

ALEXANDER IL'ICH AKHIEZER

(1911 – 2000)



Alexander Il'ich Akhiezer was born on October 31, 1911, in Cherikov (a small town of a west of the Russian empire, nowadays this city is in Byelorussia). His father was a municipal doctor ("zemsky doctor"), who graduated from Kharkov University. A.I. Akhiezer displayed an interest in mathematics and physics at an early age.

After studying in Kiev Polytechnical Institute from 1929 to 1934 A.I. Akhiezer moved to Kharkov on the advice of his elder brother Naum Il'ich Akhiezer, a mathematician, who at that time already worked in Kharkov.

Although A.I. Akhiezer had received his diploma in radioengineering, theoretical physics attracted him much more. In Kharkov he met with L.D. Landau, later a Nobel Laureate (1962), who was then the Head of the Department for Theoretical Physics at the Ukrainian Physical-Technical Institute (usually abbreviated to UPhTI in Russian). This Institute was at that time one of the largest physical institutes in the USSR (now it is the National Science Center "Kharkov Institute of Physics and Technology", short name is NSC KIPT). As A.I. Akhiezer recollected many years later, after the conversation with L.D. Landau, bearing rather a resemblance of examination on theoretical physics, he was included in the staff of the Department for Theoretical Physics.

The first works of A.I. Akhiezer were done in quantum electrodynamics and were carried out under the Landau guidance. After the appearance of the Dirac theory, it was evident that, due to an existence of electron states with negative energy, fundamentally new non-linear effects, such as light scattering by light and light scattering by a static electrical field, should take place.

The light – light scattering was investigated in the range of frequencies $\hbar\omega \ll mc^2$ by H. Euler in 1936.

L.D. Landau set for A.I. Akhiezer a more difficult problem, to develop the theory of the light - light scattering in the range of high frequencies of light (high energies of photons), where the construction of the Lagrange function (as in the work of W. Heisenberg and H. Euler, 1936) was impossible. I.Ya. Pomeranchuk, who worked at the Theoretical Physics Department in 1936-37, was also engaged into this problem.

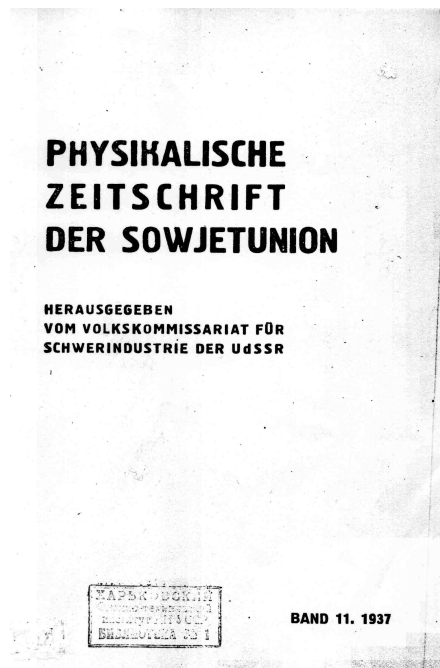
The first result of their work concerning the estimate of the cross-section in the ultrarelativistic case $\hbar\omega \gg mc^2$, was published as a brief communication in "Nature" (Scattering of Light by Light. *Nature*, 1936, vol. 138, p. 206). In a full form the results were published in *Physikalische Zeitschrift der Sowjetunion*.

The second work of A.I. Akhiezer (with I.Ya. Pomeranchuk) in quantum electrodynamics was dedicated to the theory of another non –linear effect – the coherent scattering of γ -rays in the Coulomb field of nucleus.

In 1936 A.I. Akhiezer had defended his Candidate (PhD) thesis. His supervisor was L.D. Landau and the examiners (reviewers) were I.Ye. Tamm and G. Plaček. A.I. Akhiezer recollected in detail this event in June 1994 issue of *Physics Today*.

In 1938 Alexander Il'ich Akhiezer was promoted to the position of the Head of Department for Theoretical Physics. This position became vacant because L.D. Landau left Kharkov for working in Moscow.

A.I. Akhiezer was an exceptionally creative scientist. He made outstanding contributions to a number of fields of theoretical physics, being a scientist of truly encyclopedic knowledge and possessing a genius intuition. He worked in the widest range of research field. Sometimes, it was called "the Akhiezer's phenomenon".



Journal "Physikalische Zeitschrift der Sowjetunion" and the first page of the A.I. Akhiezer's paper "Über die Streuung von Licht an Licht", volume 11, Kharkov, UPhTI, 1937

In 1938 A.I. Akhiezer considered the problem of the modification of the quasiparticle energy in a crystal with the low - frequency sound wave propagating in it.

The mechanism of absorption, provoked by the modulation of the quasiparticle energy by the external field, is known now as "Akhiezer attenuation". Taking into account the quasiparticle spectrum modification in the external field allowed A.I. Akhiezer to establish the kinetic equation for quasiparticles, to formulate the H-theorem for the quasiparticle gas and to develop the kinetic theory of the acoustic field energy absorption in dielectrics and metals.

These works formed the basis of his Doctoral thesis. In 1941, after the defence of the thesis for Doctor's degree in 1940, A.I. Akhiezer was awarded a Full Professor title.

In 1944, A.I. Akhiezer was called to work in the Laboratory No 2 (later renamed the I.V. Kurchatov Institute of Atomic Energy, Moscow), where he worked until 1952 in a group headed by I.Ya. Pomeranchuk.

It was time when A.I. Akhiezer performed the pioneering studies of the scattering of slow neutrons by crystals and the problem of neutrons slowing-down. During his work in Moscow, A.I. Akhiezer with I.Ya. Pomeranchuk wrote the first in the USSR book on the theory of resonance nuclear reactions, the theory of multiplying media and its applications to nuclear reactor design (unfortunately, published only now).

In 1945, A.I. Akhiezer and I.Ya. Pomeranchuk were the first to consider the elastic scattering of protons by absorbing nuclei. They investigated also the role of the Coulomb interaction in the formation of the diffraction scattering pattern. This approach was later called the Akhiezer-Pomeranchuk-Blair model. A.I. Akhiezer and

ÜBER DIE STREUUNG VON LICHT AN LICHT.

Von A. Achieser.

(Eingegangen am 15. Dezember 1936.)

Die aus der Diracschen Theorie des Positrons folgende Streuung von Licht an Licht wird im Falle hoher Frequenzen untersucht. Der Wirkungsquerschnitt wird für kleine Streuwinkel θ in dem Koordinatensysteme berechnet, in dem der Gesamtimpuls der stossenden Lichtquanten gleich Null ist. Es ergibt sich

$$d\sigma = \frac{a^4}{\pi^2} \left(\frac{c}{\omega} \right)^2 \log^4 \theta d\omega,$$

wobei $d\omega$ das Raumwinkelement und a die Feinstrukturkonstante ist. Der totale Streuquerschnitt ist

$$\sigma = a^4 \left(\frac{c}{\omega} \right)^2,$$

wobei a ein numerischer Koeffizient ist, dessen Ausrechnung auf grosse Schwierigkeiten stösst.

Bekanntlich folgt aus der Diracschen Theorie des Positrons die Möglichkeit einer Streuung von Licht an Licht, d.h. der Übergang von zwei Quanten in zwei andere Quanten, wobei die Energie und der Impuls erhalten bleiben.

Euler und Kockel¹ haben den Wirkungsquerschnitt für diesen Effekt für kleine Frequenzen

$$h\omega \ll mc^2$$

berechnet.² Dabei ist das Koordinatensystem zugrunde gelegt, in dem der Gesamtimpuls der stossenden Quanten Null ist. ω ist die gemeinsame Frequenz der Quanten in diesem System.

In vorliegender Arbeit³ untersuchen wir den entgegengesetzten Grenzfall

$$h\omega \gg mc^2.$$

¹ Euler, Annal. d. Phys. (5) 26, 398, 1936. Ferner Euler und Kockel, Naturwiss. 23, 246, 1935.

² h ist die Plancksche Konstante, dividiert durch 2π .

³ Siehe die vorläufige Mitteilung, Nature 138, 206, 1936.

I.Ya. Pomeranchuk developed also a general theory of inelastic scattering of slow neutrons by crystals.

In addition, A.I. Akhiezer initiated a study of the significant problems in the plasma physics.

In 1949, A.I. Akhiezer and Ya.B. Fainberg published a pioneering work devoted to instability problem of plasma-beam system that later was recognized as a classical work. It predicted a new effect: the plasma beam instability when the electron beam passes through plasma.

In 1948 the journal *Uchenye Zapiski Kharkovskogo Universiteta* (Communications of the Kharkov State University) published an article by A.I. Akhiezer and L.E. Pargamanik on the kinetic theory of oscillations in plasma in the magnetic field. A phenomenon of an electron cyclotron resonance in such plasma were also predicted in this pioneering work.

Since the middle of the fifties the field of activity of Alexander Il'ich Akhiezer and his scientific interests enlarged extremely. With the quantum electrodynamics and nuclear physics he became engaged in the theory and design of electron and proton accelerators, theory of kinetic, relaxational and high-frequency processes in magnetics, plasma physics, theory of shock waves, and magnetic hydrodynamics. During the same years a group of the talented physicists-theorists had grown under his supervision and started to carry out researches in a very wide range of physical problems.

The research in scattering of weekly bound nuclear systems led A.I. Akhiezer with A.G. Sitenko to the prediction of a new effect - deuteron diffraction dissociation in the nuclear field (1955). It should be noted that this effect was also independently predicted by Glauber and Feinberg.

In 1957, A.I. Akhiezer and A.G. Sitenko developed a consistent theory of deuteron-nucleus diffraction interactions.

A.I. Akhiezer, with V.G. Baryakhtar and S.V. Peletminskii, developed the theory of coupled magneto-acoustic waves and predicted a new effect—magnetoacoustic resonance revealing itself, in particular, in the ultrasound resonance excitation by an external alternating magnetic field (1956).

As a continuation and development of the basic work of A.I. Akhiezer on the theory of sound absorption in dielectrics and metals (1938), A.I. Akhiezer, M.I. Kaganov, and G.Ya. Lyubarsky elaborated in 1957 a theory of the ultrasound absorption in metals.

Later, in the 50s and 60s, A.I. Akhiezer developed a general theory of the processes of scattering and transformation of waves in plasma (with A.G. Sitenko, K.N. Stepanov, and R.V. Polovin). In 1957, he studied the scattering of electromagnetic waves in plasma by electron and ion fluctuations (with A.G. Sitenko and I.G. Prokhoda).

A.I. Akhiezer performed the deep investigations on theory of the non-linear waves in plasma (with G.Ya. Lyubarskii, R.V. Polovin, and K.N. Stepanov). With G.Ya. Lyubarskii and R.V. Polovin, he formulated the evolution condition and the stability criterion for magnetohydrodynamic waves.

A.I. Akhiezer have written one of the first reviews on the renormalization formalism in the quantum electrodynamics (1953) and a fundamental monographs on the quantum electrodynamics (with V.B. Berestetsky), which was published in Russian in 1953 and translated in English in 1957. Decades long, an indispensable attribute of many papers on the quantum electrodynamics processes was the reference to the monograph *Quantum Electrodynamics* by A.I. Akhiezer and V.B. Berestetsky.

A.I. Akhiezer, V.F. Aleksin and D.V. Volkov carried out the studies in quantum electrodynamics of scalar particles.

The radiation corrections in quantum electrodynamics (QED) were calculated to the scattering of electron by electron and positron at high energies, to the bremsstrahlung radiation, and to the photoproduction of electron-positron pairs at heavy nuclei (A.I. Akhiezer, R.V. Polovin, P.I. Fomin et al).

In late 60s, A.I. Akhiezer, P.I. Fomin, and N.F. Shul'ga carried out the studies of high-order QED contributions of perturbation theory to the interaction of relativistic particles with crystals. Later A.I. Akhiezer developed the quasi-classical theory of coherent bremsstrahlung radiation of ultrarelativistic electrons and positrons in crystals. The theory made it possible to study, on the same grounds, the various mechanisms of particle radiation in crystals and to predict a number of new effects (A.I. Akhiezer, V.F. Boldyshev et al). The effects of coherence were also studied for the processes of electron - positron pair formation when electrons pass through crystals or at scattering of charged particles (A.I. Akhiezer, N.F. Shul'ga et al).

In 1968, A.I. Akhiezer and M.P. Rekaló developed a theory of polarization effects in elastic scattering of

high - energy electrons by protons, taking into account the polarization of particles in initial and final states. In the 70s, A.I. Akhiezer with M.P. Rekaló conducted a large cycle of the investigations on theory of the diffraction hadron scattering at high energies and the application of quark model in the electrodynamics of hadrons.

In late 90s, A.I. Akhiezer carried out the theoretical investigations of phase transitions in nuclear matter using the generalized Fermi-liquid theory of Landau, (with S.V. Peletminskii, A.A. Isayev, A.A. Yatsenko, and A.P. Rekaló). In the framework of this approach A.I. Akhiezer, S.V. Peletminskii and N.V. Laskin studied also a spontaneous magnetization of dense neutron gas and instabilities in the quark plasma.

Renowned are the numerous monographs by A.I. Akhiezer on various fields of theoretical physics: *Quantum Electrodynamics, Some Problems in Nuclear Theory, Spin Waves, Collective Oscillations in Plasma, Electrodynamics of Plasma, Methods of Statistical Physics, Electrodynamics of Hadrons, Theory of Fundamental Interactions, High Energy Electrodynamics in Matter, Electrodynamics of Nucleus*.

With L.D. Landau and E.M. Lifshits, A.I. Akhiezer wrote a wonderful textbook in general physics for universities – *Mechanics and Molecular Physics* (Moscow, 1965, 1969).

Alexander Il'ich Akhiezer devoted a great attention to a popularization of newest advances in physical science. In 1973 he wrote small popular book *Evolution of Physical Picture of World* (Kyiv, 1973, in Ukrainian). Later he wrote, with M.P. Rekaló, popular scientific books *Physics of Elementary Particles* (Kiev, 1979), *Elementary Particles* (Moscow, 1986) and *Biography of Elementary Particles* (Kiev, 1979, 1983), and with Yu.P. Stepanovsky – *From Quanta of Light to Colour Quarks* (1993).

Altogether, Alexander Il'ich Akhiezer was an author and a coauthor of about 300 papers, 16 monographs, 11 textbooks and popular scientific books.

Since early 90s, A.I. Akhiezer became to be actively interested in history of physics and genesis of scientific theories, that led him to writing a book *Evolving Physical Picture of the World*, published in 1998 by the NSC KIPT, Kharkov. He wrote in the Preface: "This book is about the fundamental ideas, which form the basis of the physical science. The author hopes that the evolution picture of the World in all its greatness would emerge before the reader after he becomes acquainted with the history of these ideas and with the effect they exercised".

The book was written so that it seems to a reader that he "hears" a voice of the author, brilliant lecturer and talented teacher. It is not incidental since the author who completely had lost his sight, was unable to read and write in 90s. Alexander Il'ich Akhiezer dictated the text of this book to his daughter and tireless assistant Zoya A. Spolnik.

Alexander Il'ich Akhiezer was a lecturer of an extraordinary talent. His pedagogical activities cover more than half a century. It started in 1936 at the Kharkov Electrotechnical Institute. Later on, he

accepted the proposal of L.D. Landau, who chaired the Department of General Physics at Kharkov State University (KSU), and began to lecture different courses at the University. For a long time from 1936 to 1990, A.I. Akhiezer was a Full Professor at KSU. From 1945 to 1975, he also headed the Department of Theoretical Nuclear Physics of KSU. From 1951 to 1964, A.I. Akhiezer was simultaneously professor at the Artillery Radiotechnical Academy in Kharkov.

A.I. Akhiezer was, with K.D. Sinelnikov and A.K. Val'ter, one of the founders of the Faculty for Physics and Technology at KSU.

Alexander Il'ich Akhiezer continued the traditions of training of physicists for research work which were initiated in Kharkov by his teacher L.D. Landau. The talented supervisor and organizer, a person of great erudition, charming and witty interlocutor, full of new ideas and always open for discussion, A.I. Akhiezer was a true scientific leader.

He was the teacher and mentor of several generations of physics in Ukraine, one of the founding fathers of the well-known informal "community" of Kharkov theoreticians – Kharkov School of Theoretical Physics.

Many Akhiezer's former students, whose Ph. D. thesis supervisor was Alexander Il'ich, successfully work in Armenia, Canada, Georgia, Russia, Ukraine, and USA. Among them more than 40 obtained Ph.D. degrees and seven theoretical physicists, V.G. Baryakhtar, Ya.B. Fainberg, P.I. Fomin, S.V. Peletminskii, A.G. Sitenko, K.N. Stepanov, and D.V. Volkov, were elected to the Academy of Sciences of Ukraine.

In 1996, on his initiative, the Institute for Theoretical Physics (as a division of NSC KIPT) was created on the base of the Departments for Theoretical Physics of NSC KIPT. Now the Institute for Theoretical Physics is named after A.I. Akhiezer. Here, as well as in other Institutes of NSC KIPT, theoretical physicists are working, whose lecturer or supervisor was A.I. Akhiezer.

A.I. Akhiezer received the *L.I. Mandelshtam Prize* of the Academy of Sciences of the USSR (1949), the *N.N. Bogolyubov Prize* (1995) and the *A.S. Davydov Prize* (2000) of the National Academy of Sciences of Ukraine.

In 1998, he shared the first *I.Ya. Pomeranchuk International Prize*, awarded by the Institute of Theoretical and Experimental Physics (Moscow, Russia), with Professor S.D. Drell (Stanford, USA).

In 1986 Alexander Il'ich Akhiezer was awarded a honored title the Honored Man of Science of Ukrainian Republic and the *State Prize of Ukraine* for the outstanding contribution to development of science and technology.

From 1934 to the last day of his life, he worked at the Kharkov Physical – Technical Institute (UPhTI -KhPhTI–NSC KIPT).

From 1955 to 1959, A.I. Akhiezer was the Deputy Director for Science of the Ukrainian Physical – Technical Institute. A.I. Akhiezer headed the Department for Theoretical Physics at NSC KIPT until

1988, when he got the position of Scientific Adviser at the Directorate of the NSC KIPT.

He was a member Academic Councils of the Ukrainian Physical–Technical Institute and Kharkov State University, Science and Technology Council of the NSC KIPT. He was the Honored Chair of Scientific Council of the Institute for Theoretical Physics of NSC KIPT.

On October 31, 2001, the full member of the National Academy of Sciences of Ukraine (since 1964), Alexander Il'ich Akhiezer would be 90. For all who had a good chance to know him, he was an elder colleague, who's kind-heartedness, charm of manner, and devotion to science cannot be forgotten.

I. List of monographs of A.I. Akhiezer (Editions in English)

1. A.I. Akhiezer, V.B. Berestetsky. *Quantum Electrodynamics*. New York: "Consultants Bureau", 1957.
2. A.I. Akhiezer, V.B. Berestetskii. *Elements of Quantum Electrodynamics*. London: "Oldbourne Press", 1962.
3. A.I. Akhiezer, V.B. Berestetskii. *Quantum Electrodynamics*. (English edition revised and enlarged by the authors). New York – London: "Wiley – Interscience", 1965.
4. A.I. Akhiezer, I.A. Akhiezer, R.V. Polovin, A.G. Sitenko, and K.N. Stepanov. *Collective Oscillations in a Plasma*. Oxford – London: "Pergamon Press", 1967.
5. A.I. Akhiezer, V.G. Bar'yakhtar, and S.V. Peletminskii. *Spin Waves*. Amsterdam: "North – Holland", 1968.
6. A.I. Akhiezer, I.A. Akhiezer, R.V. Polovin, A.G. Sitenko, and K.N. Stepanov. *Plasma Electrodynamics. Volume 1. Linear Theory*. Oxford: "Pergamon Press", 1975.
7. A.I. Akhiezer, I.A. Akhiezer, R.V. Polovin, A.G. Sitenko, and K.N. Stepanov. *Plasma Electrodynamics. Volume 2. Non-Linear Theory and Fluctuations*. Oxford: "Pergamon Press", 1975.
8. A.I. Akhiezer, S.V. Peletminskii. *Methods of Statistical Physics*. Oxford: "Pergamon", 1981.
9. A.I. Akhiezer, A.G. Sitenko, V.K. Tartakovskii. *Nuclear Electrodynamics*. Berlin: "Springer", 1994.
10. A.I. Akhiezer, N.F. Shul'ga. *High-Energy Electrodynamics in Matter*. Amsterdam: "Gordon and Breach", 1996.
11. A.I. Akhiezer, Yu.A. Bereznoy, and V.V. Pilipenko. *Nuclear Diffraction*. Physics Reviews, v. 18, ed. by I.M. Khalatnikov, Amsterdam: "Harwood Academic - Gordon and Breach", 1997.
12. A.I. Akhiezer, N.F. Shul'ga, and V.I. Truten'. *Coherent Effects in Scattering and Radiation of High -Energy Particles in Crystals*. Physics Reviews, v. 19, ed. by I.M. Khalatnikov, Amsterdam: "Gordon and Breach – Harwood", 1998.

13. A.I. Akhiezer, S.V. Peletminsky. *Fields and Fundamental Interactions*. London - New York: "Taylor & Francis", 2002.

II. List of monographs of A.I. Akhiezer (Editions in Russian)

1. A. Akhiezer, I. Pomeranchuk. *Nekotorye voprosy teorii jadra* [Some Problems in Nuclear Theory]. Moscow - Leningrad: "Gostechizdat", 1948 (1950, 2nd edition).
2. A.I. Akhiezer, V.B. Berestetsky. *Kvantovaja elektrodinamika* [Quantum Electrodynamics]. Moscow: "Gostechizdat", 1953.
3. A.I. Akhiezer, V.B. Berestetsky. *Kvantovaja elektrodinamika* [Quantum Electrodynamics]. Moscow: "Nauka", 1959, 1969 (3rd rev. ed.), 1981 (4th rev. ed.).
4. A.I. Akhiezer, I.A. Akhiezer, R.V. Polovin, A.G. Sitenko, K.N. Stepanov. *Kollektivnye kolebanija v plazme* [Collective Oscillations in Plasma]. Moscow: "Atomizdat", 1964.
5. A.I. Akhiezer, V.G. Baryakhtar, and S.V. Peletminsky. *Spinovye volny* [Spin Waves]. Moscow: "Nauka", 1967.
6. A.I. Akhiezer, I.A. Akhiezer, R.V. Polovin, A.G. Sitenko, K.N. Stepanov. *Elektrodinamika plasmy* [Electrodynamics of Plasma]. Moscow: "Nauka", 1974.
7. A.I. Akhiezer, S.V. Peletminsky. *Metody statisticheskoj fiziki* [Methods of Statistical Physics]. Moscow: "Nauka", 1977.
8. A.I. Akhiezer, M.P. Rekalov. *Elektrodinamika adronov* [Electrodynamics of Hadrons]. Kiev: "Naukova dumka", 1983.
9. A.I. Akhiezer, S.V. Peletminsky. *Teoriya fundamental'nykh vzaimodeystvij* [Theory of Fundamental Interactions]. Kiev: "Naukova dumka", 1993.
10. A.I. Akhiezer, N.F. Shul'ga. *Elektrodinamika vysokikh energij v veschestve* [High Energy Electrodynamics in Matter]. Moscow: "Nauka", 1993.
11. A.I. Akhiezer, A.G. Sitenko, V.K. Tartakovskii. *Elektrodinamika jader* [Electrodynamics of Nucleus]. Kiev: "Naukova dumka", 1989.
12. A.I. Akhiezer, I.Ya. Pomeranchuk. *Vvedenie v teoriyu mul'tiplitsiruyushchikh sistem (reaktorov)* [Introduction into the theory of neutron multiplying systems (reactors)] Moscow: "IzdAT", 2002.

III. List of textbooks

1. L.D. Landau, A.I. Akhiezer, and E.M. Lifshitz. *Course of General Physics: Mechanics and Molecular Physics*. Moscow: "Nauka", 1965, 1969 (2nd revised. edition) (in Russian).
2. A.I. Akhiezer. *General Physics. Electric and Magnetic Phenomena*. Kiev: "Naukova dumka", 1981 (in Russian).

3. A.I. Akhiezer, I.A. Akhiezer. *Electromagnetism and Electromagnetic Waves*. Moscow: "Vysshaya Shkola", 1985 (in Russian).
4. A.I. Akhiezer. *Atomic Physics*, ed. by V.A. Miransky, Kiev: "Naukova dumka", 1988 (in Russian).
5. A.I. Akhiezer, Yu.A. Bereznoy. *Nuclear Theory*. Kyiv: "Vyshcha Shkola", 1995 (in Ukrainian).

IV. Selected A.I. Akhiezer's publications and reviews

1. Scattering of light by light (with L. Landau, I. Pomeranchuk) // *Nature*. 1936, v. 138, p. 206.
2. Uber die Streuung von Licht an Licht // *Sow. Phys. (Phys. Zs. Sowjetunion)*. 1937, v. 11, p. 263-283.
3. On the sound absorption in solids // *Zh. Eksp. Teor. Fiz.* 1938, v. 8, p. 1318-1329.
4. On the absorption of sound in metals // *J. Phys. USSR*. 1939, v. 1, p. 289-298.
5. On the heat conductivity of salts used in the magnetic cooling method (with I.Ya. Pomeranchuk) // *J. Phys. USSR*. 1944, v. 8, p. 216-218.
6. On the elastic scattering of fast charged particles by nuclei // *J. Phys. USSR*. 1945, v. 9, p. 471-476.
7. Theory of the relaxation processes in ferromagnets at low temperatures // *J. Phys. USSR*. 1946, v. 10, p. 217-230.
8. On the scattering of slow neutrons by crystals (with I.Ya. Pomeranchuk) // *J. Phys. USSR*. 1947, v. 11, p. 167-179.
9. Free oscillations of electron plasma in magnetic field (with L.E. Pargamanik) // *Uchenye Zapiski Kharkovskogo Universiteta*, v. 27. *Trudi Fiz. Otdel. Fiz.-Mat. Fak.* 1947, v. 1, p. 75-104, (*Comm. Kharkov State Univ. Proc. Phys. Div. Phys. Math. Depart.*).
10. On the interaction of charged particle beam with electron plasma (with Ya.B. Fainberg) // *Dokl. Akad. Nauk SSSR*. 1949, v. 69, p. 555-556.
11. Diffraction scattering of fast particles by nuclei. (with I.Ya. Pomeranchuk) // *Uspekhi Fiz. Nauk*. 1947. v. 39, p. 153-200.
12. On nonlinear theory of plasma oscillations (with G.Ya. Lyubarsky) // *Dokl. Akad. Nauk SSSR*. 1951, v. 80, p. 193-195.
13. On the high -frequency oscillations of electron plasma (with Ya.B. Fainberg) // *Zh. Eksp. Teor. Fiz.* 1951, v. 21, p. 1262-1269.
14. Radiation corrections for scattering of electron by electron (with R.V. Polovin) // *Dokl. Akad. Nauk SSSR*. 1953, v. 90, p. 55-57.
15. On diffractive scattering of fast deuterons by nuclei (with A.G. Sitenko) // *Dokl. Akad. Nauk SSSR*. 1956, v. 107, p. 385-388.
16. On the interaction of electromagnetic waves with charged particles and on the oscillation of the electronic plasma // *Suppl. Nuovo Cimento*. 1956, v. 3, p. 591-613.

17. On the theory of stripping reaction at high energies (with A.G. Sitenko) // *Zh. Eksp. Teor. Fiz.* 1957, v. 32, p. 1040-1042 [*Sov. Phys. JETP.* 1957, v. 5].
18. Diffractive scattering of fast deuterons by nuclei (with A.G. Sitenko) // *Phys. Rev.* 1957, v. 106, p. 1236-1246.
19. On stability of shock waves in magnetic hydrodynamics (with G.Ya. Lyubarsky and R.V. Polovin) // *Zh. Eksp. Teor. Fiz.* 1958, v. 35, p. 731-737 [*Sov. Phys. JETP.* 1958, v. 8].
20. Coupled magnetoacoustic waves in ferromagnets and ferroacoustic resonance (with V.G. Baryakhtar and S.V. Peletminskii) // *Zh. Eksp. Teor. Fiz.* 1958, v. 35, p. 228-239 [*Sov. Phys. JETP.* 1958, v. 8].
21. Spin waves in ferromagnetics and antiferromagnetics, I; II (with V.G. Baryakhtar and M.I. Kaganov) // *Uspekhi Fiz. Nauk.* 1960, v. 71, p. 533-579; v. 72, p. 3-32 [*Sov. Phys. Uspekhi.*].
22. On theory of slow neutrons scattering in Fermi liquid (with I.A. Akhiezer and I.Ya. Pomeranchuk) // *Zh. Eksp. Teor. Fiz.* 1961, v. 41, p. 478-487 [*Sov. Phys. JETP.* 1962, v. 14].
23. On the theory of fluctuations in plasma (with A.G. Sitenko) // *Zh. Eksp. Teor. Fiz.* 1961, v. 41, p. 644-654 [*Sov. Phys. JETP.* 1962, v. 14].
24. On stability conditions of electron distribution function in plasma (with G.Ya. Lyubarsky and R.V. Polovin) // *Zh. Eksp. Teor. Fiz.* 1961, v. 40, p. 963-969 [*Sov. Phys. JETP.* 1962, v. 13].
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