

LETTERS TO PROGRESS IN PHYSICS

Israel L. Bershtein (1908–2000) — the Founder of the Theory of Fluctuations in Self-Oscillating Systems

(In Commemorating the 100th Birthday Anniversary)

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Israel L. Bershtein (1908–2000) was one of the famous radio physicists in the world. He had constructed the theory of amplitude and frequency fluctuations for the electromagnetic wave generators working in the radio and optical scales. He also had developed numerous methods for precise measurement of the fluctuations, which also can be applied to ultimate small mechanical displacements. Besides these he was the first person among the scientists, who had registered the Sagnac effect at radiowaves.



Fig. 1: I. L. Bershtein in 1930 (the left corner in the picture), being a 5th grade university student at the Low Current Lab (a common name for a radio laboratory in those years). This photo is interesting from the historical viewpoint, because the background of a radio laboratory of the 1930's.

In November, 2008 we celebrate the 100th Birthday Anniversary of Israel Lazarevich Bershtein, Doctor of Science in Physics and Mathematics, a distinguished radio physicist, the author of theoretical and experimental research methods for fluctuations of radio and optical electromagnetic oscillators. The paper deals with I. L. Bershtein's basic scientific achievements.

I. L. Bershtein started his scientific activities when radio-physics originated and broke new ground, so he took a part in its development. I. L. Bershtein was born on November 22, 1908 in the Mogilyov city of the Russian Empire (nowadays the Republic of Belarus). After graduating from school he studied physics at the Electromechanical Faculty of the Leningrad Polytechnical Institute (1926–1930). A. F. Ioffe,

V. F. Mitkevich, D. D. Rozhansky, A. A. Chernyshev, and M. A. Shatelen were among his teachers. A well-known debate concerning the nature of electric current, electric and magnetic fields and also the long-range action problem between V. F. Mitkevich, the full member of the USSR Academy of Sciences, and Ya. I. Frenkel, the corresponding member of the Academy, took a place in 1929–1930 at the Polytechnical Institute. P. Ehrenfest was invited by A. F. Ioffe to participate in two sessions of the debate. I. L. Bershtein took a part in all three sessions of these.

After graduating from the Polytechnical Institute in 1931 I. L. Bershtein was employed at the Central Military Research Radio Laboratory (later — the Frunze Factory). He however preferred scientific activities. In 1930 N. D. Papaleksi, the corresponding member of the Academy, paid attention to the talented student. On his advice I. L. Bershtein addressed Prof. A. A. Andronov who agreed to become his scientific supervisor. In 1933 I. L. Bershtein was enrolled for A. A. Andronov's in-service training postgraduate course. His task was to obtain expressions for amplitude and frequency fluctuations of a self-oscillating system (by the example of valve oscillator) close to its periodic motion. I. L. Bershtein managed to show that frequency fluctuations of the generator "blurred" the infinitely narrow radiation line of an ideal oscillator and it acquired width, while amplitude fluctuations created a rather wide but low "pedestal" of the generation line. Results of this work were recommended to publishing by L. I. Mandelstam, the full member of the Academy, and they were published in *Soviet Physics — Doklady* [1]. Paper [1] considerably exceeded the maximum permissible volume and A. A. Andronov reached an agreement with the Editor-in-Chief S. I. Vavilov, the full member of the Academy, on publishing [1] in total. In 1939 I. L. Bershtein under supervision of A. A. Andronov defended a Ph.D. thesis. The official opponents were M. A. Leontovich and G. S. Gorelik. In 1941 I. L. Bershtein



Fig. 2: I. L. Bershtein in 1938, among the research scientists and professors of the Gorky Physics and Technical Institute (GPTI). In the 1st row (from left to right): unknown person; unknown person; Prof. S. M. Rytov; I. L. Bershtein; Prof. Jakov N. Nikolaev; Kholodenko. In the 2nd row (from left to right): Prof. Alexandra G. Lyubina; Prof. Victor I. Gaponov (the husband of Prof. Maria T. Grekhova, the Director of GPTI, and the father of A. V. Gaponov-Grekhov, the full member of the Academy); unknown person.

published a more detailed statement of the theory of fluctuations in valve oscillator [2]. The original theoretical results he had obtained required experimental validation, however the Fascist Germany aggression upon the USSR forced I. L. Bershtein to postpone his fundamental research.

During the World War II I. L. Bershtein developed radio receiving equipment for the Soviet army and aviation needs. In 1946 I. L. Bershtein stopped his industrial activity and was employed at the Gorky Physics and Technical Institute (GPTI) in G. S. Gorelik's department, and held a post of Assistant Professor and Full Professor of radioengineering at the newly organized Radiophysical Faculty of the Gorky State University. Nevertheless, until 1952 he continued to supervise the development and production of radio equipment at a factory. At that time I. L. Bershtein starts to develop experimental methods for measuring amplitude and frequency fluctuations of valve oscillator. In particular, he was the first person who suggested to process measurement of small phase fluctuations by the so-called method of triangle, based on the interference of the measured and reference signals having an insignificant constant phase shift relative to each other and close amplitude values. The experimental measurement carried out by I. L. Bershtein in [3, 4] completely verified his earlier theoretical results [1, 2]. His paper [4] was awarded the Mandelstam Prize presented to L. I. Bershtein at a session of the USSR Academy of Sciences by N. I. Vavilov, the President of the Academy.

In papers [3, 4] I. L. Bershtein managed to measure the lowest level of periodic phase modulation of the order 10^{-8}

rad in the frequency band 1 Hz. This permitted to carry out a very interesting physical experiment, i.e., to measure the Sagnac effect at radio waves employing a cable of the 244 m length coiled round a barrel [5]. The radio wavelength was 10 m and the angular velocity of the barrel's rotation was 1–1.3 revolutions per second. Since the phase difference of counter-running waves caused by the rotation is inversely proportional to the wavelength, it is evident that the Sagnac interferometer sensitivity at radio waves is 10^7 lower than the sensitivity under the other equal conditions expected in the optical range.

I. L. Bershtein's papers on fluctuations and the Sagnac effect [3–5] brought him world-wide popularity. He became a leading Soviet scientist on fluctuation measurement. In 1954 he measured extremely small mechanical displacements employing the interference method, and recorded a displacement of the order 10^{-3} Å (see [6]). (It should be noted that, in 1998, one of I. L. Bershtein's disciples, namely — V. M. Gelikonov, managed to increase the measurement accuracy of mechanical displacements by 4 orders to it. See [7] for detail.) That year I. L. Bershtein defended a Dr.Sci. thesis (his opponents were G. S. Landsberg, Yu. B. Kobzarev, S. M. Rytov, and G. S. Gorelik) and after G. S. Gorelik's departure for Moscow he headed a scientific department in GPTI. In the same time he became a Full Professor at the Radioengineering Faculty of the Gorky State University.

In 1957 I. L. Bershtein and his department were transferred to the Radiophysical Research Institute (RRI), where he studied klystron oscillators and matched their frequencies to the frequencies of a quartz oscillator and an ammonia maser,



Fig. 3: I. L. Bershtein in 1948. This is the time of the upper point of his scientific achievements.

then investigated the oscillator fluctuations in AFC system operation. In the mid-60's I. L. Bershtein's department started developing a subject related to the pioneering experimental and theoretical studies in the field of fluctuation processes in gas lasers with Fabry-Pérot and ring resonators, including gas lasers with an absorbing cell used for elaboration of the optical frequency standards. At that time I. L. Bershtein developed a heterodyne method for frequency fluctuation measurement, enabling his disciples Yu. I. Zaitsev and D. P. Stepanov to be first persons in the world who measured frequency fluctuations of a gas laser at the wavelength 0.63μ [8]. In 1969 I. L. Bershtein was invited to held a lecture on his department's activities at P. L. Kapitsa's workshop in Kapitza's Institute for Physical Problems in Moscow.

In 1970 the so-called polarization resonances in counter-running waves in an amplifying laser tube at the wavelength 3.39μ [9] were discovered with the participation of I. L. Bershtein. He also studied the influence of the light back-scattering on laser operation and reciprocal capture of the counter-running wave frequencies in a ring gas laser. The AFC systems for laser generation developed by I. L. Bershtein permitted his disciples to discover new effects in gas lasers with an absorbing cell. The new effects they have discovered were the dynamic self-stabilization of the generation frequency which occurs not only at the centre of the transition line of the absorbing gas, but also at the boundaries of the entire non-uniformly broadened absorption line, the dependence of the self-stabilization coefficient on the modulation frequency [10], and the so-called dispersion resonances they have recorded.

I. L. Bershtein was a member of the Editorial Board of the journal *Soviet Radiophysics* published in RRI for about

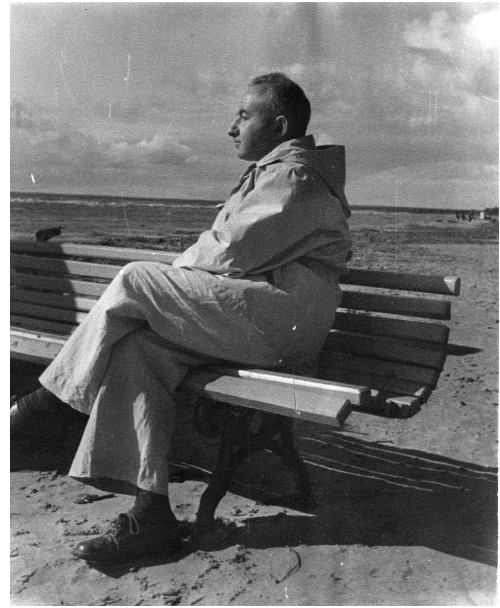


Fig. 4: The mid-60's. I. L. Bershtein being taking relax at the coast of the Black Sea.

twenty years (1958–1976).

From 1977 to 1986 I. L. Bershtein headed a research laboratory at the Institute of Applied Physics dealing with fiber-optic interferometers. From 1987 to 1999, being a leading consulting scientist, he continued his studies in the field of fiber-optic gyroscopy and semiconductor radiation sources for fiber optics. I. L. Bershtein died on August 16, 2000.

The life and scientific activity of I. L. Bershtein is a worthy example of service to science. His work in the field of self-oscillating system fluctuations and micro phase metering are the classics of science, and are extremely valuable for radiophysics. He is the author of more than 60 scientific publications and many inventions certified by patents. He was also awarded several prizes provided by the USSR Government [11].

Under careful leading of I. L. Bershtein three persons have got a Ph.D. degree. Those were I. A. Andronova, Yu. I. Zaitsev, and L. I. Fedoseev (the last person was led by I. L. Bershtein commonly with V. S. Troitsky, the corresponding member of the Academy). Many other research scientists were also I. L. Bershtein's disciples: Yu. A. Dryagin, D. P. Stepanov, V. A. Markelov, V. V. Lubyako, V. A. Rogachev. The next generations of research scientists were also I. L. Bershtein's disciples. Those are I. A. Andronova's disciples, namely — I. V. Volkov, Yu. K. Kazarin, E. A. Kuvatova, Yu. A. Mamaev, A. A. Turkin, G. V. Gelikonov, and Yu. I. Zaitsev's disciples — V. M. Gelikonov, V. I. Leonov, G. B. Malykin, and also D. V. Shabanov who was V. M. Gelikonov's disciple, and also L. M. Kukin, who was Yu. A. Dryagin's disciple. I. L. Bershtein patiently transferred all his scientific experience to the aforementioned persons, who are actually his disciples and followers in science.



Fig. 5: I. L. Bershtein at the working desk in his cabinet. This photo, pictured in 1967, is very specific to his nativity of a man who spent his life in science.

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