THE WAR IN UKRAINE: DOES PHYSICS HAVE A FUTURE?

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The war in Ukraine is still going on. The number of victims is increasing every day. Many research centers are destroyed, researchers are displaced, and the conditions and nature of work in almost all regions of Ukraine have undergone significant changes. Is it time to talk about the future of physics in Ukraine under such conditions now? It is our deep conviction that it is necessary.

For most Kyiv families, the foreseen war started unexpectedly on 24th of February at 4 am by explosions and alarming telephone calls from friends. In a few hours the roads were blocked by millions of cars, some were trying to reach the workplaces but most were aimed to the west. Surprisingly, the internet and all other telecommunications remained working and all the civilians, either in traffic jams or discovering not well prepared shelters, were united in following the news and believing in military forces. The scientists behaved similarly. All research was stopped for about a month and researchers in shelters, jams or trenches got much time to think about the future of Ukrainian science.

The Institute for Condensed Matter Physics of the National Academy of Sciences of Ukraine (ICMP NASU) in Lviv holds its regular seminars on Thursdays. The online seminar scheduled for the 24th of February appeared to be an extraordinary one: instead of physics we discussed what is going on in our country and how to stand and cope with the new wave of Russian aggression. Our daily work of physicists seemed meaningless in the face of existential threat to us and to the whole world. The same day we started to receive messages of support from our colleagues from all over the world [1,2].

Kharkiv, the main scientific, cultural and industrial center at the East of Ukraine was - and continues to be - severely damaged by Russian attacks. Already at the first days of the war the missiles hit the fluorescence spectroscopy laboratory of the Department of Medical Physics and Biomedical Nanotechnologies, ruined other buildings of the physical and technical department of Kharkiv National University, and destroyed the neutron source substation of the Kharkiv Institute of Physics and Technology NASU [3,4]. All seven buildings of the Usikov Radiophysics and Electronics Institute NASU were significantly damaged by rocket and bomb attacks, and most of the experimental installations of the institute were fully destroyed.

Besides these cities, physical research and education has a long-standing tradition in all regions of Ukraine. At the beginning of Ukrainian independence in the 1990s, physics and related sciences were the dominant fields of research. To a large extent, this had its roots back in the USSR, which, at the request of the military complex, had an orientation on solid-state physics and, like almost all sciences in the former USSR, was largely closed off from the world. The main institutes of the physical profile were focused on defense problems and were financed to a large extent from the corresponding funds. As examples may serve the Paton Electric Welding Institute NASU, which made a significant contribution to the technology of production of tanks and other heavy weapons, or the aforementioned Usikov Institute of Radiophysics and Electronics and its developments of cruise missile control systems, tactical air defense equipment, *etc.* In the next thirty years, scientific relations with the world expanded significantly, internships of Ukrainian scientists in leading international centers of physics became a practice, and the field of fundamental research expanded. To a large extent, this process was facilitated by the Science and Technology Center in Ukraine [5], which opened up new perspectives for international cooperation, as well as Ukraine's accession to the EU framework cooperation programs. New principles and approaches began to be used in the organization of research in Ukraine, in particular due to the creation of the National Council of Ukraine for Science and Technology Development and the start of the National Research Foundation of Ukraine [6]. Representatives of Ukraine participated in a number of scientific collaborations, including at the Large Hadron Collider.

The war affected all aspects of life in Ukraine and all its residents. The scientific community, in particular the physical one, was no exception. In this respect, among the main problems one has to mention the following:

- **Scientific infrastructure.** Research centers in the occupied zone have stopped their activities. The war is a destruction that also affects the premises of scientific institutions, the equipment and entire infrastructure are destroyed. As a result of the shelling of Kyiv, Dnipro, Kryvyi Rih and Kharkiv, the occupation of Mariupol and Kherson, as well as the seizure of nuclear energy facilities (Chornobyl, Zaporizhia) and the bombing of large chemical production enterprises, there were growing risks for both the environment and people. Restoration of the scientific infrastructure will require significant financial investments.
- **Scientific personnel.** During the war, a large number of forcibly displaced persons left their places of permanent residence due to the threat to their lives and the lives of their families. Many scientists from Ukraine worked in leading centers of the world even before the war. This trend, which began after the collapse of the USSR and continued for decades, has now significantly intensified. Some scientists are fighting in the ranks of the Armed Forces of Ukraine, there are many casualties among the civilian population, including the science community. Due to the threat of missile strikes, the conditions and nature of work in almost all regions of Ukraine have undergone significant changes.
- **Topics and requests for research.** In the conditions of war, military expenditures become an absolute priority, and therefore other budgetary expenditures, in particular for science, are reduced. The priority areas of research are those that can contribute to victory and are focused on quick applied results. Basic research is in a dangerous state. It is obvious that all these problems will be acutely felt in the post-war period as well. The dynamics of the development of all sciences in Ukraine, particularly physics, will depend on their solution.

◂ P. 20: Ukrainian physicists at IFW Dresden in April 2022. © IFW Dresden.

▲ A neutron source substation at Kharkiv Institute of Physics and Technology destroyed by Russian attacks on 6 March, 2022. © State Nuclear Regulatory Inspectorate of Ukraine.

The war in Ukraine is going on. The number of its victims is increasing every day. A significant number of scientists are called to the ranks of the Armed Forces or are involved in territorial defense units. Thousands of them work as volunteers and do their best to help financially, facilitate the placement of temporarily displaced persons, or help the military in other ways. Note that due to the peculiarities of wartime, women, the elderly and children dominate among temporary refugees to other countries of the world, while men under sixty remain in Ukraine and form a mobilization reserve. Considerable attention is paid in Ukraine to the preservation of the infrastructure of scientific institutions, primarily in terms of the implementation of urgent works to save damaged buildings and their temporary conservation until the end of hostilities. In most physical laboratories, research work continues, although for obvious reasons, in volumes smaller than before the war. The first attempts to analyze the impact of the war on scientific research in Ukraine have already appeared [7]. Is it possible to talk about the future of physics in Ukraine under such conditions? In our deep conviction, it is not only possible, but also necessary.

In the long term, Ukrainian science evidently would require a "Marshall Plan" to survive. We may hope to get easier access to European research infrastructures and the international grants like within Horizon Europe, but development of joint research labs and institutes in Ukraine would be especially helpful. One of the key tasks will be not just to restore the pre-war level of scientific infrastructure, but to create new points of rapid growth - possibly through the creation of a few centers of interdisciplinary basic research with modern equipment as well as with the access to global computer facilities and the wide involvement of international specialists in research topics. These centers should be closely integrated into the educational process. It could give a powerful stimulus both for the training of young physicists and for maintaining the level of basic research with the integration into the European Research Area.

Some forms of help to Ukrainian scientists and students emerged immediately with the rise of the war. We have got a number of offers from colleagues around the world to host Ukrainian scientists. Examples are PAUSE and JESH programs in France and Austria and many others [8]. In places with long lasting collaborations the special programs have been started. For example, the Ukraine Scientific Scholarship Program has been promptly established in Dresden, and in the first month 19 students and scientists, mostly physicists, have gone to the Leibniz Institute for Solid State and Materials Research Dresden to continue their research [9]. Such scholarships remain attractive also in the middle term, when it is about establishing new collaborations. Although there is a danger of a new wave of "brain drain". Other positive examples of foreign help to Ukrainian researchers or students staying in Ukraine are the IRIS-HEP Ukrainians Fellows program or the Pauli Ukraine Project [10]. The remote projects seem to be indispensable to support Ukraine and its researchers and lecturers in the middle time scale.

In the current situation, it also increases the importance of PhD studies carried out in frames of the split-side agreements (co-tutelle). To give an example, the first co-tutelle PhD thesis in the field of physics was defended in 2008 within collaboration between the University of Lorraine (then – Henri Poincaré University Nancy) in France and ICMP in Lviv. Now this collaboration is widened to the International Doctoral College "Statistical Physics of Complex Systems" that joins ICMP with Universities of Lorraine, Leipzig and Coventry. We think that such and similar initiatives have to be further supported both by the local decisions of University councils as well as on the level of international programs.

As sociological studies show, the vast majority of Ukrainians are convinced of the victory of Ukraine, despite the terrible methods of waging war (methods that have been recognized globally as terrorist in essence), when the Russians try to intimidate and in this way subjugate through the total destruction of civilian infrastructure objects and bombing of peaceful residents. But the victory (as Ukraine imagines victory) is possible only when the international community helps Ukraine to endure. This is the way to lasting peace in Europe and the world, this is the way for peace in Ukraine and this is the way when physics (like other sciences) will have a future in Ukraine. And every citizen of the world can contribute to this process, or be a passive observer, and therefore an active opponent of such a scenario. This is an answer without guile to the question about the future of physics in Ukraine. ■

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