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A Memoir of the Teacher

Yu A Romanov

My story covers the period 1948–1954, during which time the creative activity of I E Tamm was mainly associated with studies aimed at the creation of a national thermonuclear weapon.

A few words about history first. Given the strained Soviet-American relations, the USA nuclear monopoly could not but worry the political leadership of the USSR. To eliminate it in as short time as possible, top nuclear physicists, with I V Kurchatov as leader, and talented engineering personnel were mobilised. Not without intelligence information from the prominent scientist Klaus Fuchs, but mainly through the selfless efforts of Soviet physicists and engineers, a national atomic bomb was tested in 1949, to redress the East-West balance.

That the USA was looking for ways of producing fusion weapon, or Super-bomb as Americans called it, became known back in 1945. I V Kurchatov, addressing himself to a group of prominent physicists (I Gurevich, Ya A B Zel'dovich, I Ya Pomeranchuk, and Yu B Khariton) asked them a question, "Is it possible to make a Superbomb?" While the group's report, "The Utilisation of the Nuclear Energy of the Light Elements" (which, incidentally, was published in full in 'Uspekhi Fizicheskikh Nauk' ('Physics–Uspekhi') in 1991) did contain basic theoretical considerations on the subject, the main problem, how to make the thing, remained far from clear. The report was given at a hearing of the technical council of a special Government committee, and by the committee's resolution the Institute of Chemical Physics, where a special theoretical task-force under Ya B Zel'dovich was being set up, was entrusted with a systematic study of the problem. At sessions of the Scientific and Technological Council of the 'Primary Chief' Management, performance reports were regularly heard. The importance of the problem, the difficulty of its realisation, and the necessity for additional scientific efforts for speeding up its solution were becoming increasingly evident.

It was then that I V Kurchatov took the decision to rely on I E Tamm, a scientist of wide-ranging interests, a high-class theoretician enjoying indisputable authority among the scientific community. Thus, on June 10, 1948, under Resolution No 1990/774 of the Central Committee, a panel headed by Igor' Evgen'evich and including S Z Belen'kiĭ, V L Ginzburg, A D Sakharov and myself, the author of this paper, was set up at the Institute of Physics (FIAN) to investigate the feasibility of creating a hydrogen bomb. As soon as in late June, three high-security rooms were made available in the FIAN building at the Miuss Square, and the top secret work got underway.

Today, hints began appearing in the foreign press that the basic ideas on the development of the first hydrogen bomb were due to American rather than Soviet physicists. This view is convincingly refuted by A D Sakharov in his memoirs. As another first-hand participant in the fusion weapons development, I would also disagree categorically. Up to early 1950, the US superbomb project had proceeded with varied success. Optimism with respect to some particular ideas turned to profound pessimism; at that period, no sweeping proposals had yet been made which would lay the real foundation for the solution of this problem. Nor had the conceptually related studies by the Zel'dovich group produced tangible results, even though they were undoubtedly instrumental in forming the backbone of the Soviet physics community with fine qualifications for tackling the supreme complexity of the domestic thermonuclear weapons programme.

The main ideas behind the first Soviet hydrogen bomb ('first' and 'second', by the classification A D Sakharov suggests in his Memoirs) were formulated by Tamm, Sakharov, and Ginzburg in the late 1948 — early 1949. They were totally original and determined the advantages of the 1953 Soviet bomb over the American Mike design which was exploded in 1952.

The question may arise as to how I E Tamm, reputed for his fundamental results in theoretical physics, might be helpful in solving a purely practical problem of the kind he was given. Unquestionably, Igor' Evgen'evich was not cut to be either an inventor, or a designer. However, he possessed uncanny scientific insight into where the perspective research should go. Under existing circumstances, with Sakharov having not yet gained a sufficient authority, it was for Tamm to bear the complete personal responsibility for the timing and quality of the work. In December 1948, addressing the council chaired by I V Kurchatov, Igor' Evgen'evich set out the new physical ideas with clarity and transparency which secured their favourable reception. When asked for his opinion, Yu B Khariton, known for his invariable caution and prudence, wrote that the Tamm-Sakharov proposals contained fresh and original ideas that merited serious study. It was necessary first to verify them by calculations and physical experiments and only then to consider their testing. It was the law of survival in those days, first to understand and then to act . What an unsuccessful test would mean for those involved is all too easy to imagine. The discussion of the new proposals resulted in a joint Central Committee-Government resolution. The resolution gave the go-ahead to Tamm group's new approach and enjoined the FIAN, specifically the I M Frank group, to proceed to experimental determination of neutron cross sections in various media.

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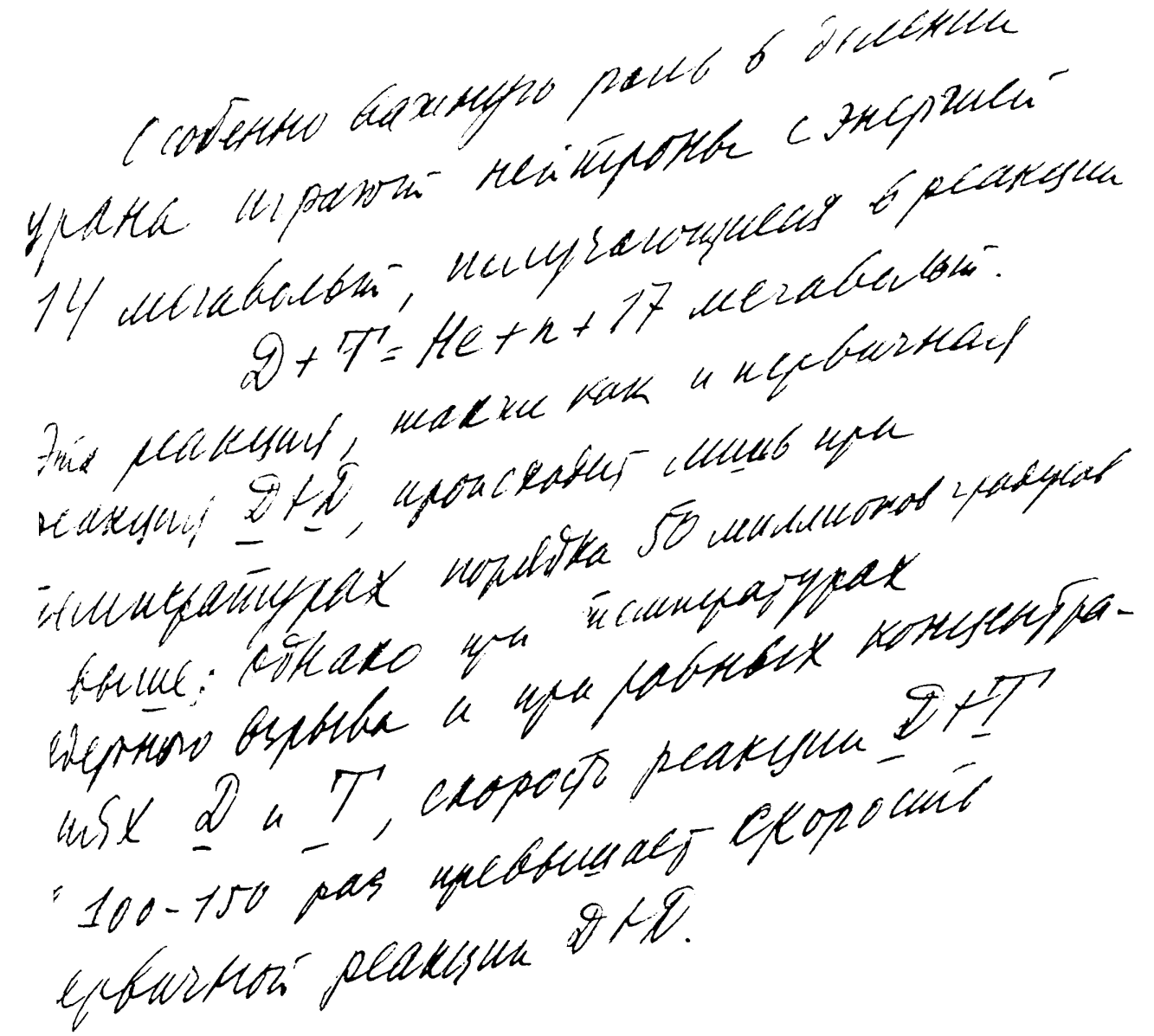
All fusion-related research was under constant surveillance on the part of high authorities, with Lavrentiĭ Beriya himself standing at the tip of the pyramid. It is to him personally that the progress of the work was systematically reported by Yu B Khariton. Looking over the archival cases of the time, I saw numerous report pages written in Khariton's handwriting (still the same after 50 years!), which, unfortunately, can still not be released. In those days, apparently for lack of confidence in typists, all documents pertaining to the scientific and technological aspects of the problem, were handwritten and would invariably end with the expression 'Compiled manually in one (two) copies by so-and-so'. The cases include council and meeting minutes indicating the contents of a particular report, the Tamm group being usually represented by Igor' Evgen'evich himself. Decisions on what to do next were taken, and the following meeting would start with reports, including Tamm's, on past performance. In archival cases of that time I encountered sheets with Igor' Evgen'evich's reports, in his customary angled handwriting. I reproduce here one of these notes, dated 1950, in which the most scrupulous censors luckily found nothing untoward by present day standards (Fig. 1).

Now some younger scientists may argue that there is actually nothing new and fundamental about the work the weapons program physicists did because the physical laws they employed had in fact been known for long. I would tend to disagree. Knowledge of the fundamental laws of physics, in itself, is not enough; there is also a larger question about how to apply them in order to solve — let alone to formulate — a specific problem. This requires broad scientific outlook and intimate knowledge of nuclear physics and hydrodynamics, as well as an entirely new discipline which has now come to be



Особенно важную роль в деле
урана играют нейтроны с энергией
14 мегавольт, получающиеся в реакции
D + T = He + n + 17 мегавольт.
Эта реакция, также как и первичная
реакция D + D, происходит лишь при
температурах порядка 50 миллионов градусов
выше: однако при температурах
взрыва и при равных концентра-
циях D и T, скорость реакции D + T
100-150 раз превышает скорость
первичной реакции D + D.

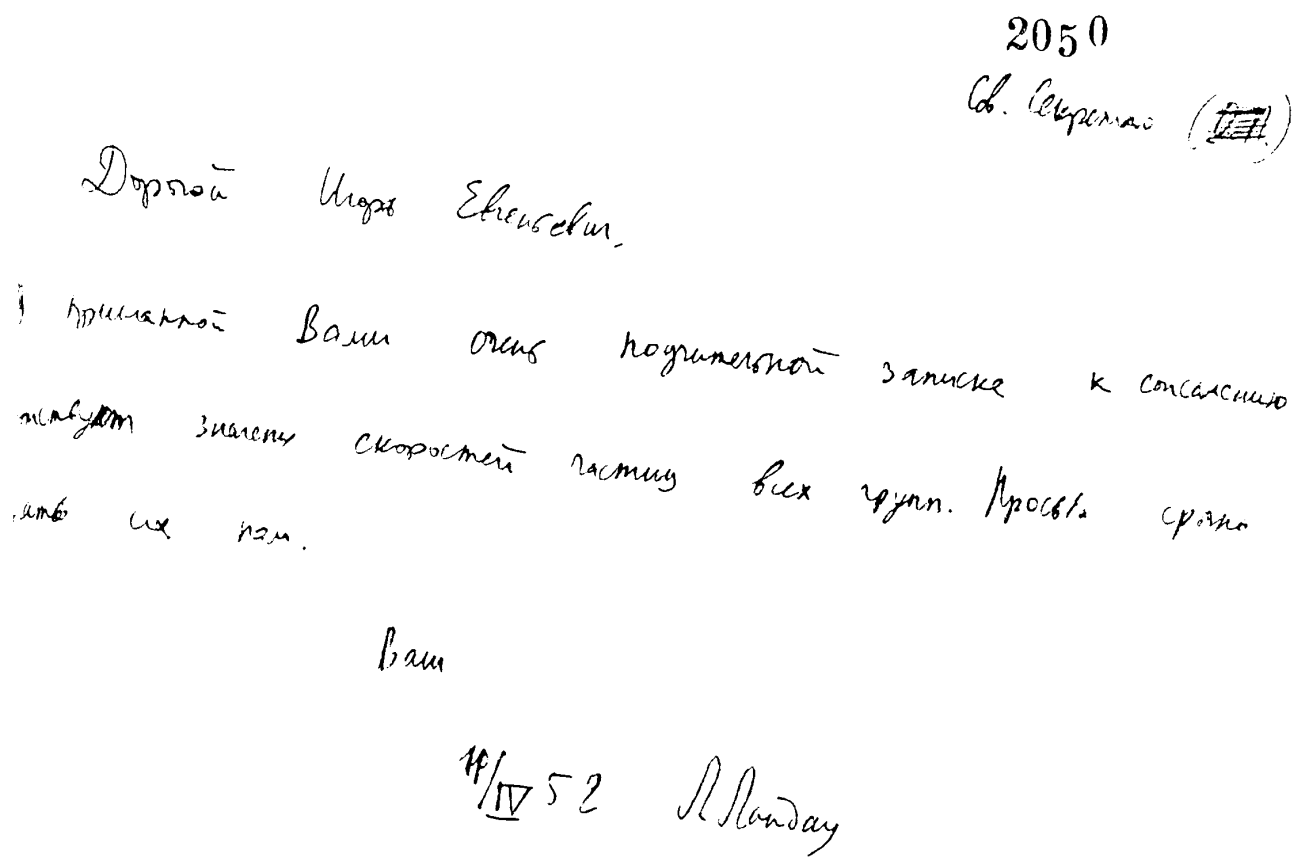
Figure 1. From I E Tamm's first Soviet H-bomb development proposal: "Of crucial importance are 14-MeV neutrons produced in the reaction D + T = He + 17 MeV. This reaction, as well as the primary reaction D + D, occurs only at about 50 million degrees and above. However, at nuclear explosion temperature and equal concentrations of D and T, the rate of the D + T reaction is 100 – 150 times that for the primary D + D reaction."

known as the physics of high-energy densities. But even after the basic differential equations have been formulated for the processes involved and for the particular design scheme — which, by the way, had to be chosen from intuitive considerations — just try to solve such a system of equations! And this without computers we have today ... Moreover, one must have some feeling for the possible influence of the effects that have been left out of account — and some always are — and to accurately predict the results of the future testing ground experiments, with parameters orders of magnitude off from those in the laboratory.

Among those enlisted to solve the problem were also the leading scientists M V Keldysh, A N Tikhonov, and L D Landau (one of Landau's letters to Tamm is shown in Fig. 2). Their co-workers carried out the initial numerical calculations for the processes involved (whose complexity, parenthetically, called for something more than the mechanical Mercedeses and Rhein-Metalls then in use). However, all the basic ideas were devised by the 'brain' method, and this created a demand for learning to reduce partial derivative equations to ordinary ones. This was the area where Sakharov and Zel'dovich were virtuosi, and although Igor' Evgen'evich split hairs — and in many cases rightly so — at every petty detail of their argument, by and large, he had a high opinion of their work.

In February 1950, a regular council took place, where I E Tamm's report for 1948–1949 and plans for 1950 were heard. After both were approved, on February 28, 1950 the top authorities ruled that the Tamm group would move to KB-II (then the code name for the institute in Sarov, now RFYaTs-VNIIEF), which in March 1950 Tamm, Sakharov, and myself, did. The group's flurry activity continued, during which a lot of new problems related to the KB-II experimental and engineering efforts began to materialise. This was a time of enthusiasm, when people worked endlessly, from early morning until late in the evening, and not just out of civic duty: all this was new and extremely interesting. Incidentally, it was in 1950 that Sakharov–Tamm's fundamental proposals on magnetic confinement in a toroidal fusion reactor were put forward. The years 1950–1953 witnessed the completion of work on the first Soviet hydrogen bomb and the preparation to its test, and during this period it is hard to overestimate the contribution of the head of our subdivision, I E Tamm, with his even temper, good will, and deep insight into the scientific roots of the project. Searching through the archives, I came across evidence of yet another facet of Igor' Evgen'evich's activity, his expert report on proposed experimental test methods. These reports were written by him personally in his typically flowing handwriting, and each ended with "Compiled manually in one copy by I Tamm".

At the beginning of 1954, with the crucial research stage over and the hydrogen bomb successfully tested, top-level permission was given to Tamm to return to FIAN. Nevertheless, in 1955 I V Kurchatov asked Igor' Evgen'evich to


2050

Дорогой Игорь Евгеньевич,

К прилагаемой Вами очень подробной записке к сожалению нельзя знаменты скоростей частиц всех групп. Просьба срочно мне их пр.

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Figure 2. From the Landau–Tamm correspondence on the calculation of the first Soviet H-bomb: "2050 Top secrecy. Dear Igor' Evgen'evich, unfortunately in your very instructive note the velocities of all particle groups are lacking. Please do send them promptly. Yours L Landau, April 11, 1952." Note the high secrecy stamp, then obligatory for correspondence between all those involved in the project.

chair a most responsible commission set up for assessing the test preparedness of a fundamentally new project, one which, to a large extent, was to determine the subsequent development of nuclear weapons research. The commission included prominent scientists V L Ginzburg, M V Keldysh, I M Khalatnikov, M A Leontovich, A D Sakharov, and Ya B Zel'dovich, in alphabetic order. Aside from revealing Igor' Evgen'evich's unrivalled scientific authority, this assignment also emphasises his deep physical insight and high-principled attitude in assessing scientific prospects.

The scientific contribution of Tamm to weapons design is marked by high government awards. In the open-access Nuclear Weapons Museum at VNIIEF, everyone can see his portrait among the other scientists who worked towards creating the country's defence shield.

* * *

Igor' Evgen'evich ... I am privileged to call my teacher this outstanding scientist, a man infinitely devoted to Greater Science, whose contribution to the solution of its mysteries is hard to overestimate, a man of the utmost kindness, staunchly opposed to any form of falsehood, lack of principle, or pseudo-science which he encountered.

I first met Tamm in my student years when, having attended a great many of lectures and read a host of textbooks, I felt the urge myself to plunge into concrete work. I proceed here by quoting I E Tamm's own words, which characterise his pedagogical approach and with which he repeatedly introduced that youngster, me, to his colleagues: 'One day a fuzzy haired, rather ill-dressed boy comes and asks me for some problem to solve. My suggestion was an RF field melding regime. Away he goes — and disappears. It must have failed, I assume. But sure enough, two weeks later he approaches me with a stack of papers and — surprise surprise — with his own solution method and the whole of the problem carried through.' The outcome was that Igor' Evgen'evich invited me to attend his seminar in FIAN.

I remember that small ground floor study in the FIAN Miuss square premises. On Tuesdays, not only the cream of Moscow theoretical physics, but also non-Moscow physicists came. The leader and pivotal figure of the seminar was Tamm. Traditionally, each time one of FIAN co-workers reviewed the literature, i. e., a number of latest journal papers (the journal of journals being Physical Review in those times), but the most interesting scientific developments we always learned from Igor' Evgen'evich, who spoke of them in his characteristically picturesque language readily understandable for each one of those present. Today, looking into a Physical Review of the latter half of the 40s, it is astonishing to see that each paper is so clear and easy-to-follow and usually sets a trend for the subsequent development of physics. Not so in the 90s. The journal has become much thicker, comes in a number of series, and, I must confess, is often incomprehensible.

In the late 40s Igor' Evgen'evich's main concern was the particle physics application of his (or rather Tamm–Dankov) nucleon interaction calculation method. It seems, however, that there was some disappointment there because the results did not prove to be as spectacular and fundamental as Igor' Evgen'evich had expected them to be. I remember him telling me that he was very satisfied to have been able to obtain, in his pessimistic period, a complete solution to the 'down-to-earth' shock wave structure problem with kinetic processes taken into account. It was just at that time (middle 1948) that a Government Resolution charged him with heading a group of theoreticians to carry out research on the hydrogen bomb production problem.

That was the beginning of Igor' Evgen'evich's 5-year-long creative activity associated with the necessity of solving major nuclear arms problems. The Tamm group included the young doctors Ginzburg and Belen'kii, the newly-fledged PhD Sakharov, and the present author, then just admitted to postgraduate FIAN research. Igor' Evgen'evich took up the task in a very energetic manner; as a patriot, he was fully aware of the political significance of his task. The commonly-held view is that the architect of the Soviet hydrogen bomb is A D Sakharov, and that significant aspects of the project are due to V L Ginzburg, which tends to belittle the personal role of I E Tamm in producing and realising the basic ideas underlying the development of the first hydrogen bomb. Contributing to its development was not only the undisputed authority of Igor' Evgen'evich as a physicist but, most of all, his exceptional intuition in advocating the most promising trends, his rigour in estimating the obtained results, his ability to appreciate and promote scientific talent, and finally his skill in setting out even the most complex ideas in a vivid and easy-to-follow fashion, something which is particularly important for persuading leadership to choose the right options.

Now the vicinity of the Moscow Sadovoe Kol'tso (Garden ring) was no doubt a wrong place to realise the ideas worked out by Tamm and his group. It was necessary to move to a town where, headed by Yu B Khariton, many and various specialists were put together for carrying out all the experimental, technological, and testing work required for bomb production. This was what is now widely known as Arzamas-16 or, before the nuclear people came there, the town of Sarov, which formerly hosted the Sarov hermitage famous all across Russia for its cloister. Today, the Institute is called the Russian Federal Nuclear Centre — All-Russian Research Institute of Experimental Physics; in those days, in the late 40s — early 50s, it had a coded name, which was often changed for security reasons.

Thus, in March 1950 we (Tamm, Sakharov, and Romanov) arrived in Arzamas-16. We were first accommodated in the town hotel, Igor' Evgen'evich in a large suite, while Sakharov and myself shared a small usual room. In spite of the hard post-war times, much effort was made to provide the 'object', as the Institute was then called, with all it required: industrial orders necessary for carrying out experiments, advanced technology equipment, and, by the standards of the time, reasonable housing and food services. On the other hand, there were very severe restrictions as to leaving the town, even for visiting relatives when on vacation. (Not for Igor' Evgen'evich or Sakharov, of course). As Lev Petrovich Feoktistov recounts (see a book of memoirs of Ya B Zel'dovich), more than one of his absence permits were due to his oath to marry during the vacation; another friend of ours was repeatedly faced with the task of selling a goat in his home village.

Igor' Evgen'evich was more inclined towards fundamental physical problems than to design, invention and technology. He became highly enthusiastic when the physical problems of magnetic confinement in a toroidal fusion reactor came under discussion. I remember Igor' Evgen'evich's work style. It consisted of an infinity of paper sheets filled with long formulas, a search for alternative solution methods

to double check the calculation, a rigorous and physically transparent final formula, and finally, a clear perspective for further work. In the completion years of the hydrogen bomb project, it is hard to overestimate the role of 'Papa Tamm', with his composure, friendliness, and deep insight into the scientific fundamentals of the technological projects under study. At that time the quality and timetable of the work were Igor' Evgen'evich's personal responsibility. Another aspect of his activity should also be mentioned here. When back from Moscow, he was always quick to let people know — and so keep them abreast of — the latest scientific developments, which was extremely important for victims of the security regime cut off from the mainstream of open science.

A few words about our living conditions now. At the beginning of 1951 we relocated to a double two-storey cottage of which in one half two rooms upstairs occupied Igor' Evgen'evich and two separate rooms below, V B Adamskii and me. In the other half N N Bogolyubov with his two associates lived. There was a hired housekeeper, aunt Sonya, who did the cleaning and also cooked our meals. All of us were either bachelors or grass widowers, nor was Igor' Evgen'evich' wife Natalya Vasil'evna a frequent visitor — indeed two or three times during this whole period.

By present day standards, Igor' Evgen'evich was not that old, 55, and it is nice to remember him going with us, young people, on long ski trips, or looking, among us, for sportsmen ready to join him in wood-grouse mating vigilance, or enthusiastically playing tennis. I remember, his powerful blow once literally jammed the ball into my half-open mouth and it took me quite a while to remove it. He was very keen on playing chess and as it turned out, I was his main partner. We were of about the same strength, which made our competition all the more acute and gave particular pleasure to the winner.

It was already back at those times that a 'privatisation' programme was announced in our cottage, and we were forced to redeems the state-owned furniture and some other stuff we used. It was Igor' Evgen'evich's joke idea to divide the carpet money by the number of carpet holes and thus to obtain a very accurate estimate of the average hole price. The carpet that I was given then is still here on the floor of my room reminding me of those far-away days when I was Igor' Evgen'evich's neighbour.

I recall Igor' Evgen'evich as a passionate card player. And this was not 'fool' or preference, but vint, an old prerevolutionary game which nobility used to play. There was a 1912 handbook to explain us the rules, and our guru was, who else, Igor' Evgen'evich, who had had experience of playing with K A Semendyaev and A N Tikhonov, grand vint masters. Vint is a fascinating game of four, two opposing pairs interchanging in the course of the play. There are profound aspects to the game, something akin to chess. The monetary aspect was purely symbolic, a lucky lead or a victory being in itself a satisfaction, as well as declaring and realising grand slam, the very crown of the game. A group of vint enthusiasts formed, which included Yu N Babaev, A A Bunatyan, L P Feoktistov, V Yu Gavrilov, V N Klimov, and myself. And what a passionate vint player Igor' Evgen'evich's was! After he had left, the game would go on, but as time flies by, many have gone, and now only the memories linger.

One funny episode returns to my memory. One of our colleagues, let us call him K, was using two small and seemingly identical mirrors when washing and shaving himself one morning, which, he suddenly noticed, reflected him differently. Rather amazed, he asked his hostel mates whether it indeed was so. Now, for all K's scientific talent and his reputation for bright ideas and hypotheses, he was gullible and naive as a child, whence this practical joke. Of course, K's friends took the opportunity and kept insisting that the mirrors were identical. (One of which was concave, as the reader might have already guessed). K continued his interrogations at work, but the answer was always the same, the mirrors are identical. At a loss, K went into the street where passing schoolgirls told him the mirrors were different after all. K's immediate conclusion was that only people with a pure soul can distinguish mirrors, and he went to see Igor' Evgen'evich for his opinion on that hypothesis. Tamm's answer was short and sweet: 'Scientific problems are not solved by voting.'

Early in 1954 Igor' Evgen'evich was given permission to return to FIAN. When on leave in Moscow, I always considered it my pleasant obligation to visit my teacher, not necessarily at the Institute but, more often, at home, where hospitable Natalya Vasil'evna met me and where her specialty, home-made candied orange rinds, were always delicious. Igor' Evgen'evich was always interested to learn what was new on the 'object', talked enthusiastically about scientific developments, and, to be sure, it all always ended up with a game of chess. In 1967, at Tamm's solicitation, I was employed at FIAN, but this was only a part-time position, and only until 1969 — such was the decision of my Ministry authorities.

I used to visit Igor' Evgen'evich in the years of his final grave illness and witnessed his youthful vigour in working on a discrete space-time model supposed to eliminate quantum theory divergences. It was the dream Igor' Evgen'evich cherished all his life — and at that hard time especially so — to live long enough to see the contours of a new theory of elementary particles and to be able to understand it. His devotion to Science never weakened until his very last days.