

HIGH INTERACTION ENERGY. INTERNATIONAL COLLABORATION IN THE FIELD OF ULTRA-HIGH MAGNETIC FIELD INVESTIGATIONS

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Scientists of the Ultra-High Magnetic Fields Laboratory at one of the largest units at VNIIEF, the Scientific Center of High Energy Density Physics, became involved in international collaboration as soon as it became possible at our behind-the-fence institute. The reason for this collaboration was not only the “perestroika” in our country, though the scientific collaboration was, certainly, one of its best consequences. The more significant reason was the scientific area to which we devoted the major part of our lives in science.

In the early 1950s, A.D. Sakharov at VNIIEF in the USSR and C.M. Fowler at Los Alamos National Lab in the US began to develop the idea of magnetic cumulation, or obtaining of ultra-high magnetic fields by explosive compression of a magnetic flux. In the mid-1960s, the first open publications on this subject appeared. Apparently, the founders of this method to obtain high densities of electromagnetic energy did not find a direct weapon application for it. Soon a kind of scientific community formed around this subject. This community was involved in problems of obtaining and applying ultra-high magnetic fields (not just explosively driven) whose induction was measured by units of Megagauss. The so-called Megagauss conferences became an important organizing factor. The first such conference was convened by F. Gerlakh and H. Knopfel in Frascati, Italy, in 1965. For understandable reasons, VNIIEF scientists then were not able to attend this conference - but they submitted abstracts.

The next conference, Megagauss-2, was organized 14 years later by P. Turchi in Washington, DC; again, Russian scientists were not able to attend it. The VNIIEF papers were presented by G.A. Shvetsov from the Institute of Hydrodynamics of the Siberian Division of RAS. Shvetsov, together with V.M. Titov, organized the third Megagauss conference in Novosibirsk in 1983. A large delegation from VNIIEF came to Novosibirsk Akademgorodok, where for the first time they had a chance to meet a lot of their foreign colleagues in person. By that time, the group headed by Alexander Pavlovsky had something to share in the subject of obtaining ultra-high magnetic fields. As a matter of fact, in Megagauss physics at that time there existed a major obstacle. Though there had been numerous attempts to realize the at-first-sight simple idea of converting HE energy into the energy of an ultra-high magnetic field by explosively driven magnetic flux compression, no one managed to achieve reliable fields of 1-3 Megagauss and higher. Efforts in this direction were stopped everywhere.

At the same time, at VNIIEF, the motherland of magnetic cumulation, a small group of scientists (Alexander Bykov, Mikhail Dolotenko, Nikolay Kolokolchikov, and Olga Tatsenko) headed by Alexander Pavlovsky continued their attempts to build a device able to generate a Megagauss-strong magnetic field. By the end of the 70s, we succeeded in constructing such a device. The device allowed us to begin to investigate material properties in extreme conditions. This device was called a “cascade MC-1 generator of reproducible 10 MG magnetic fields”.

At the end of the summer of 1992, the American delegation (M. Fowler, S. Younger, R. Reinovsky, and I. Lindemuth) visited a firing point of our department during one of our experiments with an MC-1 generator. The honor to press the button to start the experiment was given to M. Fowler, the American father of magnetic cumulation; thus he started the first

joint experiment on Sarov soil. For his successful work he was remunerated with a bottle of vodka.

At the end of 1992, VNIIEF scientists for the first time attended the Megagauss-4 conference in Albuquerque. Now, many years later, it is difficult to give a detailed and truthful account of those events. Even photos do not help. I recall a single room with a kitchenette in the “Hill Top House”, which became our home for weeks and once for more than a month during the future trips to Los Alamos. I remember empty streets in Los Alamos on Sundays and a visit to a local church where our introduction to the congregation became the central event of the week. I recall Lindemuth’s house and memorable medals that LANL Director Sig Hecker presented to us. I also remember visits to facilities, including a huge unipolar generator, meetings in the lab, lunches in a local cafeteria, and Pavlovskii’s pangs when he by chance took a bite of a New Mexican chili. And I certainly remember the friendly smiles of Americans and their hospitality, which they showed during that first visit and every time we came to Los Alamos.

Both at lab meetings and during collegial dinners at residences of our American colleagues we determined basic directions of our collaboration and developed a step-by-step plan to proceed. Both parties were looking forward to mutual benefit from our meetings and information exchange. The same happened in Sarov when an American delegation came to visit us. I remember how persistent the Americans were in asking us questions about topics and subjects for our collaboration, trying, in my opinion, to find out our level of knowledge and skills and to help them in making plans for the future. For our team that fruitful stage of development of the international collaboration ended with the sudden death of A.I. Pavlovskii. We saw how saddened the Americans were when they came to Sarov next time.

The work that Pavlovskii started was continued by his successor, V.D. Selemir, now in the form of contracts between LANL and VNIIEF. In summer of 1993, our delegation: V. Selemir (head of the delegation), A. Bykov, M. Dolotenko, V. Pavlovskii, V. Rogachev, O. Tatsenko and E. Panevkina came to Los Alamos. For the first time, VNIIEF scientists visited an explosive firing point in Ancho Canyon, where Fowler’s group performed experiments with magneto-cumulative generators. As a result of talks between Selemir and Younger, we signed an agreement to perform five large-scale experiments in LANL using our generators.

For more than a month, we worked daily face to face with the Americans. We assembled the generators, discussed results, and determined future activity. We received special uniforms and boots with metal toes that we were allowed to take home with us. We worked collaboratively, earnestly, and productively. Everything proceeded smoothly, like it would at home. The only thing we eyed with envy, and which was the pride of Bruce Freeman who was responsible for the recording equipment, was a set of high-speed digital recorders, which we bought later for our ISTC work. In the evenings, American families invited us for dinner, and since it happened every evening we even began to miss some free time. Bob Reinovsky invited us for Thanksgiving Day and shared with us how Americans celebrate this holiday. He treated us with turkey and delicious ice cream. During this holiday, the Americans took us on a visit to the Grand Canyon. I remember unforgettable sights, a valley of stone trees, the so-called Four Corners point where four states borders meet and a museum where a dark-skinned marine officer came to us to talk, having realized that we spoke Russian. There were many other interesting meetings. We were invited to the Los Alamos County Council meeting at which a decision was made about starting Los Alamos-Sarov sister cities relationship.

Thinking back to that long and busy visit, I think that we adequately represented VNIIEF. In our joint experiments we reliably recorded and validated the output parameters of our generator. In the first test, the magnetic field was >9 MG, and in the second test, using more powerful HE, it was >10 MG. Three other experiments were devoted to investigations in the ultra-high magnetic fields from our generators. We became friends with many people of Los Alamos, and this friendship lasted for many years during our mutual visits.

The year 1996 turned out to be very important for the international collaboration. The main event was the Megagauss-7 International Conference, which was organized by the efforts of people from Selemir's department. The conference was opened in Sarov, in the House of Science. Our guests, both Russian and foreign, got a chance to see our firing points where we performed tests with the MC-1 and other VNIIEF facilities. Then the Conference moved on board of a ship going from Nizhni Novgorod to Moscow along the Volga river. During this trip, we had oral and poster sessions in the morning and tours of the most beautiful and famous cities in the central Russia in the afternoon.

Another conference, Megagauss-IX, was arranged by us in 2002 and became a bright event in our lives and an important stage in the development of megagauss physics. This conference was also held onboard a boat traveling from Moscow to St. Petersburg.

In 1996-1997, in Los Alamos two sets of experiments, "Dirac-1" and "Dirac-2", were performed. Fowler decided to use the capabilities of the LANL firing point and the Russian MC-1 to the maximum and invited scientists from other countries interested in investigations in ultra-high magnetic fields to participate in the experiments.

Through Selemir's efforts and with the support of VNIIEF scientific leader V. Mikhailov, VNIIEF held the "Kapitsa" experiments. This set of experiments was designed for those who did not have funds to travel across the ocean. Another important point here was that SarFTI (The Sarov Physics and Technology Institute) students could participate at these conferences and be introduced to the advanced science. Traditionally, this experiment series was held at the end of October every second year, when no Megagauss conference was held. Every set of experiments included several plenary sessions, followed by 2-3 experiments in a 10 MG magnetic field generated by an MC-1. The last set of experiments of the 20th century (Kapitsa-4) was attended by distinguished scientists in megagauss physics, including H. Miura (Japan), F. Gerlakh (Belgium), and M. von Ortenberg (Germany). When the conference ended, we gave the participants medals with an invitation to participate in the conferences of the third millennium.

In the mid-1990s, during discussions between VNIIEF and LANL, Steve Younger expressed his interest in the experimental study of frozen inert gas properties under Megabar pressures. Our team had developed a method of material isentropic compression by ultra-high magnetic field generated by an MC-1 generator. For several years, our collaboration in this area was performed through direct contracts between VNIIEF and LANL which were established with the great support of Younger who visited Sarov many times. He attended our experiments and discussed the results with great interest and knowledge.

One more aspect of our international collaboration has had a long history: the ISTC program. When A. Pavlovskii and I wrote the first proposal to the ISTC board, we did not have a clear understanding about that organization and did not believe that it would be implemented.

However, the ISTC began to operate and we immediately submitted our proposal. The proposal was accepted and during the period 1995-1998, more than 100 VNIIEF people worked on a project related to the development of a generator of 20 MG ultra-high magnetic field. The result of this and the following projects was the record magnetic field value of 28 MG measured in an explosive experiment using a large MC-1 generator. We continued our work through the ISTC. In addition to important scientific results, the ISTC provided us with the necessary funds that helped us to participate at international conferences and maintain contacts with scientists from other countries. Our American colleagues have mentioned many times that the participation of VNIIEF scientists at conferences makes them more important.

In 1969, when I began to work at VNIIEF, which was a top secret city, I could not even dream that some day I would see some other countries or even work with our opponents from Los Alamos. But we got that chance. We began to learn about America. The euphoria from lavish store windows and beautiful houses to which we were invited has gone, though a bit of yearning is left behind. We learned that across the ocean live people that are very similar to us in their hopes, problems, joy, and challenges. It became clear that we work well, sometimes better than our counterparts, and our results correspond to the world's state of the art and that we are able to set challenging problems and solve them.

International connections have become very important for our work and our life. They have broadened our outlook, expanded our minds and showed us the value of what we had as well as things that we should adopt. And finally, we have seen so many amazing and beautiful things in various cities of the world! We have much to keep in memory and share with our grandchildren!