intensity, permit using this kind of excitation for the investigation of defects and their production processes in crystals with a wide forbidden band, in particular, in scintillators.

The technique of investigating the mechanisms of luminescence excitation is highly convenient for exploring the energy transfer in defect systems in different matrices, the energy structure of insulators, and their resistance to radiation damage.

Let us consider how radiation effects may manifest themselves in investigations based on the luminescent spectroscopy technique. These are mostly the changes of emission spectra under dose variations, which reveal themselves most often in the emergence of additional excitation bands. Next, these show up as changes in emission decay kinetics with increasing dose (radiation effects make themselves evident in the sharpening of the initial decay stage and the emergence of a slow emission component).

Changes in energy transfer are mostly manifested as changes in the ratio between the contribution probabilities from different relaxation channels in insulators.

What is the convenience of using VUV and X-ray SRs in the investigation of radiation damage? VUV and X-ray photons produce the same electronic excitations (electron–hole pairs, excitons, core-level holes, initial stages of defect production) as high-energy ionizing particles (because in the course of relaxation of ionizing particle tracks so-called delta electrons with energies from 20 to 10,000 eV emerge). Furthermore, the absorption coefficient in this spectral domain is so high that the photons are absorbed in a very thin layer and the dose accumulated in this layer is quite significant for moderate photon fluxes.

In summary, we notice that vacuum ultraviolet and X-ray synchrotron radiations permit one not only to examine the basic mechanisms of electronic relaxation and energy transfer in wide band crystals, but also to investigate the resistance of scintillators to radiation damage.

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The Petersburg period in the life and scientific work of D V Skobeltsyn

I N Toptygin

They are not born to be outstanding scientists — they become such to the best of their research abilities and especially so due to their persevering labor. The success of such a formation is largely due to the foundation laid in a person in his green years. The foundation is determined both by biological genes (from one's parents) and by 'social genes' — from the family

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Vladimir Vladimirovich Skobeltsyn — D V Skobeltsyn's father.

D V Skobeltsyn's parents — Vladimir Vladimirovich and Yuliya Dmitrievna.

V V Skobeltsyn with his son Dmitrii.

and the milieu — as well as by the historical period. The prerequisites for D V Skobeltsyn's outstanding accomplishments are hard to understand without considering family traditions and many decisive scientific, as well as social and political, factors which formed him as a scientists, science organizer, and patriot.

Dmitrii Vladimirovich came into the ancient aristocratic family of Skobeltsyns (A M Baldin [1] refers to a record of the boyar Skobeltsyn in ancient encyclopedias, who was second voivode (governor) in Novgorod under Ivan the Third, i.e., in the first half of the 16th century). In nobility, a comparison comes to mind between the Skobeltsyn family and Dmitrii Vladimirovich's peer — a titled physicist prince Louis de Broglier — whose Italian de Broglia ancestors were mentioned in chronicles back in the 12th century but passed into French service in the middle of the 17th century (see Ref. [2]).

Dmitrii Vladimirovich's father, Vladimir Vladimirovich Skobeltsyn, was born in Kursk, but he led all his conscious life in Petersburg. He graduated from the First Petersburg Classical School and then from the Faculty of Physics and Mathematics of Petersburg University in 1886, to stay in the university for 'training for professorship'. He got married when he was a student, but his first wife died early, leaving him with two small sons. His second wife and Dmitrii Vladimirovich's mother was Yuliya Dmitrievna Ustrugova.

Their son Dmitrii was born in 1892, and they had seven children in all (an absolutely incredible number for a professor's family in modern Russia!). In the year of the birth of his third son, V V Skobeltsyn occupied the modest position of laboratory assistant (an assistant according to the modern 'table of ranks') in the university and taught physics in several classical schools to earn a necessary living for his large family. V V was engaged in investigations into the electrical and thermal properties of electrotechnical insulators and experiments with X-rays. Although no records of V V's major accomplishments in this area have survived, Dmitrii Vladimirovich thought highly of his father's experimental skills and at a mature age would repeatedly emphasize this.

Apart from covering purely material needs, work in the classical schools and in the Pedagogical Museum of Military Training Institutions served to develop educational skills, which V V attached great importance to; as evidenced by his contemporaries, his teaching skills were perfect. A study group for exchange of teaching experience worked at the Pedagogical Museum, and V V participated actively in its work. Even when he was a university laboratory assistant, he worked out a brilliant technique of lecture displays and assisted university professors Petrushevsky, Khvolson, Borgmann, and others. As a result, within several years after graduating from the university, V V Skobeltsyn proved to be a talented and skilled lecturer in physics, and in 1894 he was offered the position of lecturer (of a professor in 1899) at the Electrotechnical Institute, and in 1895 the same position at the Institute of Civil Engineers.

However, the early 1900s saw a rise in revolutionary ferment in the Russian Empire, and in the spring of 1901 Professor V V Skobeltsyn was dismissed, by the order of the Minister of Internal Affairs D S Sipyagin, from both institutes for his support of students' demands. He resumed teaching in classical schools once again. At this stage, however, the course of events for Professor Skobeltsyn evolved according to the saying 'every cloud has a silver lining'.

In those years, the buildings of the Petersburg Polytechnic Institute (PPI) — an institution of higher education of a new type — were erecting at a stepped-up tempo in a beautiful pine-tree forest in Lesnoy near Petersburg ('eight versts from the Finland railway station', as written in official documents). The structure of the future technical university and the lines of training of specialists were specified by a government committee, which included prominent Russian scientists D I Mendeleev, A N Krylov, and others. The conception developed by this committee involved the principle of fundamental training of future engineers in natural, technical, and economical disciplines and a close relationship between engineering education and practical activity. An imperial decree about the organization of the institute was signed by Nicholas II in 1899, and the first studies commenced in the autumn of 1902 — an example to be followed by modern protracted construction.

The new institute was supervised by the then omnipotent Minister of Finance, count Sergey Yu Witte, who was not only an 'efficient manager', but also a technical expert with an operational experience in rail transport. Minister Witte and Director of the institute, prince A G Gagarin (a prominent engineer, who was engaged in research in material strength and construction durability) invited V V Skobeltsyn, a gifted and highly trained professor in physics, to join the new institute and charged him to organize a physics laboratory in the institute. For this purpose, the Minister of Finance allocated sufficient funds, and V V Skobeltsyn was sent on a mission to European countries (Germany, France, and Switzerland) to purchase the newest laboratory equipment and measuring instruments. Due to his efforts, the physics laboratory of the Polytechnic Institute was equipped like the cutting-edge European laboratories of that time. It became the center of attraction for leading Russian scientists. In particular, owing to V V Skobeltsyn's efforts, A F Ioffe was put on the list of the physics laboratory as a supernumerary senior laboratory assistant. Shortly before, A F Ioffe had returned to Russia from Münich on completion of a four-year work on probation under the supervision of the first Nobel Laureate in Physics 1901, Wilhelm C Röntgen.

The Physics Laboratory of the Polytechnic Institute had a direct bearing also on Dmitrii Vladimirovich Skobeltsyn: it was precisely in this laboratory that he conducted a considerable part of the investigations during his Leningrad period. Getting ahead of the story, we note that the procedure of equipping the laboratory was repeated in 1921, upon foundation of the Physical-Technical Institute (1918) and the Faculty of Physics and Mechanics at the Polytechnic Institute (1919). At that time, a group of scientists led by A F Ioffe was sent on a mission to European countries to buy scientific literature and scientific equipment. This mission during the years of the Civil War and ruined economic system was made possible due to the People's Commissar of Education A V Lunacharsky and Vladimir Lenin personally. The equipment and the literature were actually transferred to the same laboratory, because the Physical-Technical Institute during the first five years of its existence occupied several rooms of the Physics Laboratory at the Polytechnic Institute [3]. A top photograph (1927) of the staff members of the Laboratory depicts, apart from the Skobeltsyns (father and son) and A F Ioffe, many famous scientists who permanently or occasionally worked in the laboratory. Among them are N N Semenov, A I Tudorovsky, V R Bursian, L S Mysovsky, A I Leipunskii, D A Rozhansky, V F Mitkevich, I V Meshchersky, and some others. (P L Kapitza, in 1919 an electrical engineering student who had actively participated in the organization of the Faculty of Physics and Mechanics, in 1927 was already working under Rutherford's supervision in England).

The organization of the Faculty of Physics and Mechanics in 1919 as a part of the Polytechnic Institute, undertaken by A F Ioffe and his like-minded colleagues, among which was V V Skobeltsyn, carried on the task of building a cutting-edge technical university, which had been started in the 1900s [4, 5]. By the early 1920s, progress in basic science gave rise to the rapid development of technology and engineering. New practising engineers needed extensive knowledge of the new physics which underlay electrical and radio engineering, lighting technology and optics, technical electronics, new structural materials, and — more recently — nuclear power engineering and quantum electronics, molecular biology, and computer componentry.

Even in the pre-war years, the tandem Physical-Technical Institute–Faculty of Physics and Mechanics of the Polytechnic Institute served the purpose of working out a close collaboration between academic institutions and higher education establishments. In the post-war years, this system of interrelationship was transferred to Moscow and was embodied in the Moscow Engineering Physics Institute, the Moscow Institute of Physics and Technology, as well as Moscow University, Novosibirsk University, and some others.

From 1902 on, V V Skobeltsyn was on the Board of PPI Administration (Council) as a professor who was in charge of students, and he delivered lectures in physics to first-year students of all divisions of the institute. In 1907–1911, he was a Dean of the Electromechanical Division; in the most difficult years, 1911–1917, he was Director of the Polytechnic Institute. He continued teaching physics after the revolution. He passed away in Leningrad in 1947.

The author has so enlarged on Skobeltsyn-the-father's biography, because the decisive influence of V V Skobeltsyn

Physics Laboratory of the Leningrad Polytechnic Institute. Sitting (from left to right): I V Meshchersky, A F Ioffe, S N Usatyi, S I Shcheglyaev, V V Skobeltsyn, A A Shaposhnikov, A I Tudorovsky, V M Filippov, F A Miller, M V Ivanov; second row: D A Rozhansky, N N Semenov, S I Zilitinkevich, L Kulikova, Ya R Shmidt-Chernysheva, V F Mitkevich, V R Bursian, T F Borovik-Romanova, N Ya Selyakov, P S Tartakovsky, K F Nesturkh, D V Skobeltsyn, M A Levitskaya, L S Mysovsky, V V Besikovich-Doinikova, O A Kostyreva, A I Tkhorzhevsky; last row: A F Val'ter, E N Goreva, A I Leipunskii, V N Kondrat'ev, M I Korsunskii, and N N Mirolyubov (1927).

on his son is quite evident. His son adopted the most important and attractive of the father's features: the gift of a physicist and devotion to science, prodigious human decency and intelligence, the lofty sense of official and social duties. However, mother's influence on the son should not be underestimated, either. All of Yuliya Dmitrievna's children had very good upbringing and pre-school education, in which she took an active part. Dmitrii Vladimirovich had a hard time when she died from an infectious disease in 1920.

During the first decade of the 20th century Dmitrii Skobeltsyn studied at the Tenishev School — one of the best Petersburg secondary schools — which he retained good memories of. After finishing school, he enrolled at the Electromechanical Division of the Polytechnic Institute, but after one year of learning he entered to the Faculty of Physics and Mathematics of St. Petersburg University. In 1915, he completed the full course of studies at the then Petrograd University in the specialty of 'Physics' and, not breaking away from the university, he started teaching as assistant at the Women's Medical Institute and the Physics Department of the Polytechnic Institute. According to the personal history of D V Skobeltsyn [6], which is kept in the archive of the Polytechnic Institute (now St. Petersburg State Polytechnic University), he worked in the institute from 26 October 1916 through 1 February 1938. At the same time, he was affiliated with the Physics Department of Petrograd University with the aim of 'training for scientific activity' under Professor D S Rozhdestvensky's supervision (03.11.1915 – 01.01.1919). After undergoing tests in mathematical and physical disciplines and getting the highest mark of 'very satisfactory', he was awarded a first degree diploma on 13 December 1918 [6].

D V Skobeltsyn became interested in research on elementary particle and cosmic ray physics in the Physics Laboratory of the Polytechnic Institute in late 1923; it has been just this research whose results brought him world-wide reputation. And early in 1924 his native town changed its name once again and received the name Leningrad. That is why there are grounds to refer to the whole period of D V Skobeltsyn's intensive scientific activity in the city on the Neva River as the Leningrad period.

D V Skobeltsyn himself wrote: "I started studying gamma-ray radiation (and then cosmic radiation as well) at the end of 1923 in the laboratory of my father, V V Skobeltsyn — Professor in Physics at the Leningrad Polytechnic Institute. The work emerged spontaneously under the influence of the outstanding discovery of that time — the Compton effect — and resulted from a happy idea of mine — to investigate the recoil electrons of gamma rays in a cloud [Wilson] chamber. My first photographs were obtained in the absence of a magnetic field."

Interestingly, D V familiarized himself with the Wilson chamber when he was still a postgraduate student at Petrograd University [7]. His supervisor, Professor Rozhdestvensky, gave him the Wilson chamber assembled by another student (Pontryagin), who had failed to put it into operation. D V was given the task to get the chamber into working condition. By mounting considerable effort, he fulfilled the task and was warmly congratulated by his supervisors and colleagues. Recall that the Wilson chamber was invented in 1912, and the inventor was awarded a Nobel Prize in Physics 1927.

Among the characteristic features of Dmitrii Vladimirovich's experimental work were: individual creative work, almost without assistants; a small number of publications; a careful analysis of results, and a well-substantiated, well-thought-out interpretation of the data obtained.

D V Skobeltsyn's work, which was published in Russian and foreign languages, was well known by the scientific community. Several times D V went on a mission abroad to attend scientific conferences and carry on research. The longest academic trip of the Leningrad period was his trip to the Institute of Radium in Paris (1929–1931), which became possible due to a grant from the Rockefeller Foundation with support from Marie Curie, an outstanding scientist in the area of radioactivity and a Nobel Laureate in Chemistry 1911.

For his major scientific accomplishments, in 1934 Dmitrii Vladimirovich was conferred the degree of Doctor of Physical and Mathematical Sciences (without defending a thesis) and the title of Professor. Later on, he was elected a Corresponding Member (1939) and then Full Member (1946) of the USSR Academy of Sciences.

D V Skobeltsyn's scientific work in Leningrad, at the Polytechnic Institute and, after 1 November 1925 also at the Physical-Technical Institute [8], continued until 1938. At that time, he accepted the proposal of the President of the USSR Academy of Sciences, S I Vavilov, and moved to Moscow to be appointed Head of the Department of Cosmic Rays at the Physical Institute of the Academy of Sciences. Here, we cannot make a comprehensive analysis of D V Skobeltsyn's outstanding work performed in Leningrad, but we will endeavor to outline below the most significant results, whose importance has been borne out with time and the subsequent development of science.

(1) The first major scientific achievements of D V Skobeltsyn are related to his participation in attaching status to the first quantum field theory — quantum electrodynamics, and the first basic boson — the photon, a quantum of electromagnetic field. A comparison involuntarily suggests itself with the circumstances under which the last (in the framework of the Standard Model of the hierarchy of elementary particles) basic boson — the Higgs boson — came to light recently (i.e., was discovered in experiments). This was verily a long-expected child adored by experimentalists and especially by theorists, for whom a huge price was paid in hard currency (in the form of expenses for the unique collider, associated equipment, and a large team of researchers and operating personnel), to say nothing of the expenditure of mental energy, which defies estimation.

Unlike the Higgs boson, the first Planck–Einstein–Compton boson, whose corpuscular nature had not been recognized for a long time, was the stepchild of its numerous parents, some of whom were ready to repudiate it. Max Planck, even after his triumphant explanation of the spectral density of equilibrium radiation in 1900, did not abandon attempts to construct a classical theory which left no room for discrete portions of electromagnetic field energy. Einstein's explanation of the photoeffect laws (1905) proceeding from the quanta hypothesis was considered by many physicists (and by the Nobel Committee, which awarded a Nobel Prize to Einstein for that, but not by Einstein himself) as a particular result applicable to only a specific, though important, phenomenon. Many specialists in physics (even supposedly Niels Bohr) believed that the corpuscular nature of the 'transverse' electromagnetic field was impossible to combine with the wave phenomena of interference and diffraction. Early in the 20th century, the consciousness of a large number of researchers was dominated by the mechanistic picture of 'luminiferous ether' as a medium in which electromagnetic wave phenomena occur. And though the discreteness of atomic electron energies had been stated by Bohr in 1913, it was still a long way to the experiments of Davisson–Germer and Thomson (1927), who discovered electron diffraction.

Even now, after the lapse of a century, the term 'electric induction' in English is not infrequently denoted as 'displacement', which distorts the meaning of electric phenomena. Initially implied was the displacement of 'perfectly transparent' and 'perfectly elastic' ether. This term, in the author's opinion, is as irrelevant as the ancient term 'phlogiston' for denoting heat.

First row (from left to right): F Joliot, A F Ioffe, I Joliot-Curie; second row: D V Skobeltsyn (on the left) and S I Vavilov.

The light quanta of Planck and Einstein possessed experimentally measured energies, but were not yet rigorous elementary particles, because their momenta were not observed in experiment. To verify that a light quantum was a valid particle, its interaction with a free (or an almost free) electron had to be studied. It was precisely this experiment that was performed by Compton, and D V Skobeltsyn immediately recognized in full measure its significance for physics. In his first experiments, Compton discovered an increase in scattered radiation wavelength. Skobeltsyn studied the angular distribution of recoil electrons in experiments with gamma rays. Therefore, he could fully reconstruct the corpuscular picture of quantum–electron interaction as an elastic collision of relativistic particles. In the same series of studies, he checked experimentally and thereby verified the Klein–Nishina–Tamm formula, the first formula of quantum electrodynamics obtained proceeding from the relativistic quantum Dirac equation, which described the effective differential scattering cross section and the angular distribution of particles.

(2) Dmitrii Vladimirovich played an important role in establishing the general notion of an 'antiparticle' in elementary particle physics. The existence of a positively charged particle with an electron mass followed from the quantum Dirac equation formulated in 1928 under some extension of the notions of the nonrelativistic theory. But at that time, the only positively charged 'elementary' particle known from experiment was the proton. That is why Dirac initially identified his antiparticle with the proton (see, for instance, his paper "On the annihilation of electrons and protons" [9]).

Two years later, Millikan and Anderson obtained photographs with tracks (ionization trails) of positively charged particles produced by cosmic rays. The authors considered these particles as protons. Dmitrii Vladimirovich analyzed the specific ionization in the photographs presented and raised objections to this interpretation (actually observed were the tracks of high-energy positrons). But the authors advocated their version for a long time, and it was not until Anderson's 1933 paper, "The positive electron", that the existence of positrons was recognized once and for all (the Nobel Prize in Physics 1936). Positron tracks were also present in Skobeltsyn's 1929–1931 photographs, but the weak magnetic field did not permit him to reach definite conclusions. As data on antiparticles were accumulated, it was recognized that every particle had its antiparticle (in some cases the antiparticle is identical to the particle — for instance, the photon). In particular, the group of Emilio Segré (E Fermi's pupil) discovered the antiproton in 1955.

(3) Dmitrii Vladimirovich's next significant contribution to modern physics is related to the elucidation of the nature of cosmic rays. D V Skobeltsyn ascertained that cosmic rays consist primarily of high-energy charged particles. Even in his first experiments, Dmitrii Vladimirovich observed that energetic particles exhibit the tendency to emerge in groups rather than singly. Investigations of this phenomenon led to the discovery of extensive air showers, which in turn became a powerful instrument of investigating cosmic rays themselves, as well as the diverse electromagnetic and nuclear interactions of elementary particles. The findings of the first stage of cosmic ray research are set out in D V Skobeltsyn's monograph [10].

These discoveries actually ushered in the era of high-energy physics. Since then, cosmic rays have remained the unrivaled (but, unfortunately, uncontrollable) source of high-energy particles (up to 10^{20} GeV and above). Apart from positrons, muons, pions, kaons, and lambda hyperons were also discovered in cosmic rays, and data were gathered about their decays and interactions. Nevertheless, the role of cosmic rays in the study of elementary particle interactions is decreasing in importance with the progress of accelerating technology. However, our understanding of the role played by cosmic rays in astrophysics has greatly improved during recent decades. The acceleration of charged particles to high and ultrahigh energies has turned out to be a natural process in nonequilibrium and rapidly evolving astrophysical objects (stars, galaxies, galactic clusters). Relativistic particles and their electromagnetic radiation in a broad energy range, from the radio-frequency band to gamma-ray energies in TeV domain, permit obtaining unique astrophysical information about galactic and extragalactic objects.

To summarize the Leningrad period (1924–1938) of D V Skobeltsyn's scientific activity, it is valid to say that he enriched science with many achievements at the Nobel Prize level, which promoted the recognition of the fundamental base of quantum electrodynamics by the scientific community and gave birth to new avenues in physics development, which have retained significance until the present day. However, Dmitrii Vladimirovich did not become a Nobel Laureate. Discussions about the reasons for this injustice have persisted up to the present. Readers may familiarize themselves with different viewpoints on this question and with the appraisal of D V Skobeltsyn's scientific achievements from A N Starodub's collection of articles [11] and Refs [12–16].

In parallel with research, Dmitrii Vladimirovich delivered lectures at the Polytechnic Institute in general physics and, after 1934, in the special course 'Radioactivity and nuclear structure'. And so, when A S Predvoditelev, Dean of the Faculty of Physics of Moscow State University, suggested in October 1939 that D V "organize teaching on the atomic nucleus and radiology", Dmitrii Vladimirovich responded quickly and concretely. In particular, he asked to plan 6(!) lecture hours per week for the next semester, and the Department of Atomic Nucleus and Radioactivity organized by D V Skobeltsyn commenced its work in the MGU Faculty of Physics on 11 June 1940.

In those pre-war years, no scientist in the Soviet Union was more erudite than D V in matters of personnel training on the nuclear issue. He had personal experience in scientific and educational work in this area, which he had gained in Leningrad. The same is true of his work as Head of the Department of Cosmic Rays at the Physical Institute in Moscow. He was a supervisor with a strong personal background of experimental research and a strong team of pupils and collaborators. Among them were S N Vernov (he moved from Leningrad), V I Veksler, I M Frank, L V Groshev, P A Cherenkov and many others, who also participated in teaching.

There is no escape from mentioning that the scientific achievements of D V Skobeltsyn and his school, and success in numerous scientific-administrative and public posts were largely due to the general development of culture, science, technology, and industry in the Soviet Union and to the strong emphasis placed on research by the Soviet state. This is especially evident to the people of the older generations, who happened to pass from the epoch of 'developed socialism' to the present-day epoch of unbridled brigandish capitalism. However, it is impermissible to lose optimism, although it is doubtful whether the 'golden age of science', which the country went through during the Soviet period of its development, will ever be restored in present-day Russia.

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