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CONTRIBUTION OF UKRAINIAN SCIENTISTS TO THE DEVELOPMENT OF OPTICS

The contribution of Ukrainian scientists to the development of optics as a science, in particular, within the Soviet period, has been analyzed. World's priority for some of those studies is demonstrated. The attention is drawn to the pedagogical and educational activities of Ukrainian scientists. The material is classified according to the optics domains.

Keywords: ukrainian scientists, applied optics, physical optics, spectroscopy, nonlinear optics.

1. Introduction

In 2017, a group of scientists from the US and the Netherlands reported about the existence of a new state of matter, excitonium [1]. The new state is a condensate consisting of excitons and possessing superfluid properties. To confirm the existence of the excitonium, the researchers measured the spectrum of low-energy collective bosonic excitations in crystals at a temperature of about 190 K. The discovery of the excitonium opens a new direction for the development of quantum technologies.

Note that it was the works of physicists belonging to the Kyiv scientific schools headed by A.F. Prikhotko and O.S. Davydov, in which excitons in crystals were studied and which were carried out at the Institute of Physics of the Academy of Sciences of the UkrSSR (IP AS UkrSSR), that laid the foundation for the spectroscopy of nonmetallic crystals in the world science [2–5]. The achievements of some Ukrainian physicists have been thoroughly analyzed in a number of papers [6–11]. But the achievements of other Ukrainian scientists are also significant, so that their contribution to the development of physics requires a further detailed analysis. The aim of this work was to demonstrate the importance of the researches made by Ukrainian scientists for the development of optics.

2. Applied Optics

Volodymyr Pavlovych Linnyk (1889, Kharkiv–1984, St.-Petersburg, Russia), Academician of the Academy of Sciences of the USSR (1939), graduated from the St. Volodymyr University of Kyiv (1914), lectured at the Kyiv University (from 1915) and the Kyiv Polytechnic Institute (1923–1926), worked at the State Optical Institute (Leningrad, from 1926), Professor of the Leningrad University (1933–1941) and the Pulkovo Observatory (1946–1968). The main directions of his scientific activity were applied optics and the history of physics.

The first scientific papers of V.P. Linnyk dealt with the optical studies of X-radiation. Together with E.V. Lashkaryov, he carried out a series of experiments devoted to the methods of X-radiation focusing [12] and the determination of the corresponding refractive index [13]. He proposed a method for studying the structure of crystals with the help of X-radiation [14]. It is difficult to reproduce classical interference and diffraction experiments, by using X-radiation because of its small wavelengths. Nevertheless, V.P. Linnyk performed the Lloyd interference

V.P. LINNYK

G.G. DE-METZ

experiment with X-radiation and measured the wavelength of this radiation [15].

The scientist carried out thorough researches dealing with the development of new methods aimed at studying the image quality in optical systems. He was an inventor of the method for studying the aberration in optical systems, the method of optical system centering, the method of microscope lense composing. V.P. Linnyk constructed a double microscope (1929), as well as a microinterferometer (1933), which is used to control the surface treatment quality. With the help of a microinterferometer, defects about 10^{-7} m in size can be detected. V.P. Linnyk was also an inventor of a number of methods and instruments for astronomical purposes such as the analysis of star spectrograms, by using a stereocomparator, a solar interferometer, and a slitless star spectrograph with interference reference markers.

The scientist was among the firsts who pointed at the necessity to use photoelectronics in optical devices for the control automatization. A large number of optoelectronic devices were developed under his supervision, for instance, for the automatic measurement of the optical system aberration, for the testing of the profile of plane surfaces, for a precise position fixation of the zero interference band. V.P. Linnyk is also known by his researches in the history of physics [16, 17].

3. Physical Optics

Georgii Georgiyovych De-Mets (1861, Odessa–1947, Kyiv), Dr. Sci. in physics (1891), Professor (1923), Honored professor (1923), the dean of the Engineering faculty of the Kyiv Polytechnic Institute (1909–1910), the dean of the Faculty of Chemistry of the Kyiv Polytechnic Institute (1910–1911), the rector of the Kyiv Polytechnic Institute (1919–1920), the head of the Department of Physics of the A.M. Gorkii Pedagogical Institute of Kyiv (1934–1947), worked at the Kyiv University (1891–1930). The main directions of his scientific activity were optics, radioactivity, molecular physics, the history of science and engineering, and the methodology of teaching physics.

After graduating from the Novorossiiskii University (Odessa) in 1885, G.G. De-Mets was awarded the gold medal for his scientific work "*An essay on anomalous dispersion*" and was left to work at the University. He improved the methods developed by Maxwell for the observation of the birefringence phenomenon in liquids at a deformation and studied this phenomenon in 16 liquids. De-Metz experimentally researched the Kerr effect in pure water, as well as in the gelatin and collodion solutions [18: 46]. When working at the Kyiv Polytechnic Institute, the scientist demonstrated that the birefringence in liquids does not depend on the viscosity.

G.G. De-Metz was a famous methodologist. The scientist created the first exemplary methodological physical laboratory in the Russian Empire (Kyiv,

1906). He was an author of the first Soviet textbook on the physics teaching methodology [19]. He was a member of the committee for the foundation of the Kyiv Polytechnic Institute, where he created the Museum of physical equipment. At the Kyiv University, De-Mets created a museum of physical instruments. De-Mets was the chair of the Organizing Committee of the Ukrainian Association of Physicists, which was created in 1928, and was among those who organized the congresses of this association. He was interested in the history of science and engineering [20]. The scientist edited the popular scientific journal *Fizicheskoe Obozrenie* (*Physical Review*).

Leonid Isaakovych Mandelshtam (1879, Mogylyov, Belarus–1944, Moscow, Russia), Academician of the Academy of Sciences of the USSR (1929), Privatdozent at the Novorossiiskii University of Odessa (1915), Professor of the Odessa Polytechnic Institute (1918–1922), Professor of the Moscow University (from 1925). The main directions of his scientific activity were physical optics, radiophysics, and quantum mechanics.

In his doctoral dissertation "*On optically homogeneous and turbid media*" (1907), L.I. Mandelshtam pointed at a mistake in the Rayleigh theory concerning the explanation of blue color of the sky. According to the Rayleigh theory, light is scattered by air molecules. Mandelshtam proved that these are not air molecules, but fluctuations of the atmospheric air density. In such a way, the scientist showed that the Rayleigh formula is true in essence, but the physical origin of the light scattering is different. Mandelshtam's doctoral thesis was one of the first works, in which fluctuations were studied. Those works formed the basis of statistical physics.

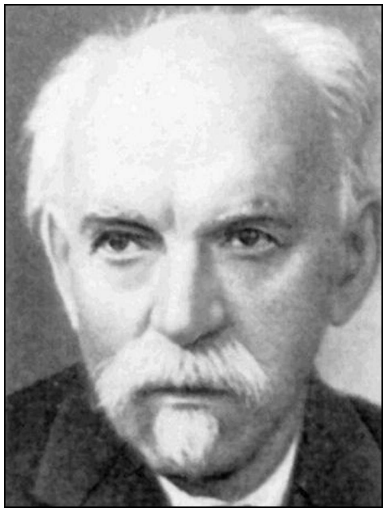
In his paper "*On light scattering by an inhomogeneous medium*" (1918), the scientist theoretically analyzed the process of fluctuation appearance. Mandelshtam was the first physicist who paid attention to the fact that pressure, temperature, and concentration fluctuations affect the incident light by modulating it. He substantiated the appearance of two additional waves with the wavelengths λ_1 and λ_2 in the scattered light that are symmetrically shifted with respect to the initial wavelength λ_0: $\Delta\lambda = \lambda_1 - \lambda_0 = \lambda_0 - \lambda_2$. This work [21] was published much later than the corresponding work of the French physicist L. Brillouin [22]. The predicted phenomenon is called the Mandelshtam–Brillouin effect. The existence of the Mandelshtam–Brillouin doublet, which is located near the main line, was experimentally confirmed by E.F. Gross (1930).

L.I. MANDELSHTAM

In 1930, the Indian physicist Ch.V. Raman (1888–1970) was awarded the Nobel Prize in Physics for the discovery of combination light scattering (1928). Independently of Raman and the same year, the combination scattering was discovered by L.I. Mandelshtam and G.S. Landsberg [23]. At first, Raman erroneously described his discovery as an optical analog of the Compton effect. In their first works (1928), Mandelshtam and Landsberg immediately pointed to the delusiveness of this assumption.

Mandelshtam was one of the founders of the Odessa Polytechnic University (1918). Despite the hard conditions at that time, the scientist, when working as the head of the chair of physics, created a physical laboratory and elevated lecturing and practical courses at the university to a high scientific level.

Oleksandr Henrihovych Goldman (1884, Warsaw, Poland–1971, Kyiv), Academician of the AS UkrSSR (1929), Dr. Sci. in physics and mathematics (1935), Professor (1946). He studied at the Leipzig University (1905–1908), where he defended his doctoral dissertation entitled "*Photoelectric research of elements in dye solutions*" (1908) and obtained the Ph.D. degree. In 1908, he returned to Kyiv and, after graduating from the St. Volodymyr University of Kyiv (1909), began to work at University's physical laboratory as a laboratory assistant. The main directions of his scientific activity were the



O.H. GOLDMAN

S.I. PEKAR

physics of semiconductors and insulators, electroluminescence, and the history of physics.

Being the head of the electroluminescence laboratory at the IP AS UkrSSR (since 1959), O.H. Goldman successfully studied the electroluminescence and electrophotoluminescence phenomena. He obtained and studied the bulk electroluminescence, which is accompanied by the hot-electron emission. Goldman discovered a new type of photographic processes, which is based on the application of a latent image formed in phosphor. This discovery enabled the infrared image to be transformed more effectively into the visible one in comparison with the application of sensibilized photographic plates. In 1963, the scientist began to study the Gudden–Pohl effect, which manifests itself in the light intensity enhancement in strong applied electric fields. O.H. Goldman and his collaborators showed that the Gudden–Pohl effect is an indicator of the photopolarization state in zinc-sulfide phosphor materials [24].

For many years, O.H. Goldman lectured. Much attention was paid by him to the development of physical researches in Ukraine. O.H. Goldman was one of the organizers of the 2nd Congress of the Russian Association of Physicists, which was held in Kyiv in 1921. The same year, he organized and headed one of the first scientific physical centers in Ukraine, the Physical research laboratory at the Kyiv Educational Department, which was reorganized in 1922 into the Kyiv research chair of physics at the Kyiv Polytechnic Institute. A large work of the chair staff under the guidance of O.H. Goldman allowed the chair to be transformed in 1929 into the Kyiv Research Institute of Physics of the People's Commissariat of Education of the Ukrainian SSR. In 1936, the institute was renamed into the IP AS UkrSSR. O.G. Goldman was the director of the IP AS UkrSSR till 1938. The scientist was the creator and the editor of the first physical journal in Ukraine *Fizychni Zapysky* (*Physical Notes*).

Solomon Isaakovych Pekar (1917, Kyiv–1985, Kyiv), Academician of the Academy of Sciences of the UkrSSR (1961). He graduated from the Kyiv University in 1938, lectured at the Kyiv State University in 1941–1944, worked at the IP AS UkrSSR in 1938–1960 and the Institute of Semiconductor Physics of the AS UkrSSR in 1960–1985. The main directions of his scientific activity were the solid state theory, the theory of nuclear forces, the plasma theory, the theory of lasers, and crystal optics.

S.I. Pekar showed theoretically that the spectrum of light absorbed by excitons should be similar by its composition to the spectrum of hydrogen atom [25]. Later, this spectrum was experimentally revealed by E.F. Gross [26]. Pekar is an author of the scientific discovery "The phenomenon of additional light-wave propagation in crystals" (the discovery certificate No. 323 obtained in 1986). His researches in crystal optics, Pekar summarized in the monograph "*Crystal Optics and Additional Light Waves*" [27], which was also translated into English [28].

When defending his Ph.D. thesis in 1941, S.I. Pekar was awarded the degree of the Dr. Sci. in physics and mathematics. This proposition was put forward and supported by such well-known physicists as V.E. Lashkaryov, I.E. Tamm, and Ya.I. Frenkel. S.I. Pekar was one of the founders of the Institute of Semiconductor Physics of the AS UkrSSR. At this institute, he worked from 1960 to 1985 and headed the Department of Theoretical Physics.

4. Spectroscopy

Antonina Fedorivna Prikhotko (1906, Pyatigorsk, Russia–1995, Kyiv), the first woman in the Soviet Union that was awarded the scientific degree of Dr. Sci. in physics and mathematics (1943), Academician of the AS UkrSSR (1964). She worked at the Ukrainian Physico-Technical Institute of the AS UkrSSR in Kharkiv (1930–1941), the Institute of Physical Chemistry of the AS UkrSSR (1941–1944), as the head of the Crystal Physics Department of the IP AS UkrSSR (from 1944), the director of the IP AS UkrSSR (1965–1970). The main directions of her scientific activity were the low-temperature spectroscopy and optics of non-metallic crystals.

The scientific activity of A.F. Prikhotko began at the Leningrad Physico-Technical Institute. In 1930, together with a group of young scientists, she was transferred to Kharkiv to a new Ukrainian Physico-Technical Institute. Her first scientific publications coincided in time with the beginning of a new physics domain, crystal spectroscopy. When working at the Ukrainian Physico-Technical Institute of the AS UkrSSR in Kharkiv, A.F. Prikhotko, under the supervision of I.V. Obreimov, began an important study of the spectra of molecular crystals registered at extremely low temperatures [29].

In 1931, Ya.I. Frenkel theoretically predicted the existence of excitons. When solving the problem about excitations in a perfect crystal, the scientist showed that the excited state of any atom in such a crystal cannot be localized at the atom, but should move over the crystal as an excitation wave. The scientist called this wave the exciton. The excitation energy wanders from atom to atom until one of the atoms, having obtained it, emits it as an energy quantum and transits into the unexcited state. Owing to the exciton migration, light is absorbed and emitted by different atoms that could be separated by a distance much longer than the crystalline lattice period. Therefore, such a glow should be inherent only to objects with a crystalline structure.

A.F. PRIKHOTKO

In the late 1940s, when studying the absorption spectra of molecular crystals (naphthalene, anthracene, benzene, naphtacene, and others), Prikhotko revealed multiplets of bands that were strongly polarized along crystallographic directions, and which were lacking in the spectra of free molecules. The presence of those bands is a characteristic feature of the existence of excitons. The existence of excitons was experimentally detected by E.F. Gross [30, 31]. Later, they were studied in the works of the Kyiv scientific school.

A.F. Prikhotko together with her colleagues experimentally discovered and investigated the optical spectra of excitons in various nonmetallic crystals [32]. She developed a number of methods for growing ultrathin crystals of organic compounds that were suitable for low-temperature spectral researches. One of the first works performed by her at the IP AS UkrSSR (Kyiv) was the study of ultrathin (10^{-8}–10^{-6} m) naphthalene single crystals at hydrogen temperatures.

A.F. Prikhotko established the main regularities in the absorption and emission of light by organic crystals [33], carried out the first low-temperature measurements of normal and anomalous light dispersions in them, experimentally discovered and studied excitons in molecular crystals, and performed a number of works with cryocrystals, which resulted in the dis-

O.S. DAVYDOV

M.T. SHPAK

covery of bi- and multiexcitons. She created a scientific school in Kyiv, whose researches were recognized throughout the world. The works performed by the scientists belonging to Prikhotko's scientific school at the IP AS UkrSSR are fundamental researches in crystal spectroscopy, which opened a new direction in the crystal optics domain.

Oleksandr Sergiyovych Davydov (1912, Yevpatoria – 1993, Kyiv), Academician of the UkrSSR (1964). He worked at the IP AS UkrSSR (1945–1953, 1964–1966), the Obninsk Physico-Energetic Institute (1953–1956), the Moscow University (Professor, 1953–1964), the Institute for Theoretical Physics of the AS UkrSSR (from 1966; as the director from 1973). The main directions of his scientific activity were the theory of excitons in molecular crystals, the theory of atomic nucleus, and quantum biophysics.

O.S. Davydov theoretically substantiated the theory of excitons in molecular crystals [34,35: 328–390]. A light quantum, by acting on the atomic electrons in a crystal, induces the appearance of excitons. Davydov gave a theoretical substantiation of this idea. According to his concept, Frenkel's excitons freely propagate over the crystal in a resonance manner by engaging all molecules in the crystal. The Davydov theory explained the specific features of the light absorption, emission, scattering, luminescence, and dispersion in molecular crystals.

In 1951, Davydov predicted that if a unit cell in the crystal contains a few molecules, the interaction between them results in the multiplet splitting of nondegenerate molecular energy levels. This phenomenon known as the Davydov splitting is a spectral manifestation of the exciton formation and was experimentally detected for the first time at the IP AS UkrSSR.

O.S. Davydov also performed a significant scientific-managerial and editorial work [36: 514]. He was a deputy editor-in-chief of the journal *Dopovidi AN URSR* (*Reports of the AS of the UkrSSR*, from 1980), a member of the editorial and publishing board of the AS UkrSSR, a member of the editorial boards of the journals *Teoreticheskaya i Matematicheskaya Fizika* (*Theoretical and Mathematical Physics*, from 1972), *Yadernaya Fizika* (*Nuclear Physics*, from 1965), and *Ukrainskyi Fizychnyi Zhurnal* (*Ukrainian Journal of Physics*, from 1967).

Marat Terentiyovych Shpak (1926, the village of Chupakhivka, the Sumy region–1993, Kyiv), Corresponding Member of the AS UkrSSR (1969), Academician of the AS UkrSSR (1990). From 1955, he worked at the IP AS UkrSSR (in 1970–1987, as the director). The main directions of his scientific activity were the spectroscopy of solids and quantum electronics.

M.T. Shpak discovered and studied the intrinsic exciton luminescence of molecular crystals and the influence of crystal lattice defects on it. He also studied local exciton states in crystals. M.T. Shpak participated in the development and fabrication of highly stabilized ring lasers on the solutions of organic dyes and on liquid crystals. He carried out thorough re-

searches in the field of crystal luminescence. In particular, he elucidated the role of impurities and defects and studied the spectra of thermally deformed crystals. All those studies comprised a significant contribution to the spectroscopy of molecular crystals.

The scientist was the author and co-author of more than 300 scientific papers and books [37, 38]. The book *Spectroscopy of Defects in Organic Crystals* was translated into English [39]. M.T. Shpak was a head of the Scientific Council on Quantum Electronics of the AS UkrSSR. He took part in the work of the Scientific Council "Luminescence and the development of its application in the national economy" of the Academy of Sciences of the USSR, the Presidium of the republican board of the community *Znannya* (*Knowledge*). He was the deputy editor-in-chief of the *Ukrainian Journal of Physics* and the founder of the Republican School "Spectroscopy of Molecules and Crystals" (1973). M.T. Shpak was the head of the Photoactivity Department at the IP AS UkrSSR from the time moment of its foundation (1966–1993). In 2006, two departments were created on the basis of the Photoactivity Department: the Department of coherent and quantum optics and the Department of laser spectroscopy.

Mykhailo Ulyanovych Bilyi (1922, the village of Moskali, the Chernigiv region–2001, Kyiv), Corresponding member of the IP AS UkrSSR (1969), the head of the Chairs of experimental physics, solid-state optics, and optics at the Faculty of Physics of the Taras Shevchenko State University of Kyiv (1963–1993), and the rector of this university (1970-1985). The main direction of his scientific activity was physical optics.

In 1964, M.U. Bilyi defended his thesis for the degree of Dr. Sci. in physics and mathematics [40]. He performed a number of important studies concerning the luminescence of salt solutions of some heavy metals and their physico-chemical state in the solution. The scientist found conditions for the photoluminescence to appear in electrolyte solutions; namely, he proved the absence of luminescence in such solutions as a result of its strong temperature quenching. M.U. Bilyi was the first who discovered and studied the glow of solutions of bismuth, tin, tellurium, germanium, gallium, indium, copper, gold, and silver salts. Those important researches allowed him to establish a number of regularities in the spectral characteristics of luminescent solutions.

M.U. BILYI

M.P. LISITSA

Mykhailo Pavlovych Lisitsa (1921, the village of Vysoke, the Zhytomyr region–2012, Kyiv), Dr. Sci. in physics and mathematics (1961), Academician of the AS UkrSSR (1982), obtained 40 author's certificates of invention. The main directions of his scientific activity were spectroscopy, nonlinear optics, and quantum electronics.

In 1961, M.P. Lisitsa organized a Department of optics at the IP AS UkrSSR, where a number of world-class discoveries were made. Together with his disciples, he studied comprehensively the behavior of refractive index in the excitonic transition bands at various laser radiation intensities. This research made

V.V. YEREMENKO

I.I. KONDILENKO

it possible to clearly demonstrate the effect of exciton disappearance at high concentrations of photogenerated charge carriers and the emergence of an electron-hole plasma. Under the supervision of M.P. Lisitsa, the combined Fermi–Davydov resonance was discovered in the crystal spectroscopy domain; an exact theory of multilayer systems was developed, which became a basis for the creation of important optical systems for blooming optics, multilayer polarizers, and light reflectors; working exemplars of solid-state lasers were fabricated; and mechanisms of coherent radiation generation and nonlinear optical phenomena were studied. Two new nonlinear optical polarization phenomena were discovered: the extra nonlinear optical activity of gyrotropic crystals and the giant optical activity in non-gyrotropic cubic crystals with impurity tunnel centers. The discovery of those phenomena allowed new methods for the control over light radiation parameters to be implemented.

Academician M.P. Lisitsa formulated a general theory for multilayer optical systems. The technologies of manufacturing infra-red polarizers, multilayer mirrors, light-splitting systems and filters, which were developed by the scientist, were introduced into the industrial production. The international recognition of the works made by the Ukrainian scientist M.P. Lisitsa resulted in his awarding, as an outstanding spectroscopist, of the Johannes Marcus Marci Memorial Medal by the Czechoslovak Academy of Sciences.

Mykhailo Pavlovych was the author and co-author of about 500 scientific works. Among them, there is the textbook *Volokonnaya Optika* (*Fiber Optics*) [41] first in the world, which was translated into English. The scientist was also a well-known popularizer of science, who published a few textbooks [42, 43].

Victor Valentynovych Yeremenko (1932, Kharkiv–2017, Kharkiv), Dr. Sci. in physics and mathematics (1967), Professor (1968), Academician of the AS UkrSSR (1978), the head of the Laboratory of Electrical Conductivity and Superconductivity (1961–1963), the head of the Department of Magnetism and Magnetooptics (1963–1986), the head of the Department of Spectroscopy of Magnetic and Molecular Crystals (1986–1994) at the B.I. Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine (ILTPE NASU), the director of the ILTPE NASU (1991–2006), the Chief Scientist and the Counselor to the administration of the ILTPE NASU (from 2006). The main directions of his scientific activity were the optical and photovoltaic properties of semiconductors and magnetooptics.

V.V. Yeremenko was a co-author in a number of important works dealing with the optical and photovoltaic properties of semiconductors [44–46] and the spectroscopy of molecular crystals [47, 48]. The Ukrainian scientist was the first who discovered the existence of exciton-impurity complexes and introduced the corresponding notion in his Ph.D. thesis "*Optical and photovoltaic phenomena in CdS crystals at low temperatures*" (1959). The scientist carried out important researches of the spectral and magneto-optical properties of antiferromagnetic crys-

tals. In 1966, he defended his Dr. Sci. thesis entitles "*Optical spectroscopy of antiferromagnets*". Those experimental researches played a crucial role in the formation of modern concepts about the interaction of light with magnetic crystals. It was proved for the first time that the electron-magnon light absorption bands are more sensitive to the magnetic ordering than the electron ones.

V.V. Yeremenko was a co-author of more than 400 publications, including the books "*Introduction to Spectroscopy of Magnets*", "*Magnetooptics and Spectroscopy of Antiferromagnets*", and "*Magnetic and Magnetoelastic Phenomena in Antiferromagnets and Superconductors*". The last two books were translated into English. For many years (1966–1999), V.V. Yeremenko lectured at the Kharkiv State University. He was a co-author of the textbook "*Lectures on Magnetism*". Much attention was paid by V.V. Yeremenko to the international cooperation. He was the editor-in-chief of the journal *Fizika Nizkikh Temperatur* (*Low Temperature Physics*).

5. Nonlinear Optics

Ivan Ivanovych Kondilenko (1919, the village of Velyke Mishkove, the Donetsk region–1993, Kyiv), Corresponding member of the AS UkrSSR (1967), the head of the Department of Experimental Physics (1951–1963), the dean of the Faculty of Radiophysics (1963–1972), and the head of the Department of Nonlinear Optics (1963–1981) at the Taras Shevchenko State University of Kyiv. The main directions of his scientific activity were the molecular and atomic spectroscopy, Raman scattering, quantum electronics, solid state physics, and nonlinear optics.

In 1950, I.I. Kondilenko successfully defended his Ph.D. thesis entitled "*Luminescence and absorption of thallium salt solutions*" and, in 1965, the Dr. Sci. thesis "*Influence of excitation conditions and physical state of the medium on the intensity of Raman spectra*". He studied of the indicatrix of the Raman scattering and measured, for the first time, the absolute energy yield for this phenomenon with the help of a specially created low-pressure cylindrical mercury lamp, which turned out to be 300 to 400 times more efficient than the existing analogs. I.I. Kondilenko obtained the values of the Fermi resonance in Raman spectra and revealed a competition between components of the induced Raman scattering. On the basis of the own researches, he created a device for the remote determination of the atmosphere composition (the lidar: light, detection, and ranging).

I.I. Kondilenko was the founder of the scientific school of Raman scattering spectroscopy in Ukraine. He was engaged into the educational activity, was the chairman of the board of the Ukrainian community *Znannya* (*Knowledge*) in 1970–1978). The scientist was a co-author of some tutorials [49, 50].

6. Conclusions

The analysis of the works of Ukrainian scientists allowed a conclusion to be drawn about the priority of some of their researches in the world science.

The modulation approach to the light scattering phenomenon proposed by L.I. Mandelshtam in 1918, when he worked at the Odessa Polytechnic Institute, favored the rapid progress in optics. The discovery of Raman scattering enabled L.I. Mandelshtam to develop a new method for the spectral analysis of molecules, which received recognition in world's scientific community.

In the 1920s, researches of the Lippman color photography and light dispersion were carried out at the Chair of Physics of the Odessa University under the supervision of M.P. Kasterin. Those works formed a basis for the creation of the scientific school of E.A. Kirillov, which has made a significant progress in the development of the theory of latent photographic images.

The works performed by I.V. Obreimov and A.F. Prikhotko in the 1930s at the Ukrainian Physico-Technical Institute of AS UkrSSR started new directions of physical science: low-temperature spectroscopy and optics of nonmetallic crystals. For the first time in the spectroscopy history, a wide range of researches were carried out dealing with the properties of molecular crystals at temperatures close to 0 K. Those researches made it possible to establish a close relationship between the spectra of substances and their crystalline structure.

The manifestations of excitons in absorption spectra was experimentally revealed by E.F. Gross and studied in detail in the works of the Kyiv scientific school (V.L Broude, A.F. Prikhotko, E.Y. Rashba). In 1944, A.F. Prikhotko created a Crystal Physics Department at the IP AS UkrSSR, which was initially aimed at the low-temperature spectroscopy of molecular crystals. A.F. Prikhotko orga-

nized a spectral laboratory, which became world's largest center of the low-temperature spectroscopy of nonmetallic crystals. The role playing by impurities and defects of the crystalline lattice in the fluorescence of molecular crystals was studied. The intrinsic exciton luminescence of molecular crystals was discovered and researched. A method to study the genesis and structure of exciton zones was developed. Precise methods of measurement of the light absorption and dispersion in molecular crystals were developed, which allowed effects predicted by the theory in the exciton absorption range, e.g., additional light waves in crystals due to the spatial dispersion, to be revealed. The shapes of exciton absorption bands were measured for the first time, and their relationship with the excitation of excitons of various types was demonstrated.

The researches of excitonic states performed by A.F. Prikhotko, M.T. Shpak, and M.S. Brodyn at the IP AS UkrSSR are classified as fundamental works in crystal spectroscopy. Those works laid a basis for the creation of a new method to study imperfections of the crystalline structure, a new method to study the deformation origin, and the theory in the crystal optics of absorbing media. In close connection with those works, the scientists belonging to the scientific school of O.S. Davydov (A.F. Lubchenko, E.Y. Rashba) developed the theory of excitons in molecular crystals. This theory explained the specific features of the absorption, radiation, luminescence, scattering, and light dispersion in molecular crystals. These were fundamental experimental and theoretical studies of excitons in crystals, which initiated a broad study of the spectra of nonmetallic crystals in world's science.

In the domain of incoherent optoelectronics, significant works were performed by S.V. Svechnikov at the Institute of Semiconductor Physics of the AS UkrSSR, which made it possible to develop a number of optoelectronic devices for the analog and discrete measurements and computational facilities. Academician V.V. Yeremenko performed important works dealing with the optical and photovoltaic properties of semiconductors, as well as optics, spectroscopy. and phase transitions in magnetically ordered crystals. Academician M.S. Brodyn is now working in the field of nonlinear optics. He has trained a group of talented disciples (I.V. Blonskyi, A.A. Borshch). The scientist measured the optical characteristics of molecular crystals in the interval of characteristic absorption, which enabled such parameters of exciton excitation as oscillator forces to be determined. Together with his collaborators, M.S. Brodyn carried out, for the first time, thorough researches of the shape of low-temperature curves for the main optical characteristics of molecular and semiconductor crystals. As a result, data on the exciton-phonon interaction were obtained.

Besides the scientific and research work, the scientists pay a considerable attention to the teaching one. Many of the researchers created their scientific schools and are engaged in the educational activity. It is well-known that, in his introductory lecture to the course of physics at the Odessa Polytechnic Institute, Academician L.I. Mandelshtam addressed the students with the following words: "If any of you feels a desire to study physics, I will always help with a great pleasure in this endevour" [51].

1. A. Kogar *et al.* Signatures of exciton condensation in a transition metal dichalcogenide. *Science* **358**, No. 6368, 1314 (2017).
2. A. Prikhotjko. Absorption spectra of crystals at low temperatures. *J. Phys. USSR* **8**, 257 (1944).
3. A.F. Prikhotko. Research of the spectra of molecular crystals at low temperatures. *Opt. Spektrosk.* **3**, No. 5, 434 (1957) (in Russian).
4. A.S. Davydov. *Theory of Molecular Excitons* (Plenum, 1971).
5. V.L. Broude, E.I. Rashba, E.F. Sheka. *Spectroscopy of Molecular Excitons* (Springer, 1985).
6. Antonina Fedorivna Prykhotko (to her 100th birthday). *Ukr. J. Phys.* **51**, No. 4, 327 (2006).
7. Mykhailo Pavlovych Lisitsa (to his 85th birthday). *Ukr. J. Phys.* **51**, No. 4, 423 (2006).
8. O. Proskura. Creative work regardless of obstacles: The Ukrainian physicist Oleksandr Goldmann (1884–1971). *Ukr. J. Phys.* **51**, No. 10, 1028 (2006).
9. A. Tan'shyna. To the 110-th anniversary of Academician of the NAS of Ukraine B.G. Lazarev's birthday. *Ukr. J. Phys.* **61**, No. 8, 753 (2016).
10. V.G. Lytovchenko. Academician of the NAS of Ukraine Vadym Evgenovych Lashkaryov: The outstanding physicist of the 20-th century, the discoverer of a $p-n$-junction (to the 55-th anniversary of the Foundation of the Institute of Semiconductor Physics of the NAS of Ukraine). *Ukr. J. Phys.* **61**, No. 2, 181 (2016).
11. V.G. Lytovchenko. On some important results in semiconductor surface science obtained in Ukraine during the independence years (1991-2016). *Ukr. J. Phys.* **62**, No. 1, 80 (2017).
12. V.P. Linnyk, V.E. Lashkaryov. Methods of X-ray focusing. *Ukr Fiz. Zap.* **1**, No. 1, 5 (1926) (in Ukrainian).
13. V.P. Linnyk, V.E. Lashkaryov. Determination of the X-ray refractive index from the total internal reflection

phenomenon. *Ukr. Fiz. Zap.* **1**, No. 2-3, 3 (1927) (in Ukrainian).
14. W. Linnik. Method of determining the position of the symmetry axis of a crystal by means of X-rays. *Nature* **124**, No. 3138, 946 (1929).
15. W. Linnik. Der Interferenzversuch von Lloyd mit Röntgenstrahlen. *Z. Phys.* **65**, No. 1-2, 107 (1930).
16. V.P. Linnik. Academician D.S. Rozhdestvenskii's works in microscopy. *Izv. Akad. Nauk SSSR Ser. Fiz.* **5**, No. 6, 622 (1941) (in Russian) .
17. V.P. Linnik. Kepler's works in optics (On the 400th anniversary of his birth). *Usp. Fiz. Nauk* **109**, No. 1, 167 (1973) (in Russian).
18. G.G. Kordun. *Soviet Physicists* (Vyshcha Shkola, 1975) (in Ukrainian).
19. G.G. De-Mets. *General Methodology of Teaching Physics. Theory and Practice of Teaching* (DVU, 1929) (in Ukrainian).
20. G.G. De-Mets. Centenary of metric system (1799–1899). *Fiz. Obozr.* **2**, 5 (1901) (in Russian).
21. L.I. Mandelshtam. On the problem of light scattering by an inhomogeneous medium. *Zh. Russ. Fiz. Khim. Obshch.* **58**, 381 (1926) (in Russian).
22. L. Brillouin. Diffusion de la lumière et des rayons X par un corps transparent homogène. Influence de l'agitation thermique. *Ann. Phys.* **17**, 88 (1922).
23. Gr. Landsberg, L. Mandelstam. Eine neue Erscheinung bei der Lichtzerstreuung in Krystallen. *Naturwissenschaften* **16**, H. 27, 557 (1928).
24. A.G. Goldman, A.I. Proskur. On the nature of Gudden–Pohl effect. *Dokl. Akad. Nauk SSSR* **150**, No. 3, 519 (1963) (in Russian).
25. S.I. Pekar.The theory of electromagnetic waves in a crystal in which excitons are produced. *Zh. Èksp. Teor. Fiz.* **33**, No. 4, 1022 (1958) (in Russian).
26. E.F. Gross. Excitons and their motion in crystal lattices. *Usp. Fiz. Nauk* **76**, No. 3, 433 (1962) (in Russian).
27. S.I. Pekar. *Crystal Optics and Additional Light Waves* (Naukova Dumka, 1982) (in Ukrainian).
28. S.I. Pekar. *Crystal Optics and Additional Light Waves* (Benjamin. 1983).
29. I. Obreimow, A. Prichotjko. Die Absorptionsspektren der Krystalle einiger Verbindungen der aromatischen Reihe bei niedrigen Temperaturen. *Phys. Z. Sow.* **1**, 203 (1932).
30. E. Gross, M. Vuks. Sur le nouveau type du spectre de diffusion des cristaux et la structure des liquides. *J. Phys. Radium* **7**, No. 3, 113 (1936).
31. E.F. Gross. Excitation spectrum of excitons in crystal lattice. *Usp. Fiz. Nauk* **63**, No. 3, 575 (1957) (in Russian).
32. V.L. Broude, A.F. Prikhotko, E.I. Rashba. Some problems of crystal luminescence. *Usp. Fiz. Nauk* **67**, No. 1, 99 (1959) (in Russian).
33. *Absorption Spectra of Molecular Crystals. Benzene, and Some of Its Homologs.* Edited by V.L. Broude, A.F. Prikhotko (Naukova Dumka, 1965) (in Russian).
34. A.S. Davydov. *Theory of Light Absorption in Molecular Crystals* (Academy of Sciences of the Ukrainian SSR, 1951) (in Russian).
35. A.S. Davydov, *Solid State Theory* (Academic Press, 1980).
36. Yu.B. Gaididei, V.M. Loktev. Oleksandr Sergiyovych Davydov (1912–1993). *Ukr. Fiz. Zh.* **58**, No. 6, 513 (2013) (in Ukrainian).
37. E.A. Tikhonov, M.T. Shpak. *Nonlinear Optical Phenomena in Organic Compounds* (Naukova Dumka, 1979) (in Russian).
38. N.I. Ostapenko, V.I. Sugakov, M.T. Shpak. *Spectroscopy of Defects in Organic Crystals* (Naukova Dumka, 1988) (in Ukrainian).
39. N.I. Ostapenko, V.I. Sugakov, M.T. Shpak. *Spectroscopy of Defects in Organic Crystals* (Kluwer, 1993).
40. M.U. Belyi. *Luminescence and Absorption in Electrolyte Solutions.* Dr. Sci. thesis (Kyiv, 1964) (in Russian).
41. M.P. Lisitsa, L.I. Berezhinskii, M.Ya. Valakh. *Fiber Optics* (Tekhnika, 1968) (in Russian).
42. M.P. Lisitsa, M.Ya. Valakh. *Entertaining Optics: Atmospheric and Cosmic Optics* (Logos, 2002) (in Russian).
43. M.P. Lisitsa, E.F. Wenger. *Entertaining Optics: Physiological Optics. The People's World* (Vyshcha Shkola, 2003) (in Russian).
44. V.L. Broude, V.V. Yeremenko, E.I. Rashba. Light absorption by CdS crystals. *Dokl. Akad. Nauk SSSR* **114**, No. 3, 520 (1957) (in Russian).
45. V.V. Yeremenko. Luminescence of CdS crystals. *Opt. Spectrosk.* **4**, No. 3, 348 (1958) (in Russian).
46. V.L. Broude, V.V. Yeremenko, N.N. Chikovani. Structure of absorption and photoconductivity spectra of CdS crystals at 20 K. *Dokl. Akad. Nauk SSSR* **119**, No. 5, 911 (1958) (in Russian).
47. V.V. Yeremenko, V.S. Medvedev. On the dependence of photoconductivity and luminescence intensity of anthracene crystals on the exciting light wavelength. *Fiz. Tverd. Tela* **2**, No. 7, 1572 (1960) (in Russian).
48. V.V. Yeremenko, Yu.G. Litvinenko, E.M. Ogneva. Temperature dependence of the band intensity of "cooperative" light absorption by crystalline oxygen. *Zh. Èksp. Teor. Fiz.* **48**, No. 6, 1611 (1965) (in Russian).
49. I.I. Kondilenko, P.A. Korotkov. *Introduction to Atomic Spectroscopy* (Vyshcha Shkola, 1976) (in Russian).
50. I.I. Kondilenko, P.A. Korotkov, A.I. Khizhnyak. *Physics of Lasers* (Vyshcha Shkola, 1984) (in Russian).
51. *Academician Leonid Isaakovich Mandelshtam (Collection of papers)* (Znanie, 1980) (in Russian).

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ВНЕСОК УКРАЇНСЬКИХ
ВЧЕНИХ У РОЗВИТОК ОПТИКИ

Р е з ю м е

Доведено важливість досліджень українських вчених у становленні оптики як науки. Проаналізовано значний внесок робіт науковців АН УРСР. Визначено пріоритетність низки досліджень українських вчених у світовій науці. Звернено увагу на педагогічну та просвітницьку роботу вчених. Матеріал систематизовано згідно з відповідними розділами оптики.