of the paper by N. D. Papaleksi at the 1st All-Union Conference on Oscillations in Moscow in November 1931.

The 1st International Conference on Nonlinear Oscillations took place in January 1933 in Paris. Nikolaĭ Dmitrievich presented two papers there on the studies being conducted in the USSR along this line, and the high point of the papers was the story of the studies performed by L. I. Mandel'shtam and N. D. Papaleksi and under their immediate direction. The advances in this field of science resulted in our country becoming a center of worldwide studies in the field of oscillatory processes in nonlinear (and primarily radiotechnical) systems.

During the same years (1926-1934) Nikolaĭ Dmitrievich directed the section on nonlinear problems of the Leningrad Electrophysical Institute, where certain problems pertaining to oscillatory processes in nonlinear radiotechnical systems were being investigated and fundamental studies on generation of electric oscillations involving a mechanical variation of the inductance or capacitance of the oscillator circuit were carried out. The first models of parametric generators with variable inductance and capacitance were built under N. D. Papaleksi's direction. The features of parametric excitation of oscillations were studied (parametric resonance), and fundamental data were obtained for constructing models of parametric generators. The design of prototype of electrical machines of a fundamentally new type based on the latter was started. These studies had advanced so far by 1935 that the problem became quite practical of manufacturing industrial specimens of Mandel'shtam-Papaleksi parametric generators.

It should be mentioned that the studies on parametric regeneration and parametric excitation of electric oscillations performed under the immediate direction of Nikolaĭ Dmitrievich brought these problems to full clarity, and when it became possible to build semiconductor controllable capacitors in the radio frequency range (which was first pointed out in 1954 by B. M. Vul), development of parametric amplifiers and HF and UHF converters could rest on the already-developed theory and the distinct physical picture of the oscillatory processes that occur.

Along with the intensive scientific research work at the CRL and the Leningrad Institute of Electrophysics, Nikolai Dmitrievich taught from 1926 to 1935 at the Leningrad Polytechnic Institute. Here he was professor in the physicomechanical faculty, and he gave a course on thermionic devices, a course in vacuum physics, and conducted the seminars on current problems of radiotechnology. The present author had the occasion to take the course in vacuum physics given by N. D. Papaleksi. I recall that we the students in this course were all greatly impressed by the fundamental quality and the deep physicality, if one can so term it, of the material presented, which encompassed a broad set of problems of gas dynamics and the theory of the interaction of rarefied gases with surfaces. We were also caught up in the purely practical problems of the technique of obtaining a high vacuum, of measurements, and of choice of design of the pertinent instruments and devices.

In 1931 this course was stenographed, but unfortunately was never published. Undoubtedly, at that time, prior to publication of such materials abroad or here, this would have been a most valuable guide for practical workers and students— the future cadres of the vigorously growing vacuum industry. Nikolaĭ Dmitrievich's lectures analyzed with exhaustive completeness many important problems, and they manifested in full measure his very rich practical experience and extreme erudition. The seminars that he conducted were always devoted to the current problems of contemporary radiotechnology, and each time the deep theoretical analysis was accompanied by a global treatment of the practical aspects of the problem being discussed.

In the CRL, and later in the Leningrad Institute of Electrophysics, N. D. Papaleksi together with L. I. Mandel'shtam began to develop radiointerferometric methodology and to design a radio interferometric rangefinder utilizing phase measurements of coherent signals at commensurable frequencies emitted by a reference station and a controlled ("reflecting") station remote from it. The tests of radio rangefinders with tunable frequency performed under field conditions and the test of certain other variants of radiointerferometric methodology demonstrated their actual practical value for geodesics and navigation. These full-scale tests were carried out at the permanent field base in Luga and

during expeditions in which Nikolaĭ Dmitrievich invariably participated. However, the effective practical application of radiointerferometric rangefinders required an exact knowledge of the value of the velocity of propagation of radio waves along the Earth's surface, since the actual distance measurement is carried out by determining the distance to be measured on the scale of the wavelength of the radio waves being employed. Therefore, in the course of the studies directed by N. D. Papaleksi at the CRL, Leningrad Institute of Electrophysics, and later also at the Institute of Physics of the Academy of Sciences of the USSR, one of the central problems became the study of the phase structure and velocity of propagation of radio waves along the Earth's surface.

In 1931 N. D. Papaleksi was elected as a corresponding member of the Academy of Sciences of the USSR, and his participation in the work of the Academy of Sciences started at that time. At the end of 1934 he accepted the directorship of the newly organized oscillation laboratory of the Institute of Physics of the Academy of Sciences of the USSR, in which the work of studying propagation of radio waves by radiointerferometric methods was being developed. Here L. I. Mandel'shtam was entrusted with the overall scientific direction of the oscillation laboratory and the optics laboratory, which was directed by G. S. Landsberg. We can view this time as the culmination of the Leningrad period in the life and work of N. D. Papaleksi, and although he finally moved to Moscow only in 1938, actually as early as 1935 the center of gravity of his scientific and scientific-administrative activity was shifting to Moscow, to the Academy of Sciences. Then (1935) N. D. Papaleksi's laboratory was transferred from the CRL to the Leningrad Institute of Electrophysics, and later to the Leningrad Polytechnic (Industrial) Institute, and the scales of its activity became substantially narrower.

Nikolaĭ Dmitrievich was confirmed as the chairman of the technical physics group of the Division of Technical Sciences of the Academy of Sciences of the USSR, and in 1938 became deputy chairman of the Scientific Council (L. I. Mandel'shtam was chairman) on Radiophysics and Radiotechnology at the Academy of Sciences of the USSR. He was also designated as chairman of the Special Commission to study propagation of radio waves in the Arctic; the creation of the commission arose from the need to maintain reliable radio communication with a Soviet expedition in the region of the North Pole. All this vigorous scientific-administrative activity did not retard the tempo of the intense scientific work of N. D. Papaleksi.

The close of the Leningrad period of Nikolaĭ Dmitrievich's life and activity coincided in time with a certain consolidation of the results of the many years of investigations of L. I. Mandel'shtam and N. D. Papaleksi, who had founded their school in the field of study of oscillatory processes in nonlinear systems. Jointly with other scientists, they wrote a review with the title "New studies of nonlinear processes", which had been presented in a shorter form at the General Assembly of the International Scientific Radio Union (URSI), even before its publication in 1934. In 1936 the Academy of Sciences of the USSR awarded the first D. I. Mendeleev prize to N. D. Papaleksi and L. I. Mandel'shtam for their work on nonlinear oscillations and on radio-wave propagation.

The expedition and field studies conducted in the period from 1935 to 1941 at Lake Il'men', on the Black Sea (at Odessa and near Novorossiĭsk), on the White Sea, at the Kara Strait, in the steppe region of the Northern Crimea, in the Zavolzh'e (at Pugachev), in the Moscow Region (Pavlovskaya Sloboda and Zvenigorod), yielded very rich experimental material pertaining both to the physical side of the problem of propagation of radio waves over dry ground or the surface of the sea, and to determining the possibilities and methodology of employing radio interferometry to solve navigational, hydrographic, and geodesic problems. This brilliant set of studies brought exhaustive clarity to the problem of propagation of radio waves along the Earth's surface, made possible determination of their velocity of propagation under actual conditions, was the basis for solving the problem of coastal refraction and of a number of other effects involving a change in the properties of the Earth's surface, and created the foundation for radiogeodesics and phase radionavigation. It was only later, in the years of the Second World War and in the postwar years, that the widespread development occurred of the global phase radionavigation systems for ships and airplanes and a number of high-precision local systems employing the radiointerferometric methodology, which was first brought into operation in our country by the efforts of N. D. Papaleksi together with L. I. Mandel'shtam. And we can see in the fact that radiointerferometry in our country yielded such important scientific and practical results much earlier than abroad a confirmation of Nikolaĭ Dmitrievich's extreme perspicacity and his foresight of the paths of technical progress based on new physical ideas and principles.

Mention should also be made of the studies on the possible application of the radiointerferometric methodology for studying the ionosphere that were performed at Nikolaĭ Dmitrievich's initiative during the expedition studies of 1936 and 1937. Constantly participating in field studies, in the course of the ongoing research Nikolaĭ Dmitrievich continually posed ever newer problems for the participants in the studies, and aided in solving them with his extremely rich experience and exhaustive erudition, infecting all the other members of the expedition with his scientific enthusiasm.

In 1939 N. D. Papaleksi was elected as a full member of the Academy of Sciences of the USSR. This was a recognition of his scientific and practical achievements and a merited evaluation of his extremely great contribution to Soviet radiophysics and radiotechnology.

His unusual capacity for work enabled Nikolaĭ Dmitrievich to fulfill numerous duties, and his extremely organized habits were an unmatchable example for all his associates. At the same time Nikolaĭ Dmitrievich found time to follow the literature of the arts, played excellent chess, and seriously studied chess theory.

During his brief periods of rest he hiked in the mountains and his fitness and agility repeatedly amazed his younger mountaineering companions.

During World War II N. D. Papaleksi undertook with doubled energy the building of an experimental base near Kazan', to which the Physics Institute of the Academy of Sciences had been evacuated. He participated in planning the defense studies of the Academy of Sciences of the USSR, directed the work of the Radio Council, presented a number of scientific papers, published a book on radio interferometry, and continued to direct the laboratories of the Institute of Physics of the Academy of Sciences and of the G. M. Krzhizhanovskiĭ Power Engineering Institute.

In 1942 N. D. Papaleksi met with L. I. Mandel'shtam in Borovoĭ, and there they conceived the idea of radiolocation of the Moon. Nikolaĭ Dmitrievich showed with calculations the practicality of this experiment with the technical means existing at that time, anticipating the development of one of the most important fields of contemporary active radio astronomy. In the same year 1942, N. D. Papaleksi together with L. I. Mandel'shtam were awarded the State Prize for their work in the theory of oscillations and propagation of radio waves. In 1945 Nikolaĭ Dmitrievich was awarded the Order of Lenin for his distinguished services in the field of radiophysics and radiotechnology.

L. I. Mandel'shtam's death at the end of 1944 deeply shook N. D. Papaleksi, who survived his friend by only a little over two years.

In the last years of his life, with his characteristic energy and perseverance Nikolaĭ Dmitrievich took up the study of the radio emission of the sun, seeing in this the start of the development of a new field of science, radioastronomy. An expedition to Brazil was organized at his suggestion for radio observation of a total eclipse of the sun. In N. D. Papaleksi's view, the combination of observations of the radio emission of the sun with ionospheric and optical observations as the moon gradually covered the sun's disk should yield much valuable information, both on the radio emission of the sun itself, and on the ionosphere. However, this expedition took place only after N. D. Papaleksi's death. He died suddenly on Feb. 3, 1947.

Until the last day of his life, Nikolaĭ Dmitrievich worked hard and persistently. As before, he directed the oscillation laboratory of the Institute of Physics of the Academy of Sciences, he headed the Radiocouncil, presented papers, wrote articles on the evolution of the concept of resonance and on nonlinear oscillations, and began, but did not finish, a biography of L. I. Mandel'shtam for a collection of his works. A person of great modesty, extreme conscientiousness and organization, Nikolaĭ Dmitrievich Papaleksi gave all his efforts and talents without stint to science and to its practical applications, and to the development of our national radiophysics and radiotechnology.

[1]S. M. Rytov, Akademik Nikolaĭ Dmitrievich Papaleksi (Academician Nikolaĭ Dmitrievich Papaleksi), Izv. Akad. Nauk SSSR Ser. Fiz. **12**, 7 (1948).

[2]G. S. Gorelik, Neskol'ko Zamechaniĭ ostile nauchnogo tvorchestva N. D. Papaleksi (Some Remarks on N. D. Papaleksi's Style of Scientific Creativity), *ibid.*, p. 22.

[3]E. Ya. Shcheglev, Chetvert' veka tosu nazad (Iz vospominaniĭ o sovmestnoĭrabote s N. D. Papaleksi) [A Quarter Century Ago (From Recollections on Joint Work with N. D. Papaleksi)]. *ibid.*, p. 25.

[4]V. L. Ginzburg, N. D. Papaleksi i radioastronomiya (N. D. Papaleksi and Radioastronomy), *ibid.*, p. 34.

[5]S. M. Rytov, Nikolaĭ Dmitrievich Papaleksi (Kratkaya nauchnaya biografiya) [Nikolaĭ Dmitrievich Papaleksi (A Brief Scientific Biography)], in: N. D. Papaleksi, Sobranie trudov (collected Works), Izd-vo AN SSSR, M., L.: 1948, p. 9.

[6]V. V. Migulin, Akademik N. D. Papaleksi (Academician N. D. Papaleksi), Radio, No. 1, 7 (1968); Nikolaĭ Dmitrievich Papaleksi (K 100-letiyu so dnya rozhdeniya) [Nikolaĭ Dmitrievich Papaleksi (on the 100th Anniversary of His Birth)]. Vestn. Akad. Nauk SSSR, No. 11, 131 (1980).