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Georgii L'vovich Shnirman: designer of fast-response instruments

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Abstract. A biography is given of the outstanding Russian scientist Georgii L'vovich Shnirman, whose scientific life had been 'top secret'. He was an experimental physicist and instrument designer, the founder of many branches of the Soviet instrument-making industry, the orginator of a theory of electric methods of integration and differentiation, a theory of astasisation of pendulums, and also of original measurement methods. He was the originator and designer of automatic systems for the control of the measuring apparatus used at nuclear test sites and of automatic seismic station systems employed in monitoring nuclear tests. He also designed the first loop oscilloscopes in the Soviet Union, high-speed photographic and cine cameras (streak cameras, etc.), and many other unique instruments, including some mounted on moving objects.

A year has passed since the death of the outstanding Russian scientist Georgii L'vovich Shnirman. He died on 6 January 1993; he had not retired. The last time Georgii L'vovich came to our Institute was on 30 December 1992: he brought a new scientific paper which he had just completed and the figures were, as usual, hand-drawn by him.

His scientific life was unique in both the duration of his scientific activity (62 years) and its intensity: the number of serially produced instruments that he designed was greater than the output of some research institutes, and this was true in respect of their variety, which included electric and optical methods for investigating fast processes, general instruments, and those used in metrology and mechanics.

Georgii L'vovich Shnirman not only designed numerous unique instruments with characteristics and design quality unsurpassed in the USSR and elsewhere in the world, but was also the originator of basic instrumentation methods and instrumental systems. Moreover, he educated a whole pleiad of excellent instrumentalists. In fact, a book should be written about him.

I am happy, however, that in this short paper I can throw some light on his unusual scientific life, classified as 'top secret'.

The first scientific paper of Georgii L'vovich was published in 1927 in the magazine *Novosti Radio* (Radio News) when he was a 20-year-old student at the Leningrad University. This All-Union magazine awarded him a prize for an article on "Alternating detector communication".

The scientific life of Georgii L'vovich was exceptionally long: he was remembered by major scientists of our time, ranging from Gamow — his university friend — to Academician S L Sobolev, who died recently.

He worked with Academicians P M Nikiforov, N N Semenov, I V Kurchatov, Ya B Zel'dovich, Yu B Khariton, and M A Sadovskii.

In the course of his work he had to demonstrate his instruments to Tukhachevskii and Beria.

Georgii L'vovich outlived those who might attempt to reminisce about his activities, but this could not be done by one person because he worked with engineers and theoreticians, with glassblowers and metalworkers, with artillery men and radio operators, with pilots and sailors, with military officers and politicians.

For me personally, Georgii L'vovich had always been the highest ideal of a scientific designer. So many events in my life are linked with him and, therefore, I would like to tell the story of his life very briefly. I feel that this is a task that I must perform.

Immediately after graduation from the Leningrad University, Georgii L'vovich was invited to join the Seismology Institute of the Academy of Sciences of the USSR (the Russian acronym is SIAN). The director of this Institute, the well-known scientist P M Nikiforov, offered him the position of the Head of the Seismic Laboratory.

This was in 1930, three years before my birth. I can therefore hardly comment on the first two decades of Shnirman's creative work. However, some yellowing documents lie before me and I shall let world-famous scientists describe the scientific work of 27-year old Georgii L'vovich.

The first document reads as follows.

Academy of Sciences of the USSR

Excerpt from the minutes of the Physics and Mathematics Group on 26 April 1934, §1.

HEARD: *A paper by seimologist G L Shnirman(SIAN) on "New types of electroseismic instruments" from 11.45 am to 1.10 pm. The paper was followed by a demonstration of electroseismic instruments constructed at the SIAN.*

DISCUSSION: *Profs N N Andreev, P M Nikiforov, S I Vavilov, and S A Chaplygin participated. A N Krylov summarised the paper and said that rarely did the Group hear such a detailed and thorough paper presented in such a brilliant manner. Everthing that the author said is of*

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direct application to ships, specifically in studies of torsional vibrations of shafts, of very small displacements of the supports of thrust bearings, etc. In general, the methods presented have innumerable and very important applications in shipbuilding. They can also be used in artillery; for example, in studies of the pressure increase in a gun barrel, etc.

RESOLVED: The Group is grateful to the presenter G L Shnirman and to the Director of SIAN P M Nikiforov for the opportunity of listening to such a brilliant talk with innumerable applications in science and technology. G L Shnirman demonstrated the following instruments, all developed at the SIAN: (1) electrodynamic vibrographs; (2) an electromagnetic seismograph with a two-valve amplifier; (3) a piezoelectric accelerometer; (4) a capacitance seismograph with an oscillator, amplifier, and rectifier; (5) a six-loop oscilloscope and a tuning fork to go with it. All the instruments were built in the workshops of the SIAN.

Here is the second document.

OPINION

On the work by member of the staff of the SIAN, Comrade Shnirman, on tasks assigned by the Scientific-Research Institute of the Air Force of the Red Army

In the last four-and-a-half years comrade G L Shnirman carried out a number of research tasks. He developed new methods for special measurements and designed a considerable number of measuring instruments, which were built in the mechanical workshop of the SIAN.

Comrade Shnirman developed and improved electric and optical measurement methods.

He developed a number of original electrovibrographs of very compact size and suitable for use in aircraft.

Comrade Shnirman developed a compact electric instrument for torsion measurements designed for placing inside the crankshaft of an aircraft engine and capable of measuring torsional vibrations in the engine during flight.

The electric methods for integration and differentiation of electric currents were used by comrade Shnirman to analyse the currents induced by vibrations in electrovibrographs and electrotorsiographs, thus greatly improving the processing and interpretation of the investigated processes.

Comrade Shnirman carried out the first flight tests on a portable six-loop oscilloscope of his own design (1933).

In 1938 Shnirman developed a portable nine-loop oscilloscope, fully capable of being used on board aircraft of all types.

During the same period comrade Shnirman designed an optical instrument for the recording of loads during aerobatic flight. He subsequently introduced additional components into this instrument, so that a number of concomitant processes could also be recorded.

Among the instruments designed by comrade Shnirman one should mention in particular the portable nine-loop oscilloscope which, according to the latest information (mid-1940) available to our Institute, is greatly superior to the best foreign (Siemens and Askania) aviation oscilloscopes both in the number of loops and in the speed of the loop response, as well as in respect of portability.

Comrade Shnirman has continued his work on optical measurement methods and developed at our Institute an aviation multicomponent optical plotter for recording the necessary data during flight. This ingenious instrument (without equal abroad) can record simultaneously and with great precision up to 14 graphs representing various physical processes and is suitable for the testing of any aircraft under any flight conditions.

The instruments developed by G L Shnirman are used at our Institute routinely in aircraft and engine tests. Some of these instruments can be produced industrially and may be employed extensively in aircraft testing.

The enormous and fruitful work carried out by G L Shnirman on the development and introduction of special measurement methods in aviation practice make him not only a first-class designer, but primarily a major practical scientist who has used all his knowledge for the improvement of the defence of our country.

Director of the Scientific-Research
Institute of the Air Force of the
Red-Army Air General Major A Filin

25 November 1940

I can add that Georgii L'vovich was awarded the State prize in 1946 for his aviation research (1943–1944).

In 1946 a special section was created at the Institute of Chemical Physics of the USSR Academy of Sciences in Moscow: it was a scientific subdivision for the study and implementation of atomic explosions. The first member of this subdivision was G L Shnirman. Academician M A Sadovskii reminisces:

"G L Shnirman played a major role in the enormous task of providing the Soviet Union with atomic weapons. ...I had the good fortune to work with G L Shnirman, and to be his friend and collaborator in many studies. My task was the study of the physics of explosions, of shock air and seismic waves, and this would hardly have been possible without his design expertise."

According to M A Sadovskii, 80% of the apparatus working in Semipalatinsk in 1949 during the first nuclear explosion was designed and constructed by Georgii L'vovich personally or under his direct guidance. He led the field tests and participated personally in them: this included the setting up of the apparatus, its adjustment, and testing, as well as an analysis of the results obtained.

His contribution to the development of high-speed optical apparatus is outstanding: he designed high-speed cine cameras (which he called 'time magnifiers'), one of which (SFR) was capable of operating at 33 million frames per second — a rotating-mirror streak camera — and its numerous modifications; the FR-Yu high-speed continuous recorders, the SK-1, SK-2, SK-3 continuously recording cameras for the recording of explosions, spark discharges, etc; the TsL-1 high-speed two-chamber cine camera; and so on. This list can be continued.

All these unique instruments were designed to work under the extreme conditions at the nuclear explosion test sites.

Georgii L'vovich Shnirman

Georgii L'vovich Shnirman in Novaya Zemlya during the SP-7 Expedition (in the sixties).

I used these instruments myself and was able to judge their reliability and quality, as well as suitability for tackling the problems of recording fast processes.

However, the most impressive achievement in high-speed optical apparatus was the LV-1 rotating-mirror framing high-speed cine camera. It revealed the greatest intuition and skill of Georgii L'vovich both as a scientist and as an engineer.

Academician M A Sadovskii wrote: "One of the peaks of creativity of G L Shnirman was undoubtedly the development of high-speed cine cameras capable of operating at up to 33 million frames per second. Unfortunately, he never described these instruments personally and gave this task to one of his pupils. Even this can be regarded as helpful, but there is no doubt that he could have described these instruments better himself!"

The LV-1 camera greatly impressed foreign specialists when they examined it in 1958 at the World Exhibition in Brussels, and then in the USA.

The scientific and technological activities of Georgii L'vovich also included the development of automatic systems for the control of measuring instruments intended for nuclear explosion test sites. These systems had to:

(1) switch on the apparatus;
(2) switch on the film movement in the photographic cameras and loop oscilloscopes;
(3) open the shutters in the photographic cameras and attachments;
(4) trigger the explosives;
(5) switch off the instruments;
(6) provide a uniform system of time marks during a test.

Naturally, systems of this kind had to ensure the highest reliability of the operation of the whole site during tests.

This was achieved in particular by doubling all the automatic systems and delivering all the control signals along two independent channels. Shnirman's automatic systems operated in all the nuclear tests, whether they were ground tests, those in water, underwater, in air, or underground.

He developed several types of large and complex systems employing very complicated techniques, including radio- communication. Once again, I cannot describe all of them and I have to mention just a few: the AP blasting device (1948); the BA-55, an improved verison of the AP (both systems were operated at the Semipalatinsk test site); the MA marine system for the Novaya Zemlya nuclear test site (1955); the SA aircraft system (developed in the early sixties).

The contribution of Georgii L'vovich to physical instrumentation is also amazing and enormous. It is impossible even to name the main topics of his activity, because he worked in very many directions and was always ahead of his time.

The first oscilloscope in the Soviet Union was constructed by him in 1934. He carried out pioneering work on methods of electric differentiation and integration. In 1938 he developed a nine-loop oscilloscope with characteristics and design that had no peer in the Soviet Union or abroad.

He designed this special highly reliable loop oscilloscope (OSh1) for recording signals from many sensors, which was a part of the measuring complex in nuclear explosion tests. He also constructed another multichannel loop oscilloscope (OT), which was described thus by Academician M A Sadovskii:

"The wonderful talent of G L Shnirman as a designer with a divine spark was displayed particularly strikingly in the development of a unique automatic oscilloscope, which was installed inside a torpedo and used to study the

operation of all its mechanisms at the moment it struck the target.''

One should also mention here the high-speed cine cameras described above.

Shnirman also developed instruments for transient temperature measurements in the ground layer of air during ground nuclear tests; these were ITR-1 and ITR-2 developed in 1951–1953.

Georgii L'vovich also designed aircraft-borne apparatus for recording the parameters of nuclear explosions and their effects on the aircraft: these included the SKZ-Sh and SK-Sh high-speed photographic cameras, the SA aircraft programmed automated systems, the ITI-S instrument for measuring the integral thermal radiation, and so on.

Techniques for the investigation of the reflectivity of high-intensity light fluxes incident on materials and various protecting surfaces of the instrument-carrying aircraft were also developed by him.

Georgii L'vovich was also responsible for providing a united time service for sites of continuous recording and observation separated by large distances from one another.

Shnirman designed a series of epicentral seismic stations (ESS-1, ESS-U, ESS-UM) in the late sixties and early seventies, as well as the ASS automatic seismic station and the STS vertical-hole geophone capable of operating for a long time (developed in the early eighties).

I could fill many pages with a simple list of the remarkable instruments, techniques, stations and systems developed by Georgii L'vovich.

The reader can now see that a special, serious study is needed because of the unique talent of Shnirman and because of the secret nature of the archives recording his work.

I would like very much now to describe the role of Georgii L'vovich in my scientific life.

My relations with him can be divided into several periods. During the first period I was a young inexperienced specialist and he was an unattainable master: by this time he had received four State Prizes. It seemed to me that he could see my stupidity and all my faults very clearly, so that after my every public appearance I awaited with trepidation the reaction of Georgii L'vovich.

To anticipate somewhat, I should mention that Georgii L'vovich was a man of the highest erudition, but also extremely tactful in dealing with his colleagues. He treated very warmly those he singled out and he always supported them. Later, I found out that he noticed me right at the very beginning. When that became clear, I told him: ''Georgii L'vovich, I was so scared of you!''

In the second period I was already something of a colleague. I worked under his guidance (I am not afraid to use this well-worn phrase) on the development and implementation of high-speed recording apparatus. His leadership was always truly wise.

The most famous and popular among research physicists was Shnirman's rotating-mirror streak camera (SFR) manufactured commercially from 1949.

The SFR camera was not only unique, but also multifunctional. Georgii L'vovich made many improvements and designed a large number of attachments, which greatly extended the capabilities of this camera. I always admired this camera: I used it, so that I have the right to praise it. Now, after 44 years of its introduction in industry, a modification of the SFR is being made at the Krasnogorsk Mechanical Factory: it is now called the VFU camera.

In 1981 I visited a research laboratory in Bulgaria. I suddenly noticed the SFR camera: they also used it.

The third period of my relations with Georgii L'vovich began in the area of the construction of devices for geophysical investigations. Once again, he amazed me. He knew all, could do all, and all that was required was to apply his ideas very accurately and reliably. It is said that the great are better seen at a distance, but it seems to me that I always sensed the superiority of his intellect.

One should mention here his clever hands. He could repair a cine camera, tape recorder, clock, fridge, or TV set. He could work with lathes, a soldering iron, a burner, a file, and any hardware.

The reader should not, however, in any sense imagine Georgii L'vovich as a person deeply sunk in wires, lenses, and hardware, although he loved to play with them. One could say that he was capable of combining the 'microscopic' and 'telescopic' approaches. His mind could deal with global problems in the same detail as in the case of any of his instruments. To illustrate this it is sufficient to mention that in 1960 in Geneva at the First International Conference on Prohibition of Nuclear Tests he proposed such a fundamental method for nuclear-explosion monitoring that the Conference selected it as the optimal solution and, in the 33 years since, nobody has developed anything better!

When Georgii L'vovich began to implement this method and develop a system for monitoring nuclear explosions, I had the good fortune to take part in this work. And as I continue to do my best in developing the system, by applying more modern processing methods and new technologies, I do this without altering the principles of the system.

I would like to stress also that Georgii L'vovich was a major technologist. He could see very clearly not only the nature of a geophysical phenomenon, but also the necessary technology without which a good instrument cannot be constructed.

My last contacts with him represented the final stage of our relations when we were not just colleagues, but seemed to grow closer to one another. I often met Georgii L'vovich and I had a physical fear of what will happen when he is gone and we shall lose all this! Frankly, I was in a hurry to bring people to him so that they would pick up as much information as possible.

Indeed, I felt that when he is gone, we shall lose much and we shall not be able to carry out, in the wider sense, the work planned by Georgii L'vovich.

And now I would like to speak of the recognition of Georgii L'vovich's work. He was amazingly modest and had no desire for management positions: after graduation he was invited to head a laboratory and throughout his life, 62 years in an Academy of Sciences institute, he supervised the laboratory. He was Doctor of Technical Sciences, a full Professor, a meritorious scientist of the Russian Soviet Federal Socialist Republic, holder of many orders, and four times State Prize laureate. He will certainly be remembered in the history of science as the man who enabled two superpowers to begin realistically to monitor nuclear disarmament. I think Georgii L'vovich deserved even better recognition! His powerful scientific intellect and the unique results of his activity deserved election to the

Academy. I am surprised that this did not happen. How very unjust!

I think it was not only the modesty of Georgii L'vovich that prevented recognition, but something else which I cannot explain! Probably it was the nature of the times.

Georgii L'vovich was not only a scientist and an engineer, he was also a teacher. He taught several generations of highly qualified instrumentation specialists. Among his pupils there were many doctors and candidates of science.

In the last 30 years Georgii L'vovich lectured at leading institutes in Moscow: Moscow Higher Technical College, the Physicotechnical Institute, the Moscow Engineering–Physics Institute.

His lectures were as inspiring as his scientific and engineering work. He always lectured in special courses and described his current interests. This is how one of his students (in the 1949–1950 academic year) at the Physicotechnical Department of Moscow State University (renamed the Moscow Physicotechnical Institute)—now the well-known theoretical physicist Prof. A A Rukhadze—describes his lectures:

''It was in the autumn of 1949 when, as a student of a chemical physics group, I first saw and heard G L Shnirman. He lectured at a special course on high-speed photography. He paid great attention to the problem of increasing the photosensitivity of materials, crucial for his newly developed SFR streak camera. Although he never said this directly, it was obvious that (in cooperation with chemists) he was actively developing new photographic materials. It was evident that this was not a routine special course but the results of his current creative work. He always looked very elegant, highly intelligent, and in a manly sense very handsome. He will thus remain in my memory.''

I have in front of me one of the numerous letters sent to Georgii L'vovich when he reached the age of 75 in 1982. In gold lettering it says:

''Dear Georgii L'vovich,

''Your students and students of your students, who are living and working in the city of Zagorsk, send you greetings on your wonderful birthday.

''In view of your merits as an experimental physicist and the *No. 1 instrumentalist* (in our opinion the latter is a *higher title*), we would like to award you the title Honorary Citizen of Zagorsk... .''

I think that the students of Georgii L'vovich correctly described his position in Russian science as ''No. 1 instrumentalist''.

Maybe this is a higher title than that of Academician!