Foundation for Polish Science

REPORT

Science in times of transition

How EU-funded research is helping to protect us from global threats and take advantage of historic opportunities

European Funds Smart Growth

Republic of Poland

NCBR National Centre for Research and Development

European Union European Regional Development Fund

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The activities conducted by the Foundation for Polish Science under the Smart Growth Operational Programme 2014–2020

Warsaw 2023

Publisher: Foundation for Polish Science
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www.fnp.org.pl

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Graphic design, DTP: Grzegorz Adach

The publication was co-financed by the European Union under the European Regional Development Fund under the Smart Growth Operational Programme.

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Introduction

One could argue that breakthrough events – including scientific discoveries that benefited society the most – often occurred unpredictably and under unfavorable circumstances. Stress, global threats, or unexpected violent events heavily impact our development and, sometimes, induce completely new values. The Max Planck Society, which today gathers the largest group of Nobel Prize winners among European organizations, would never have been founded if not for the American occupation of southeastern Germany after the Second World War. American research on the atomic bomb, which also led to the peaceful use of atomic energy, would not have accelerated so significantly if not for the start of the Second World War by Hitler. Had it not been for the tragic tsunami caused by the earthquake that damaged the Fukushima nuclear power plant, the world would not have begun to work intensively on new energy production and storage technologies.

Professor Maciej Żylicz, President of the Foundation for Polish Science

We are currently struggling with the effects of the – hopefully – past COVID-19 pandemic, with growing climate change due to human activity, as well as an energy crisis caused by Russia's brutal invasion of Ukraine, among other things. In view of these current challenges, will there happen a phase transition, and will we witness the creation of a new quality in a socially important field? We cannot say for certain, but we should nevertheless strive towards such a goal. Using Structural Funds within the framework of the Smart Growth Operational Programme (POIR), the Foundation for Polish Science (FNP) has invested approximately PLN 1.2 billion in research projects in the following areas: new technologies in the field of energy storage, ecology, energy, creation of new materials, quantum technologies (including cyber security tools), improvement of the comfort of life, modern diagnostics, including neurological and autoimmune disorders.

An great example of an unconventional action by the Foundation for Polish Science in response to an unforeseen global event was its support for the involvement of Polish scientists in the fight against the COVID-19 pandemic, which was provided shortly after the pandemic began. What was unconventional was that instead of running a new competition for grants for scientists working on projects related to combating the pandemic, we opened a competition for new research tasks dedicated to the problem: for research teams that had already received EU funds from the FNP for other research topics. Therefore, we had a group of scientific teams already verified in a diligent selection process of our competitions, who based on important research results obtained in their subject, wanted to undertake additional work that could directly help to combat the pandemic. Professor Marcin Drąg from the Wrocław University of Science and Technology, who has been studying proteases for many years, developed a new technology for finding effective and specific inhibitors of these enzymes. Based on the results of these earlier studies – and within a few months of identifying the new virus in China – his team proposed chemical compounds that effectively inhibited two proteases encoded by the SARS-CoV-2 virus. Blocking these proteases inhibited the growth of the SARS-CoV-2 virus in an infected cell, regardless of its genetic variant. Thanks to this pioneering research by Professor Drąg's team, a global biotechnology company performed clinical trials on new SARS-CoV-2 protease inhibitors and obtained approval from the U.S. Food and Drug Administration for the treatment of patients infected with the SARS-CoV-2 virus based on this method. The entire process from proposing the inhibitor to starting treatment for patients took less than two years.

The team of Professor Daniel Gryko from the Institute of Organic Chemistry at the Polish Academy of Sciences designed and synthesized fluorescent probes that selectively label virus-infected cells.

The team of Professor Jacek Jemielity from the University of Warsaw was one of the first to begin work on the therapeutic use of mRNA molecules as anti-cancer vaccines. Even before the SARS-CoV-2 pandemic, Jemielity and his team sold a license to modify mRNA in such a way as to increase its expression and viability to a company that later developed anti-SARS-CoV-2 mRNA vaccines. As part of a new research task, Jemielity's team selected inhibitors of two methyltransferases encoded by SARS-CoV-2. Inhibition of modifications with methyl groups of the virus's RNA results in blocking its growth; markedly, the final stages of this project were carried out in cooperation with a Belgian biotechnology company.

Professor Agnieszka Michota-Kamińska, who received funding from the FNP to develop a new technology based on surface-enhanced Raman spectroscopy to detect pathogenic bacteria, developed a prototype device to detect the presence of the SARS-CoV-2 virus in body fluids (e.g. in saliva) as part of a new research task.

Professor Justyna Olko from the University of Warsaw, who for years had been studying ethnic groups living in Mexico and speaking languages different from their surroundings, obtained very interesting results on the functioning of minority groups (Kashubians, Silesians, Lemkos, or migrants living in Calabria) during the pandemic: how they reacted to the stress caused by the threat, and how their surroundings (majority groups) reacted to their behavior. Moreover, the research concerned how refugees from Ukraine residing in Poland reacted to the COVID-19 pandemic. This project demonstrates the extraordinary importance of social innovation that can be generated by good research teams working in the social sciences and humanities.

We encourage you to read our publication: it presents the above and many other scientific achievements of more than 30 outstanding scholars whose research was supported by the Foundation for Polish Science within the framework of the POIR funded by the European Union. We can already see that there are some among them that are positively changing reality and significantly advancing our knowledge of the world.

Professor Maciej Żylicz
President of the Foundation for Polish Science

Selected projects

COVID-19

The pandemic is just the beginning. Fight against COVID-19 paves the way for medical breakthroughs

Polish researchers supported by the European Funds provided through the Foundation for Polish Science, among others, are at the forefront of the fight against COVID-19. The solutions being developed in Polish laboratories can give us the tools to fight not only the current pandemic but also a wide range of other diseases.

When in early December 2019 reports started to come in from Wuhan, China, about a mysterious new disease that had begun to affect the city's inhabitants, scientists did not wait. When the World Health Organisation was formally informed on 31 December of the same year that a dangerous new virus had been detected, research work was already underway to find its potential vulnerabilities. Also in Poland, the SARS-CoV-2 virus has proved to be a very difficult opponent. The pathogen, rapidly spreading and variable, remains a serious threat today. A tremendous effort by scientists enabled the rapid development of innovative vaccines and therapies against the new disease known to the world as COVID-19. Thanks to all those efforts, the pandemic was halted after just several months.

Searching for virus vulnerabilities

One of the first researchers to unravel the biological machinery behind the rapid spread of the SARS-CoV-2 virus was Professor Marcin Drąg, the chemist from Wrocław University of Technology, the winner of the 2019 FNP Prize. He already knew his opponent to some extent. He had previously worked in the U.S. researching the SARS virus, a closely related coronavirus that caused more than 8,000 infections and more than 700 deaths between 2002 and 2004. Some of the experience of fighting that disease could be applied to fighting the coming pandemic.

Prof. Marcin Drąg

"I am cooperating with Professor Rolf Higenfeld's group at the German Centre for Infection Research, who has had extensive experience in the suppression of the SARS-CoV-1 outbreak. We anticipated that something like that could happen and another more dangerous coronavirus would emerge, while we do not have the right tests or drugs," Professor Drąg explains.

The Wrocław laboratory has developed technology that allows highly accurate profiling of proteases, i.e. enzymes that hydrolyse the bond between two specific amino acids. In the case of coronavirus, proteases are responsible for activating viral proteins and blocking the "alarm signals" sent by the infected cell. The research project, which was funded by the European Funds from the POIR within the TEAM programme of the Foundation for Polish Science, made it possible to determine precisely how proteases recognise the amino acids they are to separate.

The COVID-19 drug should remain effective regardless of the emergence of new variants of the virus. It should also work against all other coronaviruses in this class.

"We have developed technology to indicate amino acids and pockets of the protease under investigation that bind together. We promised Rolf that we would synthesise a library for the study of coronavirus proteases and we soon did. He was supposed to bring us samples of SARS and MERS proteases just before Christmas 2019, and that's when the pandemic started and we already had the testing tool ready," — the chemist recalls.

The work of the scientists at the Wrocław laboratory quickly brought results. The SARS-CoV-2 virus contains 29 different proteins, including two proteases, SARS-CoV-2-Mpro and SARS-CoV-2-Plpro. These are crucial for the proper functioning of the virus because without them it is unable to replicate. Professor Drąg's team prepared accurate profiles of both proteases back in February 2020. The scientists identified their vulnerabilities that would be helpful in the development of drugs that block the activity of the proteases, thus blocking the growth of the virus. Two scientific articles published by the team have been downloaded from the database more than 100,000 times. One of the amino acids identified by Professor Drąg's team as a potential key to blocking the action of viral proteases has become the basis for a revolutionary COVID-19 drug developed by Pfizer.

"Pfizer has made a great gift to us, validating our medical goal and using the knowledge we have developed to create one of the most important drugs in history," — emphasises Professor Drąg. Notably, compounds that block the action of coronavirus enzymes do not affect the function of proteases naturally present in human cells. Thus, they are not only effective but also safe for humans.

However, the findings of the team from Wrocław may have implications far beyond the current pandemic. The researchers pointed out that the so-called active centre of coronavirus proteases does not change, regardless of mutations of the virus as a whole. This is probably because any significant changes in this element would lead to the virus losing its ability to replicate. This means that the COVID-19 drug should remain effective regardless of the emergence of new variants of this virus. It should also work against all other coronaviruses of this class. This will allow us to protect ourselves against future pandemics caused by related pathogens.

Stop the copying machine

The team of Professor Jacek Jemielity from the Centre for New Technologies at the University of Warsaw also targeted the basic chemical reactions that allow the virus to replicate in our cells. However, the researchers focused on methyltransferases. These

Prof. Jacek Jemielity

are enzymes which chemically modify the RNA of the virus and thus prepare its genetic information for copying.

“A virus is nothing more than a certain envelope made up of structural proteins plus the genetic material through which this virus can replicate, as well as the proteins necessary for the expression of this genetic material,” Professor Jemielity explains. Having entered the host cell, the virus uses it to create copies of itself. Before this can happen, however, the intruder must use certain tools to persuade the cell to treat the viral RNA as its own and copy it through the cellular machinery.”

If one of the existing drugs shows properties that enable it to inhibit viral enzymes, their use in treating the new disease could be possible even after just a few months.

“The genetic material of the SARS-CoV-2 virus is RNA, but it is not the same RNA as in humans. It has to be shaped and prepared properly so that it can be translated by the human machinery,” the researcher specifies. For this purpose, the viral RNA must be equipped with structural elements that serve as identifiers of the molecules to be copied. The process is carried out by two viral methyltransferases, the nsp14 and nsp16 proteins. They modify viral RNA so as to lull the vigilance of our immune system.

The nsp14 methyltransferase builds a so-called cap at one end of the RNA molecule. The cap is a structure that protects the RNA from destruction and allows the process of transcribing genetic information into amino acid sequences in proteins to begin (this process is called translation). “The cap is a kind of postage stamp that sends genetic information to the protein factory and, on the other hand, protects the molecule from chemical degradation. Without the cap, the RNA is degraded in a few minutes,” the researcher explains. In turn, the nsp16 methyltransferase is responsible for modifying the viral mRNA in such a way that the cell recognises it as its own and does not trigger the alarm.

Without these two methyltransferases, SARS-CoV-2 would not be able to replicate effectively in our cells. Its RNA would be recognised as foreign and the immune system would seek to prevent the synthesis of a viral protein based on it. Thanks to funding from the European Funds from the POIR awarded by the FNP within the TEAM programme, Professor Jemielity’s team searched for inhibitors that would selectively inhibit precisely these two methyltransferases without affecting the normal functioning of similar human enzymes. This is difficult as methyltransferases are often very similar to each other.

“We have developed a method based on the fluorescence phenomenon that enables us to very quickly see which of the countless chemical compounds have any potential to inhibit these enzymes,” Professor Jemielity explains. The team tested 7,000 potential inhibitory substances and found 83 compounds that seemed to be promising targets for further research. After further testing, this group was initially narrowed down to 23 inhibitors that did not simultaneously inhibit human enzymes, and then — after the final phase of testing in Belgium — to three very strong drug candidates. The same method may in the future help to quickly identify substances that inhibit the replication of other viruses. “The methodology itself for finding inhibitors may prove to be quite versatile. We can take any methyltransferase from a virus and check quickly in a library of 7,000 compounds whether they have the potential to inhibit its growth and become drugs,” Professor Jemielity explains. Importantly, the vast majority of these are compounds that are already available on the market today and known to doctors. If one of the existing drugs shows properties that enable it to inhibit viral enzymes, their use in treating the new disease could be possible even just after a few months.

mRNA and drugs of the future

The research, which has been greatly accelerated by the COVID-19 pandemic, may have implications far beyond the fight against coronavirus. The mRNA technology used to produce the first vaccines against SARS-CoV-2 brings hope for the development of therapies for many diseases whose treatment today is often beyond the capabilities of medicine. The team of Professor Jemielity was one of the first in Europe to explore the therapeutic use of mRNA molecules. “mRNA is our cellular recipe for protein and, by its very nature, it is a very impermanent molecule; at the same time, however, it has a very high potential,” Professor Jemielity explains. “Inhibitors function to inhibit the activity of enzymes responsible for protein formation, and many diseases arise because the right proteins are absent from the cells.”

If this is the case, the delivery of the “recipe” in the form of mRNA to the cells could allow the curing of many genetic diseases, even chronic ones. However, there is a barrier that had to be overcome first: just as viruses modify their mRNA to hide it from our immune system, the therapeutic mRNA must contain certain elements allowing the body to treat it as its own. It is also necessary to deliver mRNA molecules to cells without degradation. Both issues were resolved to a large extent during the development of COVID-19 vaccines, which now opens the door to entirely new applications for the technology.

“The creation of mRNA-based vaccines is a breakthrough for this technology. Creating more of them against infectious diseases will already be relatively straightforward,” Professor Jemielity explains. “The next stage is cancer vaccines. In three to five years’ time, we will be treating genetic rare diseases such as cystic fibrosis, and what is so futuristic — although research is already underway — is regenerative medicine and the use of mRNA together with CRISPR-Cas9 technology, or precision genome editing.”

The Polish team is now working on technologies to deliver mRNA into cells as efficiently as possible and to use as few of its molecules as possible in each dose of the drug. mRNA-based therapies could be among the most significant breakthroughs in medicine in the coming years and the research conducted by Polish scientists during the pandemic has brought us much closer to them.

Designing a key for a viral lock

Professor Jemielity has worked closely with Professor Marcin Nowotny from the International Institute of Molecular and Cell Biology in Warsaw, whose research was also funded by the FNP under the TEAM programme with funds from the POIR. Professor Nowotny’s team works on determining three-dimensional structures of key biological molecules with the precision of individual atoms. In particular, the group specialises in obtaining structures of proteins that process nucleic acids.

“We are looking for inhibitors using protein crystallography,” Professor Nowotny says. Crystallography is a method of determining a structure of a molecule using X-rays passed through its crystals. “We generate protein crystals, hundreds of crystals of a particular enzyme, and soak them in compounds that can potentially bind to the enzyme. These compounds themselves are not usually inhibitors, but these small molecules provide a good starting point for the construction of such inhibitors. Now that we know where they stick, in what position, in what setting, we can expand them to create a new, bigger, better inhibitor.”

This, however, requires very painstaking experimentation. Professor Nowotny’s co-worker, Dr hab. Elżbieta Nowak conducted a series of experiments at the synchrotron in Berlin, which led to the discovery of dozens of promising substances that bind to viral proteins. “We have just over 20 of such larger substances identified at the moment. Luckily, they are commercially available. We can

Prof. Marcin Nowotny

simply buy them and test them," Professor Nowotny says.

However, this is just an introduction, as the goal set by Professor Nowotny is very ambitious. He wants to find substances that will block the chemical mechanisms allowing replication of not just one virus, but the entire spectrum of viruses. It is analogous to how antibiotics block the life processes of many types of bacteria.

"This is difficult because the processes in bacteria are quite similar, whereas viruses are much more diverse," the professor explains. "It's a very demanding work, yet it's such a Holy Grail of the discipline. Anyway, there are not so many true antiviral drugs. For the time being, it would be nice to have some different chemicals on the shelf that we could test very quickly in the event of another pandemic, to say to ourselves: OK, I have a new virus, but I also have a palette of options to combat it."

How to recognise a pathogen instantly

For future epidemics and pandemics, diagnosis will be of key importance. The rapid recognition of the pathogen can determine the life and health of the patient but also the further spread of the disease. In this case, the device being developed by Professor Agnieszka Michota-Kamińska's team at the Institute of Physical Chemistry of the Polish Academy of Sciences in Warsaw may prove to be a priceless ally for doctors.

The aim of the research, funded by the European Funds from the POIR within the TEAM-TECH FNP programme, is to develop a novel, portable diagnostic device based on the surface-enhanced Raman spectroscopy technique (SERS) for the sensitive and rapid detection of pathogenic bacteria and viruses (including SARS-CoV-2). It is intended to be simpler and cheaper than the standard biochemical, immunological or molecular identification methods used today.

The nanomaterials, databases of pathogenic bacteria and chemometric analyses developed by the Polish team will make it possible to identify bacteria or viruses in just 30 minutes. The FORMI device is based on Raman spectroscopy and, in particular, on one of its variants, the so-called SERS technique, which allows the detection of single molecules. The discoverer of Raman spectrography, Indian physicist Chandrasekhara Venkata Raman, received a Nobel Prize for it as early as 1930, but using it in practice has been difficult because the technique usually delivers a weak signal that is difficult to analyse. To take full advantage of its capabilities, special materials - plasmonic nanostructures, which amplify the weak signal - are required.

The creation of such materials was one of the objectives of Professor Michota-Kamińska's team. The TEAM-TECH programme has succeeded in developing plasmonic nanostructures for SERS studies that provide high sensitivity, repeatability and stability of the recorded Raman signals. The lack of such materials has so far limited the applicability of the SERS technique in medical diagnostics. "For several years, we have been working exclusively on nanostructures developed by ourselves, which are ideal for our applications," Professor Michota-Kamińska ensures. "They give us incredibly powerful spectra of biological systems, from bacteria to fungi and viruses to cancer cells. In a matter of seconds or so, we are able to obtain a spectral image."

Analysis of SERS spectra makes it possible to search for the "spectral fingerprints" of individual pathogens in saliva, blood or other body fluids. In the case of bacteria, the spectrum obtained comes from, among other things, the proteins that make up their cell walls. This makes it possible not only to distinguish between their individual species, but also between strains.

Prof. Agnieszka Michota-Kamińska

Professor Michota-Kamińska's research group is also working on the use of the SERS technique in the analysis of clinical samples, i.e. saliva, blood and nasopharyngeal swabs of patients infected with the SARS-CoV-2 virus. Analyses of the spectral data have established a "fingerprint" of SARS-CoV-2-infected fluids, molecular changes and distinct markers of physiological changes in the pathologically altered fluids. Those analyses enabled the development of a classification model for the rapid identification and differentiation of virus-infected and non-infected groups.

During the project, the team developed the world's first database of bacterial pathogens. The SERS spectra database currently contains more than a hundred species and forty strains of bacteria. "Our database and identification algorithms give us a quick answer as to which species we are dealing with and what is the likelihood of occurrence of a particular pathogen," the researcher explains. Her team's work is nearing completion and the portable, lightweight device is essentially ready. The team is still developing treatment protocols so that the results obtained with the FORMI device are as reproducible as possible and its operation is simple and intuitive.

The nanomaterials, databases of pathogenic bacteria and chemometric analyses developed by the Polish team will make it possible to identify bacteria or viruses in just 30 minutes.

Thanks to COVID-19 we have more trust in science now

The COVID-19 pandemic, and especially the decisive and effective action taken by scientists and doctors as well as research and health funding officials, has had a rather surprising and very positive effect almost everywhere in the world. The confidence citizens have in science has clearly increased in most regions.

The study conducted by Wellcome Global Monitor indicated that on a global scale participants' declared trust in scientists increased from 32 per cent in 2018 to 41 per cent in 2020. In comparison, over the same period, trust in governments rose by 3 percentage points and trust in neighbours fell by 5 percentage points.

However, the strength of this effect varied considerably from region to region. In North America, Western Europe as well as Australia and New Zealand, whose citizens already declared very high confidence in science exceeding 50 per cent, after two years it reached 55, 59 and 58 per cent, respectively. In Eastern Europe, which was the most sceptical region before the pandemic outbreak (with a declared "strong" trust in science of only 23 per cent), a survey conducted in 2020 showed that trust levels rose to 36 per cent. The only regions where confidence in science declined over the study period were sub-Saharan Africa (from 28 to 22 per cent) and Russia, the Caucasus and Central Asia (from 33 to 32 per cent).

How different social, national or ethnic groups responded to the challenges and threats of the pandemic and to the attempts to stop it, however, was an extremely complex process. Professor Justyna Olko from the Faculty of "Artes Liberales" and Professor Michał Bilewicz from the Faculty of Psychology at the University of Warsaw received funding within the TEAM FNP programme for the research project "Language as a cure: linguistic vitality as a tool for psychological well-being, health and economic sustainability", which investigated, among other things, how ethnic minorities and migrants were affected by the pandemic.

"It was clear from the start of the pandemic that some of those most vulnerable to its negative effects, both on a health and socio-economic level, were Indigenous and ethnic minority groups, as well as immigrant communities," Professor Olko explains. This is, of course, due to their long-term exposure to marginalisation

Prof. Justyna Olko

and various forms of discrimination, their inferior economic status, their impeded access to health services and the traumas they have experienced previously and passed on intergenerationally. The researchers looked at the situation of Kashubians, Lemkos, Silesians and Vilamovians as well as Ukrainian immigrants in Poland, the Greco ethnic minority and migrants living in Calabria, and Indigenous groups in Mexico. For the latter, the reported mortality rate during the pandemic was almost double the national average.

"Our research has shown that for Indigenous groups in Mexico, COVID-19 was a reminiscence of what their ancestors had experienced during the colonial period, when the Native population was reduced by 90 per cent due to epidemics, and then during the Spanish flu pandemic," the researcher explains. "COVID-19 was a stimulus to reactivate historical trauma and the sense of victimisation. We observed similar processes among other groups, such as the Kashubians and Silesians, who to varying degrees perceived being stigmatised or discriminated against during the pandemic."

Mental health issues were a major concern during the COVID-19 pandemic. In this respect, ethnic minority and immigrant groups have proven to be particularly vulnerable. "At that time, we noticed very high levels of generalised anxiety among the populations surveyed (ranging from 18 per cent among Lemkos to over 27 per cent among Ukrainians, Silesians and Kashubians). Nevertheless, strong ties with other members of a particular minority or immigrant group have been shown to serve as a buffer against anxiety and feelings of insecurity during a pandemic," says Dr Michał Bilewicz, who coordinated the psychological part of the project.

It quickly became apparent that the cohesiveness and agility of such groups could prove to be a very effective tool in the fight against the pandemic. It was especially noticeable when key information began to reach them in their own languages. "What mattered to them was not just the individual threat, but the threat to the group, its culture and heritage language. It was about the extent to which the pandemic threatened their survival," Professor Olko explains. "Consistently, in all the groups studied, it became clear that compared to the representatives of other majority groups those individuals behaved more rationally, better complied with restrictions and were less prone to conspiracy theories. They protected not only themselves but also other members of their community. Social responsibility for oneself and for older family members has been very strong. This was a widespread solidarity that we sometimes lack and which is still evident today in Mexico, for example, in terms of protection against infection."

The research of the University of Warsaw team thus indicates that despite the creation of advanced therapies and super-modern diagnostic methods, which are also being developed in Polish laboratories, one of the most important factors in caring for the health of societies tends to be empathy and concern for the weak.

New materials

From nanoscale to megastructures. Polish scientists create the materials of the future

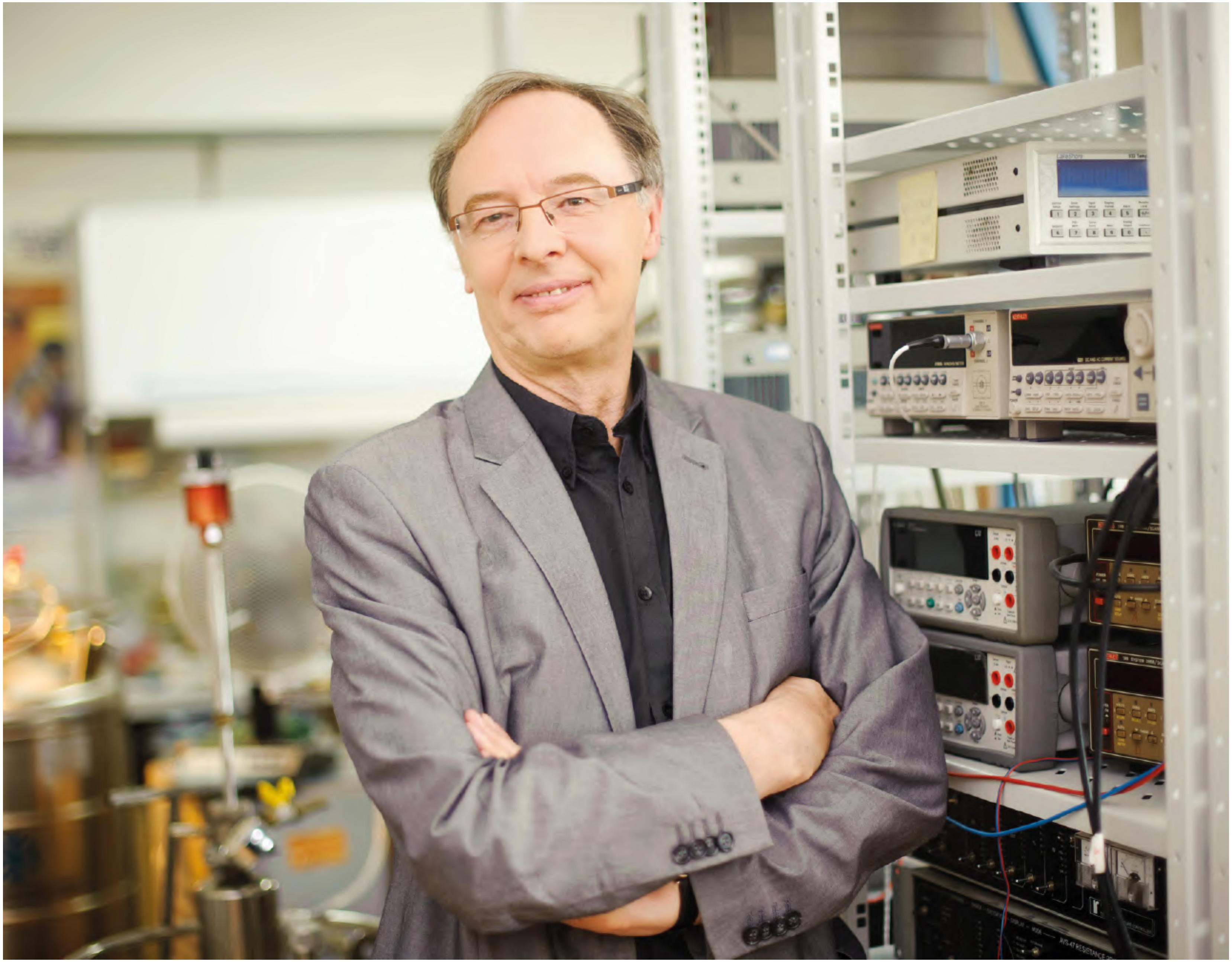
From medicine to nuclear reactors. The materials being developed in Polish laboratories can open up completely new possibilities for engineers and scientists, ones that were not available to them before. Backed by European funds, researchers are using exotic properties of matter at the nanoscale, observing nature and improving materials that have been used for millennia to open up new possibilities.

It is difficult to overestimate the role that work on new materials has played in the history of civilisational change. From the first experiments with stone processing to state-of-the-art nanostructure with extraordinary properties, new materials have always provided us with entirely new possibilities. It is no wonder that medieval alchemists were obsessed with the possibility of manufacturing them.

“Technological progress happens largely thanks to materials. This has always been the case in the history of mankind. That is why we had the Bronze Age or the Iron Age,” begins Prof. Tomasz Dietl. He himself is working to make the next age the age of topological materials.

The International Centre for Interfacing Magnetism and Superconductivity with Topological Matter (more commonly known by the acronym ‚MagTop’), headed by Prof. Dietl and Prof. Tomasz Wojtowicz and financed by the POIR within the framework of the International Research Agendas programme of the Foundation for Polish Science, is testing materials that may revolutionise data storage and, inter alia, energy sector, or even prove crucial in the construction of quantum computers.

“Geometry tells us how the properties of solid figures depend on their shape, while topology deals with those properties that do not depend on shape,” explains Prof. Dietl. “For example, a bagel has one hole regardless of whether it would be round or square.



Prof. Tomasz Dietl

One bagel can be transformed into another without tearing them apart, preserving the topology of the object."

Topological Möbius strip

The topological properties of matter are of great importance, especially at the nanoscale. In the case of materials whose edges or surfaces are even tens of thousands of times smaller than the cross-section of a human hair, completely new electron states can appear. They give such materials new properties, e.g. in terms of electrical conductivity and, in addition, make them resistant to electromagnetic interference. Research on the application of topology to the study of unusual states of matter was awarded the Nobel Prize in Physics in 2016.

"We have developed world-class methods for obtaining these materials. We also use advanced measurement methods and have a very strong theoretical group," states the physicist. MagTop employs specialists from 13 countries.

The topological properties of matter are of great importance, especially at the nanoscale. In the case of materials whose edges or surfaces are even tens of thousands of times smaller than the cross-section of a human hair, completely new electron states can appear.

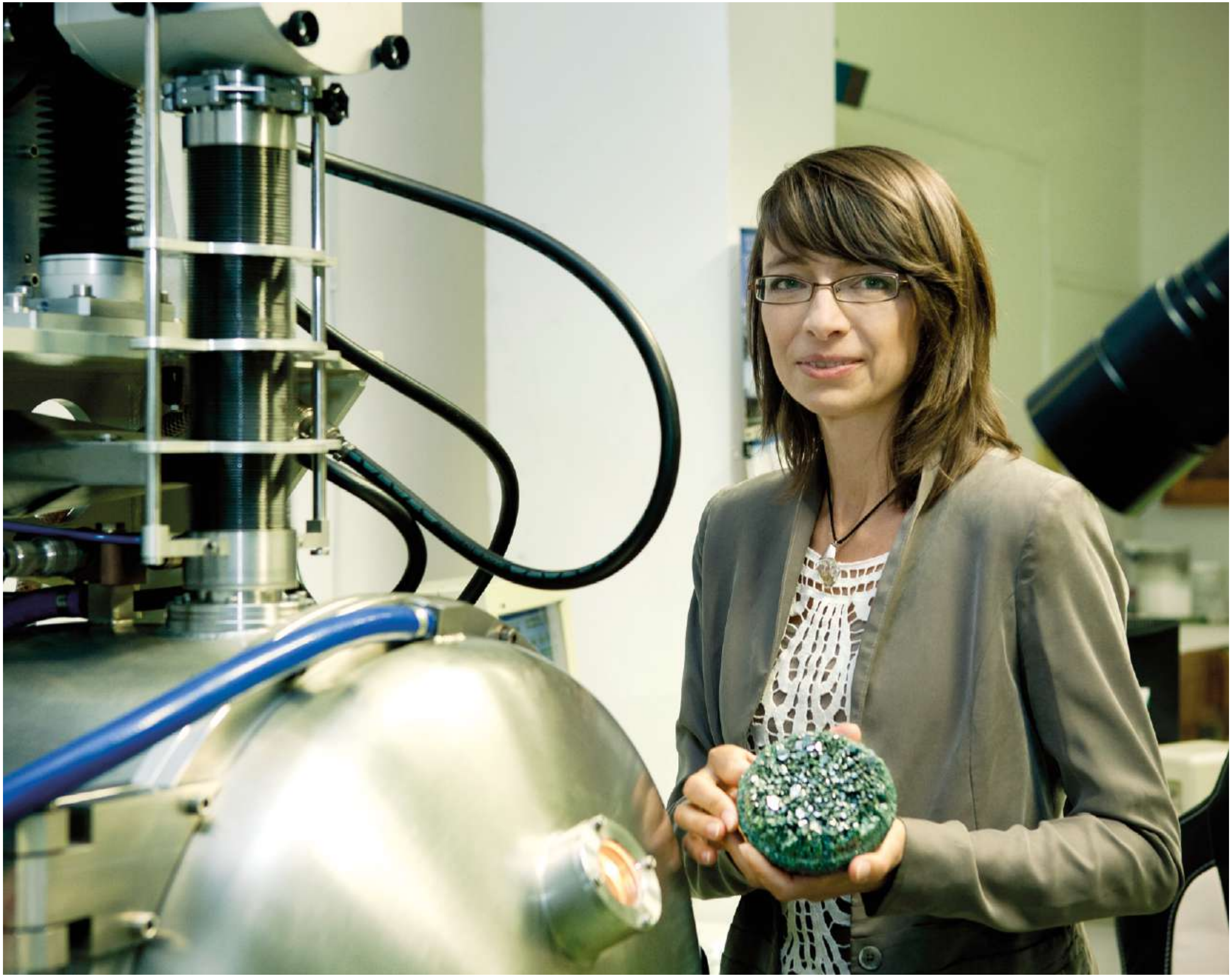
The topology of the structure is of great importance in magnetic materials, where the direction of magnetic moments can be arranged in the shape of a Möbius strip. Such arrangements are much more resistant to interference than their traditional counterparts – in the magnetic storage devices used until now, the storage density is limited by the vibrations of the atoms. A topological Möbius strip could allow increasing the amount of stored data even several times. This is important, considering that in 2022, humanity generated 2.5 billion gigabytes of data every day.

The materials being developed by the MagTop centre may be implemented in various ways. Researchers place great hopes on their use in the energy sector, where they could allow to significantly increase the efficiency of the equipment we use. "We will be considering not only how to generate energy, but also how to recover the energy that has already been lost. The engine efficiency is 20-30 per cent, at best 50 per cent. The rest of the energy is lost as heat. By recovering at least part of it, it is possible to make huge savings," says Prof. Dietl.

This may be of great significance in the process of "green transformation" of the European economy, because apart from the development of clean and renewable energy sources, increasing energy efficiency is one of the fundamental objectives of the European Union's energy policy, in which the total cost of energy - according to a BloombergNEF study - will amount to EUR 5.3 trillion by 2050. Still, this may not be the most important application of the materials developed by MagTop.

It is possible that it is the topological materials being developed in the centre's laboratories that will enable the creation of the first useful quantum computers. "A quantum computer, unlike the ones we use today, works a bit like an analogue computer and, similarly to analogue electronics, it is susceptible to noise and interference," says Prof. Dietl. "Our materials, by providing so-called topological protection, can significantly secure the device against similar disturbances."

Quantum computers, simulating systems of millions of atoms, could also be used to create new materials. This completely exceeds the capabilities of even the most powerful modern supercomputers, and gives hope that future materials designed from the level of single atoms would obtain optimal properties. Pro-



Dr hab. Dorota Anna Pawlak

fessor Dietl emphasises that although the principle that it usually takes 30 years from the first idea to practical application is true when it comes to materials science, many of the solutions developed by MagTop are already being used in practice. The centre cooperates, for example, with PREVAC, a company developing equipment for the production of ultra-high vacuum, KRIOSYSTEM, which deals with advanced cryogenic installations, or VIGO System, a world-class manufacturer of infrared detectors, who built sensors for Mars rovers.

By using the same material, but with a different dopant, we can completely change its properties and thus dramatically change its application.

Plasmonic crystals

Polish scientists have been at the forefront of researchers of new materials for a century. It is sufficient to mention that the revolutionary method of obtaining monocrystalline silicon, developed by the outstanding chemist, Prof. Jan Czochralski in 1916, has become the foundation for the production of integrated circuits, and silicon crystals grown with this method are present in almost all electronic and optoelectronic devices used worldwide.

Dr hab. Dorota Anna Pawlak, Professor at the University of Warsaw, heads the ENSEMBLE3 Centre of Excellence. The center, whose full name is the Centre of Excellence for nanophotonics, advanced materials, and novel crystal growth-based technologies, funded with EUR 30 million from the FNP's International Research Agendas programme (POIR 4.3), the Teaming for Excellence programme (Horizon 2020), and national funds focuses on developing new materials produced using methods that are based on concepts contained in Czochralski's work.

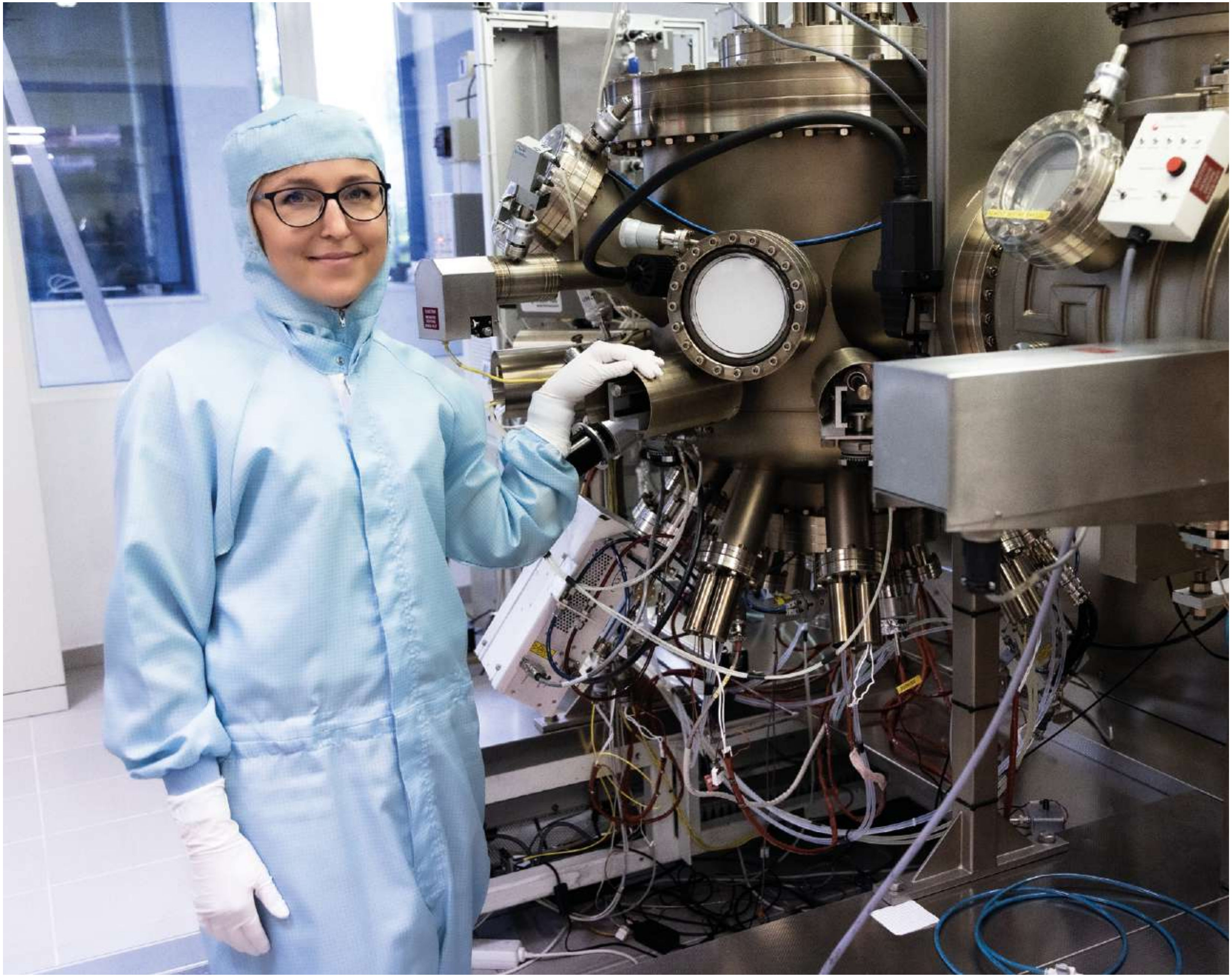
"We are primarily focused on photonics, a field that uses photons as an information carrier," explains the researcher. "We develop metamaterials, plasmonic materials, topological insulators and implement many other new ideas. As a matter of fact, we were the first to approach new concepts of materials through controlled crystal growth. No one had previously tried to obtain metamaterials in this manner."

Metamaterials, i.e. artificial materials whose properties are determined not only by their composition, but also by their structure, exhibit many unusual features, allowing the creation of completely new optical or photonic solutions. Professor Pawlak's team works, among others, on materials that may find application in security systems, telecommunications, solar energy conversion systems, medicine or obtaining hydrogen.

"The crystal growth methods used are well-developed and used commercially to obtain materials on a large scale," emphasises Prof. Pawlak. "At the same time, they make it possible to change the properties of a crystal in a very simple way by slightly changing its composition, for example by doping, i.e. adding a small amount of a selected element during the process, or doping with other species like nanoparticles. By using the same material, but with a different dopant, we can completely change its properties and thus dramatically change its application".

This allows the creation of a variety of interesting materials with specific properties, e.g. those that convert solar radiation incident on photovoltaic cells in a more effective way than those existing today, increasing their efficiency. Similar potential applications are numerous, ranging from fast and secure communication systems to medical imaging.

"In order to obtain such materials, we have used the effect known for a long time in metallurgy, i.e. the formation of eutectic structures, where the word ‚eutectic' from Greek means low-melting,"



Dr inż. Marta Sawicka

says Prof. Pawlak. “The materials created during such transformation, thanks to the phenomenon of self-organisation, make it possible to obtain materials with various structures on the micro- and nano-scale, where each phase constitutes a small single crystal. In this way, we can obtain layered, fibrous and even heart-shaped materials, and hence, when we add the beauty of the obtained micro- and nanostructures to the beauty of the single crystals, we feel not only like scientists, but also like artists”.

Eutectic materials are obtained commercially in large quantities. They are used in various types of steel, where they provide good mechanical properties, are used as abrasives, and can be even found in chocolate. It was Prof. Pawlak’s team that proposed researching these materials for applications in metamaterials, plasmonic materials, topological materials or for obtaining hydrogen. “Give us an application, and we will make a material for you,” Prof. Pawlak concludes.

Fat soldiers, skinny soldiers

Dr inż. Marta Sawicka is also involved in optical applications of new materials in the Institute of High Pressure Physics of the Polish Academy of Sciences, in Warsaw. She has been working on materials for laser light sources in the visible range within the POWROTY/REINTEGRATION FNP programme (POIR 4.4), implemented thanks to European funds.

Lasers and light-emitting diodes based on gallium nitride (GaN) exhibit exceptional optical properties. They are the key elements in advanced sensors, data recording systems, fibre optic telecommunication, and find their applications in dermatology and lighting systems. According to estimates by the think-tank Fortune Business Insights, the market for devices based on this technology is expected to be worth USD 28.4 billion globally in 2027.

“We can imagine the laser as a sandwich consisting of layers with different chemical compositions” explains the researcher. “The middle of the sandwich, where the light is generated, is the most important, but the laser action cannot be obtained without the right surrounding components. At present, the most common ‘bread’ in such a laser sandwich are AlGaN layers, consisting of aluminium, gallium and nitrogen atoms. However, the physicists know, a much better material for laser ‘bread’ could be another crystal - InAlN, in which indium atoms are replaced with gallium. Since InAlN has a lower refractive index than GaN, this new crystal will confine, that means ‘hold’ the light inside our sandwich more strongly. It has been extremely difficult to obtain high quality InAlN so far.”

“Looking at the laser structure under an electron microscope, we can see that there are different spacing between the atoms in the individual layers. The average atomic distance is determined by the chemical composition of the crystal. The atoms in the crystal can be compared to soldiers standing in rows. Some of them, like the indium atoms, are fatter, while others, like aluminium, are thinner,” describes Dr Sawicka. “If we could mix them evenly in InAlN, the average distances between them would be the same as in the GaN crystal, which is what we strive for. It turns out that when there are too many ‘thin soldiers’, the material cracks, and if there are too many ‘fat soldiers’, defects are formed.”

However, it has so far been very difficult to create an InAlN crystal with optically good properties, as the constituent elements have completely different “preferences” for the incorporation in a solid material. “Aluminium atoms bond easily and strongly, while indium atoms bond very reluctantly, which leads to the formation of an inhomogeneous structure. It turned out that the ‘skinny atoms’ prefer to stay in groups surrounded by ‘fat’ ones. This makes the structure not as ideal as we would wish,” explains Dr Sawicka. “However, we are trying various methods to control the arrangement of atoms in the crystals we produce.”

Dr hab. Bartłomiej Graczykowski

“At the same time, we have also decided to develop another idea, namely to use porous GaN for the cladding layers in our lasers. This type of solution theoretically has even more advantages, for instance due to much higher refractive index contrast to GaN, which is why we believe it is worth going in this direction. We have already successfully demonstrated the first lasers. Now we have to find out whether porous GaN can be a better ‚bread’ in a laser sandwich than AlGaN or InAlN,” says Dr Sawicka.

Thermal diodes

Dr hab. Bartłomiej Graczykowski from the Faculty of Physics at Adam Mickiewicz University in Poznań, winner of the HOMING and FIRST TEAM programmes of the Foundation for Polish Science, implemented with funds from the POIR, is, in turn, working on nanostructures that enable strict control over the flow of sound and heat. Among other things, they can convert heat directly into electricity or process high-frequency signals, which would support data transfer using 5G technology.

Prof. Graczykowski’s team has developed materials to create a thermal diode that uses heat, rather than electrical charge, to process information.

“We are talking about materials with a thickness, length or diameter in the nanometre range. It is just a little higher than the molecular level”, he explains. “In such materials, all the surface properties of the materials become highly apparent, and completely new physical properties emerge. One such material is the famous graphene, which is made of a two-dimensional one-atom-thick layer of carbon. Hundreds of materials similar to graphene have already been discovered.”

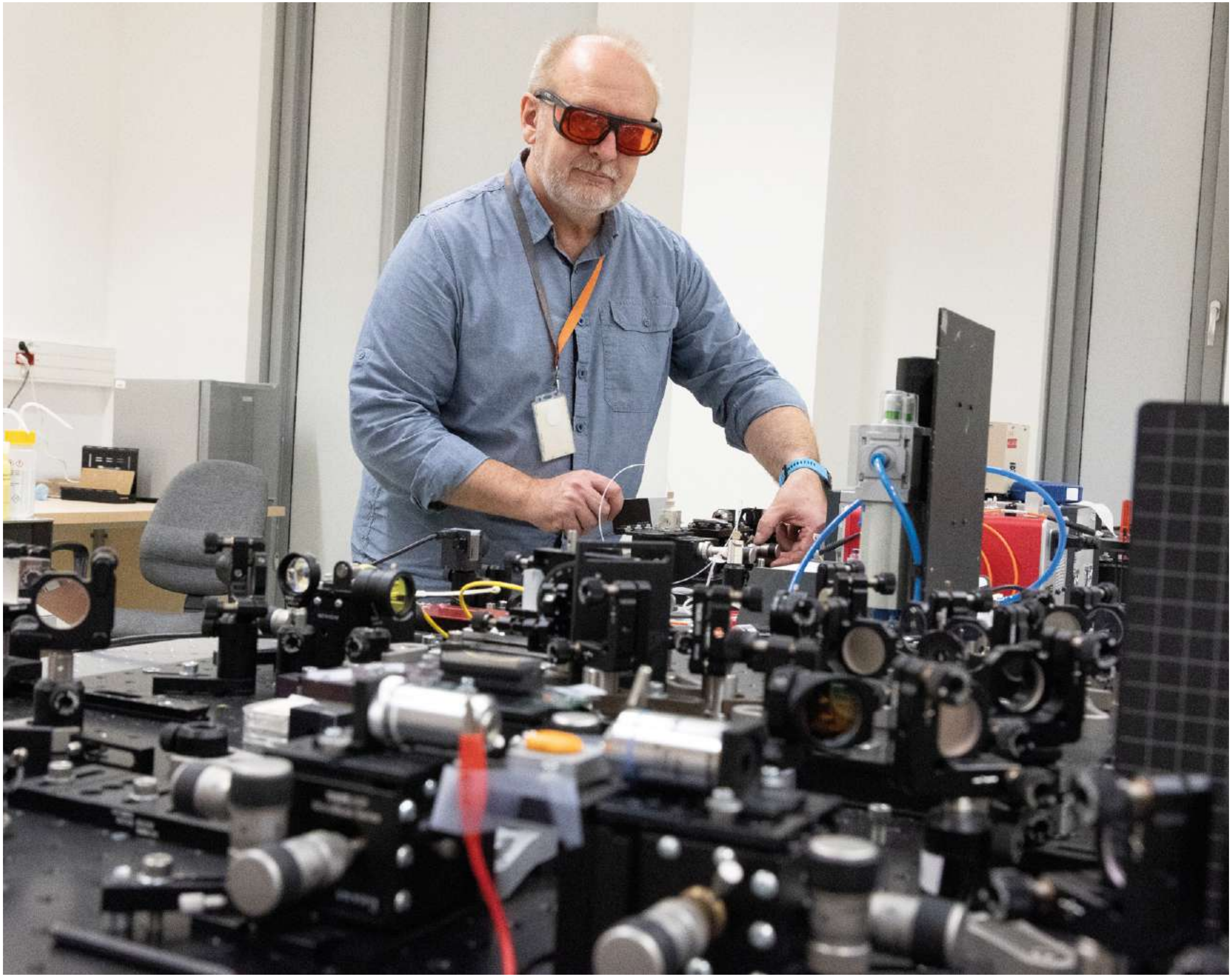
“We are focused on laser spectroscopy, which is the study of how light interacts with matter”, explains the physicist. His team has developed materials to create a thermal diode that uses heat, rather than electrical charge, to process information. Similar diodes could be used to construct simple sensors, e.g. to help monitor the condition of food on shop shelves. “In the food trade, it is often the case that food is not transported at the correct temperature. A simple sensor would show whether a given temperature has been exceeded even once and, for example, discolour the package,” says the scientist. Similar devices could also be the basis for the construction of, e.g. an adhesive thermometer patch.

However, heat diodes are not the only applications Dr Graczykowski envisages for the materials he is developing. During an internship at the Max Planck Institute, he became interested in the properties of polydopamine, a natural polymer produced, for example, by mussels. Animals use it as an adhesive that allows them to attach themselves to the surface of rocks. Polydopamine, however, is also full of many other interesting properties. It absorbs light very well, absorbs large amounts of water and, when illuminated, begins to shrink noticeably, releasing water into the environment. Materials based on it could find applications in the textile industry or in systems that precisely control indoor environmental conditions.

“The fact that thanks to polydopamine, we can convert light into motion makes it possible to use it to build remotely controlled micromanipulators, powered and operating with short response times, as short as milliseconds,” explains Dr Graczykowski.

Nanodiamonds will look deep into cells

“Our projects are highly interdisciplinary. We combine knowledge from distant fields, including material engineering, physics of atoms, magneto-optics, biology and photonics,” emphasises Prof. Ryszard Buczyński from the Faculty of Physics at the University



Prof. Ryszard Buczyński

of Warsaw. The consortium in which he works has received funding of over PLN 18.5 million from the European Funds under the TEAM-NET (POIR) programme or research on the production and practical application of nanodiamonds. The carbon structures, several nanometres in size, have properties that potentially allow them to be used for unprecedentedly precise measurements, important for example in medicine, as well as for multiplying the bandwidth of optical fibres, on which the entire global telecommunication is based.

"Nanodiamonds form highly sensitive systems based on the spin magnetic moment. They will be sensitive enough to allow us to detect single protein molecules," explains Prof. Buczyński. Nanodiamond-based sensors will detect single biological objects (viruses or proteins). They can also measure the temperature inside individual cells, making it possible to track the processes occurring within them. Finally, they can detect magnetic fields generated by individual living cells or magnetically labelled drug molecules.

"Physicists have been studying so-called cold atoms and their quantum properties for many years. This research requires temperature conditions close to absolute zero, complicated equipment and large financial outlays," says Professor Buczyński. "But it turns out that nanodiamond exhibits many properties very similar to those of cold atoms. They therefore allow us to exploit quantum effects with something that we can produce, and then use at room temperature."

Nanodiamond-based sensors will detect single biological objects (viruses or proteins). They can also measure the temperature inside individual cells, making it possible to track the processes occurring within them. Finally, they can detect magnetic fields generated by individual living cells or magnetically labelled drug molecules.

The consortium, led by the Faculty of Physics of the University of Warsaw, clearly sets its goals. One of them is to develop a technology to produce nanodiamonds with specific properties – the group led by Prof. Bogdanowicz from Gdańsk University of Technology is responsible for this. Powdered nanodiamonds produced in this way are to be used to test very weak magnetic fields, to modify the properties of glass and to manufacture biomedical sensors.

However, Prof. Buczyński is most interested in the potential use of diamonds in telecommunications. The properties of the glass used today for the production of optical fibres make it necessary to use light sources of limited power due to the so-called parasitic non-linear phenomena. This in turn limits the amount of data that can be transmitted simultaneously via a single fibre. The Warsaw group is checking whether the admixture of nanodiamonds could enable to create glass with more favourable properties, which would allow the transmission of a much greater amount of data. With the rapid growth of the Internet and the exponential increase in the amount of data that is transmitted over existing links, this is potentially priceless.

Steel different from before

Not all the materials of the future are invented from scratch. One of the most important research objectives of the NOMATEN centre, led by Professor Mikko Alava, is to create new versions of materials that are already known, but endowed with unprecedented

Prof. Mikko Alava

properties. “Our team of 25 people works on both experiments and simulations of new materials, such as new alloys and metallic glasses,” explains the professor.

The NOMATEN centre was established thanks to the European funding from the FNP’s Teaming of Excellence and International Research Agendas (POIR) programmes. The centre, based on cooperation between the National Centre for Nuclear Research, the Finnish research centre Teknologian tutkimuskeskus VTT and the French research organisation CEA (Commissariat à l’energie atomique et aux énergies alternatives), is to focus on the creation of innovative and multifunctional materials, especially those that will exhibit resistance to extremely high temperatures, corrosion and radiation.

“On the one hand, we already have structural materials for use in high temperatures or nuclear reactors. Now we need to be sure that they can withstand extreme conditions for a long time,” explains the researcher. “On the other hand, we have materials for the chemical industry that have to withstand chemical agents, pressures and temperatures. The problem is that it is often difficult to combine these properties in a single material that is strong, crack-resistant, chemically resistant and can withstand high temperatures well at the same time.”

The NOMATEN Centre is already involved in a major European project to develop materials that could form the basis for the construction of new generations nuclear reactors. The European Union has made the construction of such reactors one of its priorities. However, it is a very difficult task to develop materials with properties that enable them to withstand the conditions inside an active reactor.
“In the laboratory, we are able to develop materials with excellent properties, but it is often a real challenge to translate this knowledge into large-scale production,” says Prof. Alava. For this reason, scientists who work with materials are so frequently focused on coatings. It is easier to coat something with a thin layer of material than to create an entire component out of an advanced material.

Consortia such as the one in which NOMATEN works on technologies for the nuclear industry enable more than just the development of new materials. In addition to research centres, companies, including Polish ones, which can quickly start working on implementing new materials into production are also involved.

Modern materials developed in Polish laboratories thanks to the brilliance of scientists supported by grants from the POIR, coordinated in Poland by, among others, the Foundation for Polish Science, can influence many areas of our lives. From large, engineering structures to almost imperceptible sensors that take care of our health. It is certain that the world of the future will use completely different materials than today.

Medical diagnostics and medical innovation

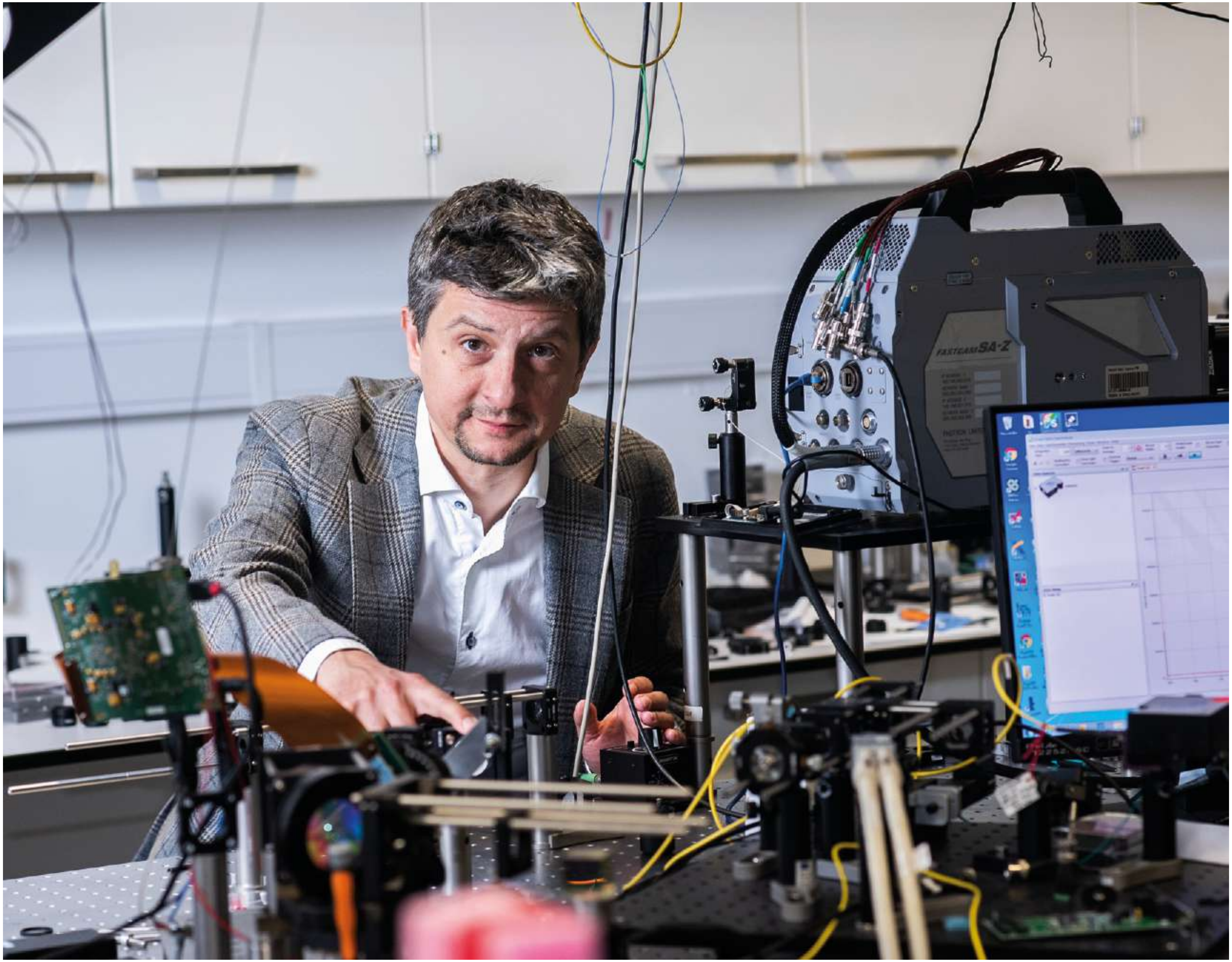
Understand, diagnose, cure. Research by Polish scientists advances medicine

From state-of-the-art vision therapies, through working out the processes behind the development of both the most common and the rarest conditions, to innovative techniques that make it possible to fight diseases with solutions developed by nature itself. These are just some of the results of medical science research funded by European Funds in cooperation with the Foundation for Polish Science.

2,2 billion people, a quarter of the Earth's population - this is how many people worldwide, according to the World Health Organisation, develop eye diseases causing reduced or total loss of sight. In Poland alone, cataracts, the world's most common cause of blindness, affects 800,000 people. According to data from the NFZ (the National Health Fund), more than 130,000 new cases of this affliction were diagnosed in 2020 alone.

Eye diseases are widespread, even though few medical disciplines have such a long tradition as ophthalmology or eye surgery. Effective combating of visual impairment remains a major challenge for doctors and researchers. "Eye surgery has been known for several thousand years," stresses Professor Maciej Wojtkowski of the Institute of Physical Chemistry of the Polish Academy of Sciences. "The first known surgical procedures were trepanation and treatment of cataracts, usually performed with a sharp object such as a needle."

Paradoxically, however, despite the very long history of eye surgery, many techniques applied today are based on the same principles as their ancient prototypes. Operating on an organ as delicate and small as the eyeball requires great concentration and precision from the surgeon. Even so, it is associated with a high risk of postoperative complications and still yields limited therapeutic results. Examples of such surgeries include epiretinal membrane removal and vitrectomy.



Prof. Maciej Wojtkowski

Comprehensive approach

International Centre for Translational Eye Research (ICTER) is intended to help overcome the challenges facing ophthalmologists. The establishment of the centre, created by Professor Maciej Wojtkowski and Professor Krzysztof Palczewski, was possible thanks to nearly PLN 35 million in funding from the European Funds under the POIR. These funds were granted within the framework of the International Research Agendas programme, which was implemented by the Foundation for Polish Science. ICTER is one of 14 centres established in Poland thanks to the programme. It brings together scientists from a wide range of fields, from biochemistry to robotics, so that, through their collaboration, techniques can be developed to effectively and cheaply save and restore human sight.

The vast knowledge in biochemistry and medicine that has accumulated in recent years makes global treatment of the eye possible. Starting from the understanding of how specific proteins function in the eye, through the development of robotic techniques to regenerative or gene therapies to treat genetic diseases.

“The vast knowledge in biochemistry and medicine that has accumulated in recent years makes global treatment of the eye possible,” Professor Wojtkowski explains. “Starting from the understanding of how specific proteins function in the eye, through the development of robotic techniques that allow very precise operation on the eyeball, to regenerative or gene therapies to treat genetic diseases.”

Although the centre has been established only recently - its work officially started on 1 July 2019 - it can already boast several successes. Researchers at the centre have developed two new imaging techniques that allow doctors to precisely find signals in the structure of the eye indicating pathological conditions.

The first of these is retinal imaging with two-photon excitation. With this technique, the proper functioning of chemical molecules involved in the vision process is checked. “A specific feature of these molecules is that they can be stimulated to fluorescence using very short ultraviolet waves,” the researcher explains. However, the problem is that this type of radiation could damage the front layers of the eye. The scientists were therefore forced to resort to a technical trick. “If we illuminate these molecules with infrared light, but with a sufficiently short pulse, we can make them ‘think’ that they are being illuminated by ultraviolet light – in so called two photon excitation process.”

For this purpose, the group of Dr hab. inż. Grzegorz Soboń of Wrocław University of Technology, working with the ICTER, has developed a special, portable laser designed for retinal examination. Implementation of this system would allow doctors to examine the efficiency of visual receptors at the level of single chemical molecules.

The second technique developed by ICTER researchers enables analysis of whether individual receptors respond to light by exploiting the unusual properties of these cells. “Some time ago, it was observed that light-sensitive cells in the eye respond to light by changing their length visible on optical examination,” says Professor Wojtkowski. “If we can measure these changes, we will be able to determine whether a receptor responds to light, i.e. whether it works properly.”

This, however, requires the equipment used for measurement to be extremely precise. Changes in the shape of cells are very subtle and are usually measured in nanometres, i.e. millionths of a millimetre. However, the entire measurement is carried out in the living eye, which is constantly twitching and making more or less rapid movements. Researchers, therefore, had to develop a method that takes into account “macro” movements and pre-

Prof. Agnieszka Błachnio-Zabielska

cisely analyses only the receptors' response to light stimulus. "We have proved that we are able to do this and measure the response of these cells to light,"— the scientist proudly states. "This could be an excellent method to replace the diagnostic techniques used today but often disliked by doctors."

New diagnostic methods are becoming more and more important as the number of patients diagnosed with sight diseases increases with the ageing of the population. Diabetes remains one of the main causes of vision loss or deterioration. Diabetic retinopathy remains the most common cause of sight loss and it affects approximately one-third of all people with diabetes to varying degrees, while impaired glucose tolerance leads to cataracts or secondary glaucoma.

We aim to discover critical points in the insulin pathway where accumulation of specific lipids impairs its action. We also want to find biomarkers that can be used for early diagnosis of insulin resistance.

What causes insulin resistance

Professor dr hab. Agnieszka Błachnio-Zabielska from the Medical University of Bialystok conducts research on the processes that can lead to the development of diabetes. The researcher has been awarded a grant under the TEAM programme funded by the POIR and implemented by the FNP. She is investigating the mechanisms of skeletal muscle insulin resistance, which can precede full-blown diabetes.

Insulin resistance refers to the inability of the body tissues to respond properly to insulin. In the case of skeletal muscle, insulin-resistant cells cease to effectively "take up" glucose, although it should constitute their primary source of energy. "Skeletal muscle is a tissue that works intensively and needs a large amount of energy", explains Professor Błachnio-Zabielska. "Under physiological conditions, muscles quickly capture excess glucose from the blood due to glucose transporters, present in the cell membrane i.e. proteins that facilitate glucose transfer into cells. The translocation of glucose transporters to the cell membrane is stimulated by insulin. Sometimes, however, various factors, such as the accumulation of bioactive lipids, block the action of the insulin pathway and deteriorate the functioning of the whole mechanism."

The exact mechanism responsible for the decrease in glucose uptake is not well-known. We do know that muscles capture free fatty acids present in plasma and then use them for lipid synthesis. Many of the lipids present in cells remain passive. They are an energy reserve and do not directly affect the functioning of insulin pathway. However, some lipids play an important role in cell function. For instance, they act as second messengers of intracellular signals. In some cases, however, their excess may adversely affect the proper functioning of the cell. In this case, it may lead to the disruption of processes aimed at glucose absorption by cells.

We do not know which specific lipids are responsible for this phenomenon or how the process itself takes place. The research carried out by the Medical University of Bialystok team is intended to determine this mechanism. "We aim to discover critical points in the insulin pathway where the accumulation of specific lipids impairs its action," the researcher explains. "We also want to find biomarkers that can be used for early diagnosis of insulin resistance."

One way to work out this mechanism is to "silence" the genes responsible for the synthesis of different lipid groups in the muscles of animals. By removing specific lipids from cells of animals and making them insulin-resistant, scientists want to determine which of these genes are most strongly associated with the development of the disorder. "Our research shows that ceramides, specifical-

Prof. Bożena Kamińska-Kaczmarek

ly ceramide containing stearic acid in its structure, play the main role," explains Professor Błachnio-Zabielska.

"This is very important information because on its basis we can look for therapeutic measures, either by inhibiting the action of enzymes involved in its synthesis or by limiting their expression." The professor emphasises, however, that this is basic research, i.e. research that allows us to understand the foundations of the phenomenon. The road to developing potential therapies remains long.

A personal approach to cancer

Professor dr hab. Bożena Kamińska-Kaczmarek from the Nencki Institute of Experimental Biology of the Polish Academy of Sciences in Warsaw is striving to find solutions that allow quick and precise diagnosis of brain tumors. The researcher, whose project was funded by the European Funds from the POIR within the TEAM-TECH Core Facility programme coordinated by the Foundation for Polish Science, attempts to develop a platform allowing a comprehensive diagnosis and providing personalised cancer therapies.

The platform, based on targeted next-generation gene sequencing (NGS) of tumour DNA and RNA, computational pipelines and specially devised algorithms, enables the rapid screening of hundreds or thousands of genes in a tumour sample. Such analysis not only allows assessing a given tumour malignancy or predicting its response to standard therapy but also allows designing the patient's specific treatment to target the patient's vulnerabilities and maximise the effectiveness of the therapy while minimising its side effects.

This would give a much better chance of successfully treating patients with brain tumours. Today, statistically, a Polish patient diagnosed with a malignant glioma survives only 15 months, despite surgical interventions, radio- and aggressive chemotherapy, due to inevitable tumour recurrence. The use of state-of-the-art genetic diagnostic tools offers a chance to significantly improve these results, especially in the case of the youngest patients. Novel druggable mutations have been found in poorly diagnosed peadiatric tumorus. One of the aims of the project was to create cellular models of paediatric tumours, serving as patient's avatars allowing to test various combinations of anti-tumour drugs.

The platform developed by Professor Kamińska-Kaczmarek has a chance of rapid implementation thanks to the fact that the researchers are working closely with the Children's Memorial Health Institute in Warsaw (Instytut Centrum Zdrowia Dziecka) and the Polish Glioma Treatment Consortium (Polskie Konsorcjum Leczenia Glejaków). Exploring tumour microenvironment and targeting malignant gliomas with immunotherapy is the subject of another research project carried out by Professor Kamińska-Kaczmarek. The work, which was awarded the 2021 FNP Prize in the area of Life and Earth Sciences, was to demonstrate how gliomas "hijack" our own immune system and use it for their own purposes.

The researcher showed that the tumour produces signals which affect the immune cells in the brain called microglia that accumulate in the tumour and instead of fighting the tumour, the cells support its progression and facilitate the formation of metastases. Professor Kamińska-Kaczmarek showed how microgia, under the influence of the tumour, produce enzymes that cut the "scaffolding" connecting the cells, the so-called extracellular matrix. This facilitates migration of tumour cells and spread inside brain tissue. Other immune cells, macrophages, are attracted from the periphery, accumulate in the tumour, and prevent the immune system from functioning properly.

The Polish researcher's discoveries have already made it possible to develop new, advanced therapies for glioma. However, understanding the biology of microglia has much wider significance than

Dr Michał Kucewicz

its role in progression of the most common and dangerous brain tumour. Microglia, once chronically activated, play a negative role in Alzheimer's disease and other neurological disorders. If we understand their biology and diverse functions, we have a chance to effectively fight these diseases as well. With increasing percentages of aging societies and growing numbers of those suffering from Alzheimer's disease (40 per cent of 90-year-olds) the novel interventions are urgently needed.

Looking inside the brain

Alzheimer's disease itself and the processes that accompany the disease still pose a mystery to scientists. It is difficult to determine the causes of the rapid memory loss affecting many patients, especially as the processes responsible for how our memory works are still largely unknown.

"We know which structures are important for memory, but there is no single place we could unequivocally point as the localisation of memory," explains Dr Michał Kucewicz, who works at Gdańsk University of Technology and the Department of Physiology and Biomedical Engineering at Mayo Clinic in Rochester, USA. "Almost all parts of the brain are involved to some degree in the formation of memories. Some parts of the brain are responsible for remembering movement, for example, and others are in charge of sound memories. Finding one area of the brain that is responsible for all memory functions is the greatest and somewhat utopian challenge of neuroscience."

It is known that there are critical nodes whose damage prevents memory from functioning properly. Dr Kucewicz is conducting research to discover the basic processes responsible for the formation of memories and the stimulation of brain function. For this purpose, the researcher has received European funding from the POIR under the FIRST TEAM programme of the Foundation for Polish Science. The aim is to understand exactly how our memory works, but also how this process can be disrupted and how it can be stimulated electrically in diseases such as Alzheimer's.

"We do not fully understand the mechanisms and origins of this disease, let alone how to treat it. In fact, none of the medical interventions known to me today can effectively prevent its development," says the scientist. "We have animal models, but they do not correspond exactly to what we observe in the human body, and the very access to the depths of the brain to analyse the processes that occur in it is very complicated".

By stimulating a small part of the brain with electrical current, we are able to make the patient remember more words than without stimulation. Thanks to stimulation, we can observe a 50 per cent improvement in epileptic patients within a year or two.

In order to gain unprecedented deep access to the most basic functions of the brain, Dr Kucewicz's Brain & Mind Electrophysiology Lab focuses on patients suffering from drug-resistant epilepsy or Parkinson's disease. The therapy often involves implanting electrodes in the patient's brain, which record and stimulate the activity of certain areas. Using these electrodes, researchers can record the work of the brain with unprecedented resolution and look for those areas of the brain that are responsible for memory formation and impairment.

"We already know which parts of the brain respond to electrical stimulation," claims the researcher. "By stimulating a small part of the brain with electrical current, we are able to make the patient remember more words than without stimulation. Thanks to stimulation, we can observe a lasting improvement of up to 50 per cent in epileptic patients within a year or two".

Prof. Wojciech Młynarski

The first patients are already using light and portable stimulation devices, developed in cooperation with the American Mayo Clinic and with the help of Dr Kucewicz's laboratory. Preparations for the first clinical trials are also underway. Dr Kucewicz himself is already working on further improvements to the therapy, its optimisation and the creation of systems that dynamically and intelligently control the operation of the device.

Distinguishing neutropenia

This is a rare but potentially very dangerous disease. Neutropenia involves the body producing far too few so-called neutrophils – white blood cells responsible for fighting certain infections, especially bacterial ones. "In the majority of such patients, there is a high risk of various types of infections, including life-threatening infections such as sepsis or meningitis," explains Professor Wojciech Młynarski of the Medical University of Lodz.

However, there are many reasons for the absence or significantly reduced neutrophil count. This may be a consequence of diseases, chemotherapy or congenital genetic mutations. It was the research of congenital immunodeficiency that Professor Młynarski received funding for from the European Funds under the POIR within the framework of the TEAM-NET programme of the Foundation for Polish Science.

The difference between acquired neutropenia and congenital neutropenia is important, as the latter is life-threatening, whereas acquired neutropenia, for example because of past illness, is usually a transient state, which, although associated with an increased risk of infection, is usually not fatal. However, it is extremely difficult to distinguish the two from each other, so in order not to take any risks, doctors are very cautious with anyone whose tests show a reduction in neutrophil count. In the case of children, this means withholding or postponing preventive vaccination that protects them from potentially dangerous diseases.

"Sometimes the child's immune system works somewhat dysfunctionally and, for example, after an infection begins to produce antibodies that destroy neutrophils. The risk of further infections increases at this time, but these are rarely life-threatening infections. This type of neutropenia should not be a reason for postponing preventive vaccination in children," says Professor Młynarski. The problem is that doctors, especially paediatricians, do not yet have access to tools that would allow them to easily determine whether they are dealing with a condition caused by genetic changes or a temporary condition. Approximately 3,000 children in Poland are not vaccinated annually due to neutropenia."

Professor Młynarski's team has set itself the goal of developing a simple, effective, and inexpensive test to differentiate between the two neutropenic conditions. "One such tool is being developed by a team of our consortium member from Wrocław University of Technology, who works on enzymes and granulocyte proteases. It is supposed to identify whether there is a specific pattern of their activity and localisation in congenital neutropenia," explains the researcher.

Developing the test is only the first step. The second is to identify all the genes responsible for congenital neutropenia because today the exact cause of almost half of them is unknown. The third and most ambitious goal is to develop gene-editing therapy using the CRISPR-CAS9 technique, which would effectively treat even congenital neutropenia by implanting modified bone marrow grown from patients' own stem cells. "We will be analysing the entire genome of individual cells all the time to check whether something else has gone wrong during neutropenia treatment," says Professor Młynarski.

This technique gives hope for faster and cheaper treatment for patients who today often have no chance for therapy at all, as the disease is currently treated with bone marrow transplants, but up to 20 per cent of patients never find matched donors.

The benefits of parasites

Dr hab. Katarzyna Donskow-Łysoniewska, as part of a programme she carried out at the Independent Laboratory of Parasitology (Samodzielna Pracownia Parazytologii) of the Military Institute of Hygiene and Epidemiology in Warsaw, also studied the functioning of the immune system, although in her case it was not a matter of stimulating, but on the contrary - inhibiting the immune system activity.

Over-stimulation of the immune system can lead to many dangerous diseases. Allergies alone, which affected only 1 per cent of the population in the first half of the 20th century, are today diagnosed in more than 40 per cent of Poles. Multiple sclerosis is an example of an autoimmune disease. However, there are ways to reduce excessive activity of the immune system. Some of these, over millions of years of evolution, have been developed by intestinal nematodes - small parasites of our gastrointestinal tract.

“This is truly fascinating,” exclaims Dr hab. Donskow-Łysoniewska. “The parasite has no interest in killing its host. On the contrary, it wants them to live as long as possible. Intestinal nematodes have, therefore, developed a number of methods that not only allow them to remain unnoticed by the host but also inhibit inflammation or inflammatory diseases. In this system, the host can benefit from having a parasite.”

A nematode “calms” the host’s immune system, as it could otherwise fall prey to it itself. There are trials of therapies using whole, live nematodes introduced into patients’ bodies. Clinical trials have been ongoing for many years. They raise many understandable questions regarding the ethics and safety of such therapies.

Therefore, Dr hab. Donskow-Łysoniewska’s team, supported by a grant from the TEAM-TECH programme of the Foundation for Polish Science, is trying to “get a sneak peek” at the mechanisms used by nematodes and learn to copy their tricks without exposing patients to the side effects caused by the presence of the parasite in the body. “Thousands of proteins with different immuno-regulatory properties are involved. We are at the beginning of a certain path allowing us to type these proteins and to know the whole spectrum of possibilities of these parasites,” says the researcher. “It is obvious that there are both immunosuppressive and immune-activating proteins among them,” she adds. We identify such proteins on the basis of the “learning from parasites” method. In an experimental setup, we observe what happens, which mechanisms are induced and which parasite proteins are involved in it.

Studies related to multiple sclerosis have been particularly successful. “We have also indicated proteins responsible for inhibiting processes occurring in other autoimmune diseases,” emphasises Dr Donskow-Łysoniewska. “The research we are conducting is, therefore, a search platform which allows us, thanks to parasites, to discover various proteins with therapeutic potential. The identified and particularly interesting proteins will be studied in further research and development projects. Thus, it may turn out that parasites will prove to be the best teachers for doctors in the fight against inflammatory diseases that nowadays pose a huge problem for medicine.”

Dr hab. Katarzyna Donskow-Łysoniewska

Energy and ecology

Energy for the future

Controlling the climate crisis requires a deep reflection on how we generate, store and use energy. Research by scientists supported by the Foundation for Polish Science with funds from the European Funds of the POIR is opening the way to an efficient, clean and environmentally friendly future.

Turning the entire global economy onto a clean, non-carbon track may be the greatest challenge facing humanity in the 21st century. BloombergNEF research centre estimates that transforming Europe's energy system alone to be low- or zero-carbon by 2050 will cost EUR 5.3 trillion. This is a huge amount of money but the stakes are just as high. It is about stopping climate change, which threatens the life and health of billions of people, about clean air without smog and, last but not least, about energy independence for the entire European Community.

However, even the largest investments will not achieve the desired results on their own if they are not accompanied by the development of new technologies and the targeted development of existing technologies for both energy production and energy storage and use. This is where programmes funded by the European Union come into play.

Not ash but diamond

One of the EU's pillars of the energy transition is a move of the European countries away from coal-fired power generation which today provides 37% of the Community's electricity needs. This process will take many years. In the meantime, scientists are trying to develop new technologies that make it possible to use the intermediates produced after coal combustion in such a way that the overall negative environmental impact of coal-fired power generation is minimised.

One of the main by-products of coal combustion is fly ash. This is a problem that should be handled by filters installed in the chimneys of power plants or thermal power plants. Except that "problem" may not be the right word because, somewhat paradoxically, recovered fly ash can be one of the most valuable coal combustion products. In certain situations, it may not only be of high economic value but can also be used to recultivate environmentally degraded areas.

"Fly ash resulting from the energetic combustion of coal is not waste. It is second-generation raw material," — explains Professor dr hab. inż. Wojciech Franus from the Faculty of Civil Engineering and Architecture at Lublin University of Technology, which is the leader of the FUNash project financed by the Foundation for Polish Science with PLN 21 million from the Smart Growth

Prof. Wojciech Franus

Operational Programme within the TEAM-NET programme. The aim of the project led by Professor Franus is precisely to manage fly ash in environmental engineering, civil engineering and agriculture.

"Hard or brown coal is the main fuel used in power plants and thermal power plants, and in addition to combustible parts, it also contains overgrowths of other rocks. During the combustion process, slag is formed from those non-flammable parts, which is a coarse fraction falling to the bottom of the furnace, and the so-called fly ash, which is a fine fraction carried away by the flue gas stream and caught on filters. The potentially useful mineral and chemical composition of fly ash makes it possible to use it in various technologies," Professor Franus explains.

The largest consumers of fly ash are cement and concrete producers. Approximately 60% of the 4 million tonnes of fly ash produced in Polish power plants and thermal power plants is currently managed in this way. The aforementioned uses of ash may be limited in the near future due to increasingly stringent regulations on the emission levels of gaseous pollutants from coal combustion. Due to these limitations, the ash currently produced is changing its chemical composition (increase in the proportion of unburned carbon) and is becoming less and less suitable for use in the cement and concrete industry. However, this does not mean that they are not suitable for use elsewhere.

"In our project, we assumed that ash would be a substrate for the production of porous materials from the zeolite group and mesoporous silicas. Those materials have numerous channels and cavities in their structure, so they have favourable and specific properties related to the development of the inner surface of particles," Professor Franus explains. Produced from fly ash, zeolites can serve, for example, as sorbents to absorb liquid or gaseous pollutants. They can also be used in agriculture as fertiliser carriers, releasing micro- and macronutrients over a long period of use, providing plants with the essential component for their growth, while protecting the environment from the rapid release of water from the soil structure.

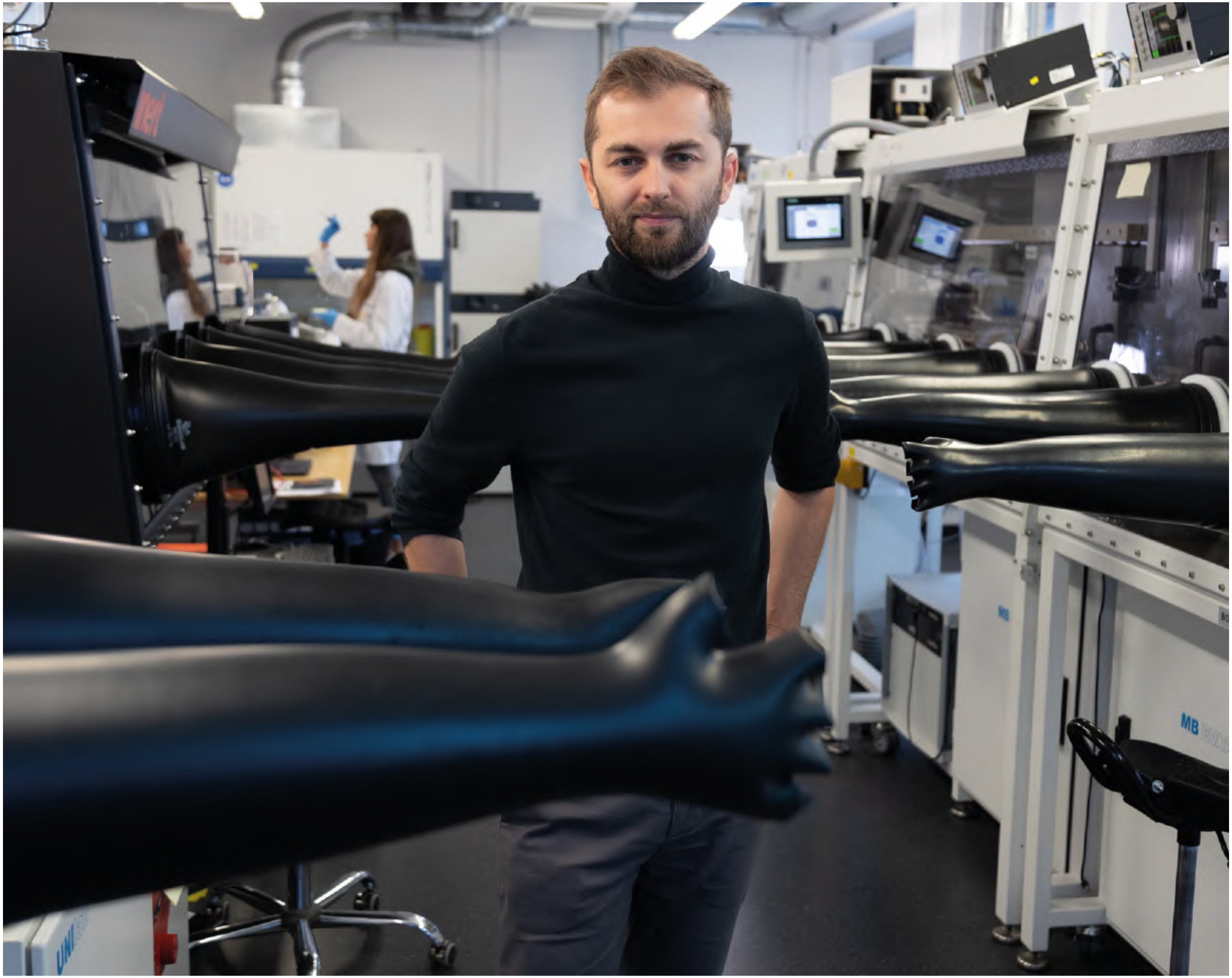
Produced from fly ash, zeolites can serve, for example, as sorbents to absorb liquid or gaseous pollutants. They can also be used in agriculture as fertiliser carriers, releasing micro- and macro-nutrients over a long period of use.

Professor Franus' team is also close to developing technology for the zeolites application in the production of mineral and asphalt mixtures on an industrial scale. They would make our roads more durable and their composition would be more environmentally friendly.

"The zeolite structure traps water in the channels and cavities, which we use to have a so-called foaming effect on the asphalt, i.e. reducing its viscosity. As a result, the heated asphalt surrounds the aggregate very well and fills in all sorts of voids. In this way, we can produce a given mix at a lower temperature, which results in an economic gain, but it is also good for the environment, as the lower production temperature means lower emissions into the atmosphere and better working conditions for the people laying the pavement," Professor Franus says. The first commercial production line for zeolites from fly ash is almost ready. Final work is currently being carried out to optimise the conditions for the synthesis of these valuable materials.

Perovskite perspective

Over time, however, coal as an energy source is set to lose its importance. A new report by industry organisation SolarPower Europe shows that in 2021 alone, the share of European solar power increased by 34 per cent, and by 2030, the amount of energy



Dr Konrad Wojciechowski

generated in the European Union through photovoltaic cells is expected to quadruple.

Although photovoltaic cells are already spectacularly successful, their development could become even faster if more efficient cells can be developed. Today, more than 90 per cent of current solutions on the market are based on silicon, but this is where the rate of development is slowing down. However, there are alternatives, such as perovskites. The term “perovskite” refers to a crystal structure, named after Russian mineralogist Lev Perovski. Metal halide perovskites, a family of compounds assuming this specific atom arrangement in the lattice, are excellent photo absorbers, and research into these materials is considered one of the most promising directions that will contribute to the photovoltaics of the future.

After decades of development, the silicon cells that dominate the market today have reached an energy conversion efficiency of around 27 per cent.

To understand why, one only has to look at the track record of engineers and scientists developing solar technology. After decades of development, the silicon cells that dominate the market today have reached an energy conversion efficiency of around 27 per cent. This means that they use and process just over a quarter of the incident solar energy. Competitive perovskite cells have already achieved such efficiency after a decade of development of the technology.

Unfortunately, perovskites have disadvantages. Part of the problem is that many of them contain toxic lead. On top of this, materials belonging to this family are relatively perishable and particularly sensitive to high temperatures or humidity. And these are, after all, factors that are a daily reality for photovoltaic cells placed outdoors.

One of the leading companies developing perovskite solutions is the Polish company Saule Technologies, founded by Dr Olga Malinkiewicz. Dr Konrad Wojciechowski, scientific director of the Saule Research Institute foundation, within the FIRST TEAM FNP programme funded by European Funds, diagnosed the most important physical problems that reduce the efficiency and lifetime of perovskite cells.

As part of the work, the researchers analysed the optimal structure of perovskite-based cells and also created the first complete, flexible perovskite cell, which underwent a full set of reliability tests, which give correlation to operational lifetimes exceeding 15 years. The team’s work has resulted in several published and internationally cited scientific papers. Production of the first long-lasting photovoltaic cells, which offer significantly better energy efficiency than classical solutions, may soon be launched.

Electricity banks

In the case of renewable energy, simply making generators more efficient does not solve the whole problem. Both of the most popular renewable energy generation techniques, wind energy and photovoltaic energy, share a common problem. Under perfect conditions, they often generate far more energy than the power grid can use. However, it is important to remember that ideal conditions are not constant: windless weather stops the windmills and night limits even the most perfect photovoltaic cells.

The solution would be to create energy banks - devices or installations that allow electricity to be stored when it is generated in excess and released when the grid needs more power than the electric sources can generate. Similar solutions are not new. Pumped

Dr Dominika Buchberger

storage plants have been playing this role for years, whereby, when there is a power surplus in the grid, electrically powered pumps pump water from a lake or river into a specially prepared reservoir located at the top of a hill. When there is not enough power, the water is released downstream and the generators use the energy from its fall to produce electricity.

The problem is that although the technology for building similar power plants is well known and they do not hide any engineering surprises, they can only be used under strictly defined conditions. Suitable hills and access to water are needed. The construction of similar power plants is very damaging to the environment, which is being profoundly transformed in the course of their construction. Today, only six such power plants are operating in Poland with a total capacity of 1.8 GW, providing the possibility of storing 9 GWh of energy. The construction of another three is in the preliminary stages of preparation. Hence the need to develop other methods of large-scale energy storage. It is a challenge, but also an opportunity. The annual value of the global energy storage market was estimated at USD 210 billion in 2021 and is expected to reach USD 435.32 billion by the end of the decade.

A solid electrolyte, using ceramic materials rather than liquids to conduct lithium ions, for example, offers greater safety because it eliminates the risk of leakage. It is also non-flammable which eliminates accidents related to lithium-ion battery ignition, and this is particularly important in electromobility.

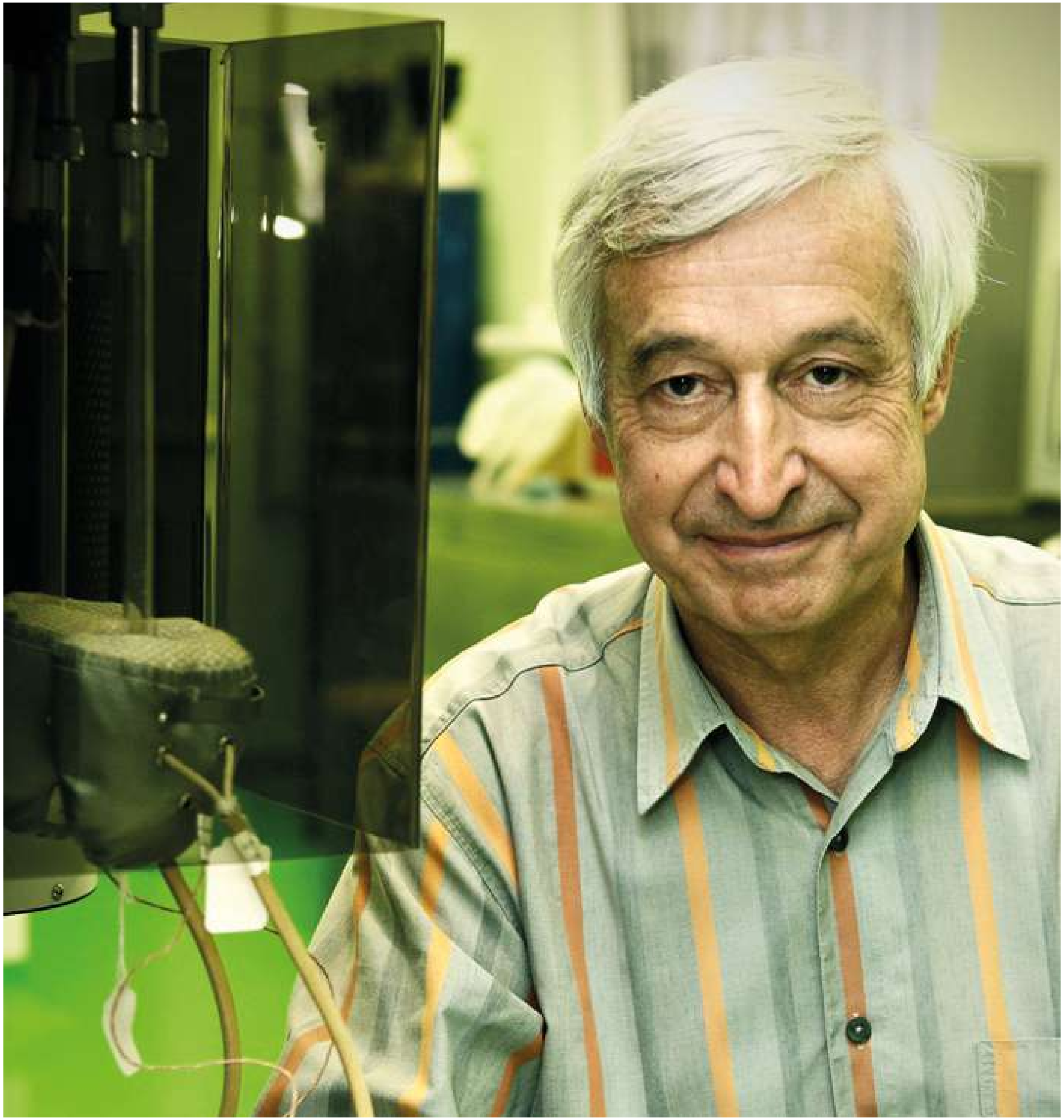
The most seemingly obvious technology that could be used to create large-scale energy storage is lithium-ion batteries, commonly used in electronic devices. Requiring rare metals, cells are today too expensive for common and large-scale use in power generation. Lithium-ion cells are therefore optimal for use in portable devices, including medical and military use.

Dr Dominika Buchberger from the Laboratory of Electrochemical Power Sources at the Faculty of Chemistry, University of Warsaw, winner of the HOMING programme of the Foundation for Polish Science, is working on a technology that could solve many of the problems associated with these cells. It deals with batteries based solely on solid components, which should increase energy density, and be cheaper, safer and more durable than today's lithium-ion batteries.

"These cells are already a global trend today," the researcher says. "A solid electrolyte, using ceramic materials rather than liquids to conduct lithium ions, for example, offers greater safety because it eliminates the risk of leakage. It is also non-flammable, which would eliminate accidents related to lithium-ion battery ignition, which is particularly important in electromobility."

Dr Buchberger's project aims to develop a method for producing a solid membrane to conduct lithium ions between the electrodes of a cell. This technology is expected to lower the cost of cell production by introducing easier material processing, to reduce the thickness of the solid electrolyte layer and to improve contact between the electrolyte and electrode. The HOMING programme is carried out by the FNP with funds from the European Union's European Regional Development Fund within the POIR.

"We already have a new, much faster and cheaper way to produce a solid electrolyte, which is the subject of an international patent application and well-cited publications. We also have prototypes of solid-state batteries using a new way of applying its individual layers," the researcher assures. "One of the problems was that



Prof. François Béguin

in order to make such a battery, you have to get the right choice of compounds from which we manufacture the electrodes and electrolyte. For example, those we initially selected as the most promising turned out to be incompatible or too difficult to process. During the project, the team gained unique expertise to understand and partially resolve several difficulties associated with the technology."

However, the game is worth the candle, as the steady-state battery market, estimated at USD 617 million in 2021, is expected to grow at an annual rate of more than 31 per cent in the coming years and exceed a global value of USD 7.5 billion as early as 2030.

If not batteries, then what?

There are basically two common ways of storing electricity. Batteries, which store energy thanks to electrochemical reactions taking place inside them, and conventional electrochemical capacitors, which store energy thanks to their ability to hold superficially an electrostatic charge. In practice, this means that the later can store less energy for a short period of time, but both charging and energy release occur here almost instantly, allowing the device to be charged quickly and deliver a high power in a short period of time.

The electrochemical capacitors can find use in transport, among other fields. Already in several places, such as Kaohsiung in Taiwan and Zaragoza in Spain, it is possible to see trams that, instead of using electric lines stretched over the route, run precisely thanks to energy drawn from electrochemical capacitors charged during short stops to take passengers on board. "After 20 seconds of charging at a stop, such a tram already has enough energy stored to travel on the next section without the need to stretch hardly aesthetically pleasing wires over the street." explains Professor François Béguin of Poznań University of Technology.

However, similar vehicles are still rare because the capacitors currently used in them are expensive and store too little energy, which limits their usefulness. Professor Béguin's team is working on the latest generation of hybrid capacitors. They combine the features of rechargeable batteries and conventional electrochemical capacitors: they use one electrode in the design based on a technology similar to that used in lithium-ion batteries, while the other electrode functions as in conventional electrochemical capacitors. They can store several times more energy than traditional capacitors while retaining their ability to charge and release energy instantly.

Hybrid capacitors can store several times more energy than traditional electrochemical capacitors while retaining their ability to charge and release energy instantly.

Professor Béguin's team is also working on a device that would use sodium, commonly found in rock salt or seawater, instead of lithium. This, however, requires the development of compatible materials to form the rest of the device. The research is funded by the FNP with funds from the POIR within the TEAM-TECH programme.

"For example, graphite, which is used in lithium batteries, is not a suitable material to be implemented with sodium. We cannot use it in our hybrid capacitors. We need to use different electrode materials. Many of the problems have been solved and we already have a small device that works and performs comparably to that of the lithium-ion system," Professor Béguin says.

Similar capacitors can have many uses, sometimes replacing and sometimes supplementing the work of conventional batteries. They can be used to start diesel engines or to help accelerate heavy, electric vehicles such as buses and trucks. Importantly, un-

Prof. Mariusz Malinowski

like lithium-ion batteries, which often need to be replaced after only a few thousand charge cycles, the hybrid capacitors developed by Professor Béguin can store and release energy at least one million times.

Electromobility companies, including Solaris, which manufactures trams and electric buses, are interested in the researchers' work.

Energy router

However, before we fully switch our electricity grids to renewables and nuclear power, and before we fully electrify transport and other areas of economic life, the entire structure of the electricity grid that today is adapted to large-scale production of completely different consumer demand needs to be rethought.

"With the rapidly developing energy industry, the development of renewable energy sources and ways of storing energy, the problem of energy-efficient energy conversion arises. The power electronic systems I deal with can efficiently manage the generation of energy from renewable sources. We call it a smart transformer." says Professor Mariusz Malinowski from the Institute of Control and Industrial Electronics, Faculty of Electrical Engineering, Warsaw University of Technology.

His team, supported by the funding from the POIR within the TEAM-TECH FNP programme, is working on smart transformers that would be able to provide efficient access to electricity from multiple distributed sources while ensuring correct operation even during the presence of strong disturbances in electricity grids. "It works a bit like an energy router, which decides how energy should flow between the various nodes-consumers, network and sources. We can optimally control the flow of electricity so that it is kept to a minimum, which at the same time reduces losses," the professor explains.

"It works a bit like an energy router, which decides how energy should flow between the various nodes-consumers, network and sources. We can optimally control the flow of electricity."

However, this is only the beginning of the new device's potential uses. The fact that smart transformers work just as well with the alternating current familiar from today's grids as they do with direct current means that they can form the basis of a change that is coming ever closer. Alternating current enables energy to be transmitted easily over great distances, but many modern technologies such as computers, LEDs and photovoltaic panels rely on direct current. The conversion between one and the other, however, usually involves a loss of several per cent of energy.

"A certain transformation of the electricity grid towards direct current is taking place, but it cannot take place abruptly, as most consumers are still based on alternating current." Professor Malinowski explains. "Such a transformer is an ideal hybrid solution that allows both direct and alternating current sources and loads to be connected. We can start the transformation of AC-based energy to DC-based energy relatively easily. This is starting to happen. In the Netherlands, the first experimental houses powered entirely by direct current are already being built."

The team has developed the first prototype devices. They are also working with industrial partners on hybrid solutions combining the functionalities of a smart transformer and a classical transformer. "In this way, it will be easier to convince companies responsible for supplying energy to the end user to use such solutions," the researcher explains, adding: "The hybrid solu-

Prof. Wojciech Macyk

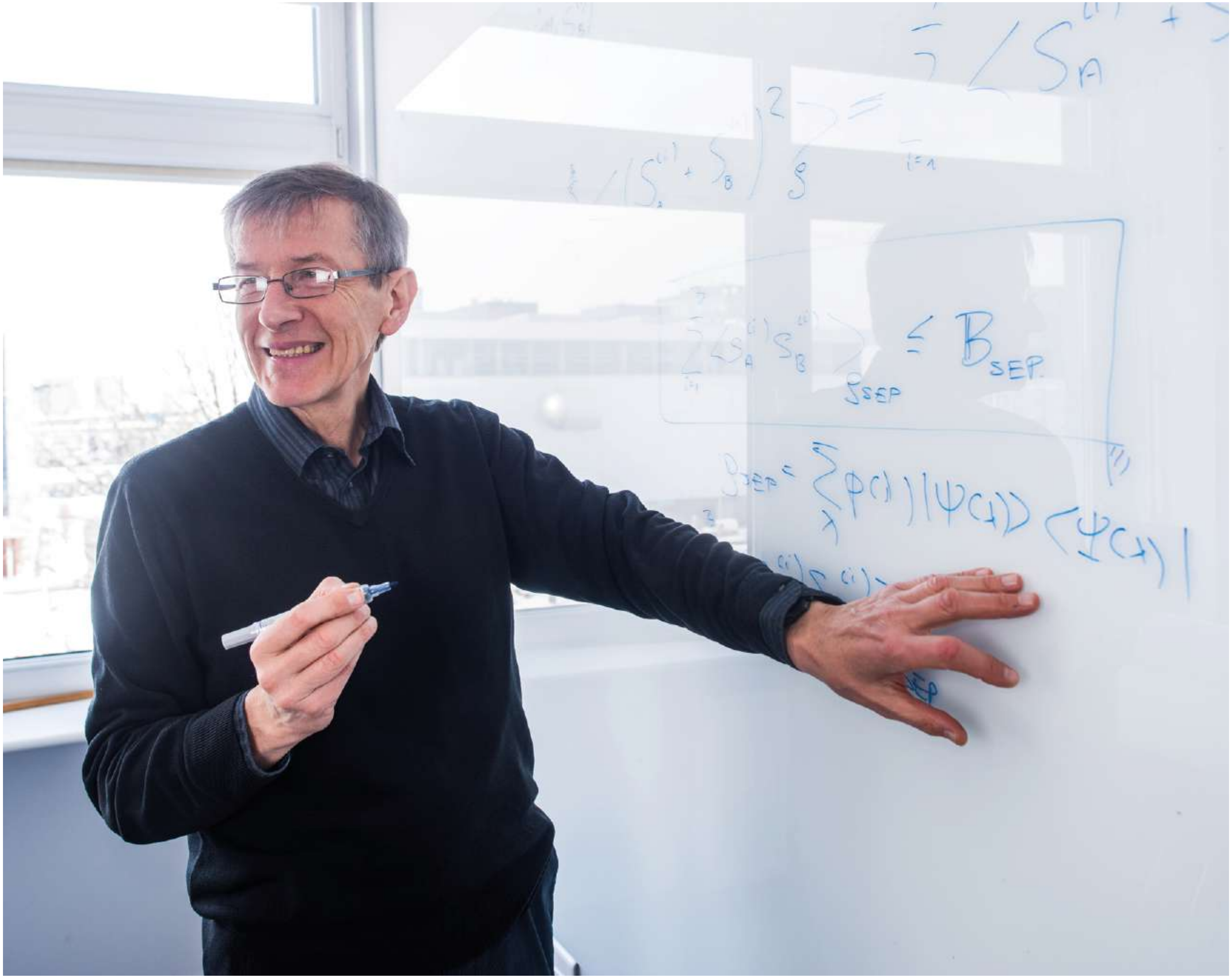
tion demonstrates all the functionalities to build an electricity network in which all the elements will communicate, just like the Internet network and will allow providing the highest energy efficiency and reliability.”

Energy for the environment

Ultimately, the new energy sources will not only serve us to generate electricity but could also change many completely unexpected areas of life. Professor Wojciech Macyk from the Faculty of Chemistry at the Jagiellonian University, whose research is being conducted within the TEAM programme of the Foundation for Polish Science with the funds from the POIR, is developing technologies to utilise so-called photocatalytic processes. These are reduction and oxidation reactions occurring in the presence of light, usually sunlight, and a catalyst, which can be, for example, metal oxides. Photocatalytic technologies can be used to remove contaminants from water and air, sterilise surfaces, produce fuel and even destroy cancer cells. The team is working on new photocatalysts offering high efficiencies.

“The materials being developed will make it possible to make better use of solar energy, for instance in its conversion into fuels. We try to achieve our goals using a variety of solutions. For example, we use appropriately structured materials, so-called photonic crystals, which enable multiple local increases in light energy density. Another approach is to combine photocatalytic and catalytic processes. As a result, the desired reactions should occur with higher efficiency,” Professor Macyk states. The photocatalysts being developed by the Krakow team are intended to help carry out complex and extremely important chemical reactions. One of their potential uses is to use solar energy to split water – a process that is expected to produce hydrogen. It can then be used as an energy source. The European Union assumes that hydrogen will be responsible for 24% of the European Community’s energy needs by 2050. Clean, hydrogen technologies will therefore be key to achieving the Community’s environmental and energy goals.

Quantum technologies



Prof. Marek Żukowski

Quantum mysteries. Polish scientists break barriers of classical technologies

Quantum communications, metrology, sensors and information processing – thanks to funding from the European Funds, Polish centres are developing quantum technologies that have the potential to transform many key areas of our civilization and give us possibilities we could hardly have dreamed of before.

The 2022 Nobel Prize in Physics was awarded to Alain Aspect, John Clauser and Anton Zeilinger for their fundamental work on quantum mechanics. – The researchers demonstrated that phenomena arising from the weird notion of quantum entanglement are observable and controllable. – What is more, their work has paved the way for technological breakthroughs. Some of them looking like science-fiction, e.g. the quantum teleportation.

As shown by John Bell in 1964 quantum entanglement has no classical explanation which is consistent with Einstein's relativity. All attempts to describe two entangled particles as "balls" carrying certain properties pathetically fail, and all more subtle approaches based on Relativity and whatever theoretical models that assume that particles carry information on all future possible measurements that one can perform each of them, also fail.

Entanglement is a feature of specific quantum states describing two or more of particles as one compound system. If we have two particles in a maximally entangled state everything about their definable mutual relations of their measurable properties is perfectly known to us, but at the same time we do not know anything about these properties for each of them individually. For example, two specifically polarized entangled photons will give opposite results in tests of their linear polarizations, no matter which polarization we choose, no matter how far apart they are, with the only proviso that we test linear polarization of the same kind on each of them. At the same time, the result of such a test on each of the photons separately is fundamentally random, i.e., completely undetermined by the state of both particles. If you think this is impossible - yes, then you feel the weirdness of entanglement.

This, combined with other features of quantum states, which lead to non-classical phenomena, makes it possible to think about ultra-fast quantum computers, sensors with unprecedented sensitivity, and already allows communication immune to any eavesdropping. Polish researchers have already made great achievements in this field and, in many cases, apply their research results in technological solutions.

Billions to quanta

According to the report "Quantum Technology Market by Computing, Communications, Imaging, Security, Sensing, Modelling and Simulation 2022–2027" of the Research and Market company, the global quantum technology market will reach a value of USD 42 billion by 2027, of which more than USD 16 billion will be accounted for by the quantum computing market alone.

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The development of such technologies is one of the scientific priorities of the European Union. The Quantum Technologies Flagship initiative assumes that the community will support the work of European researchers on quantum technologies to the tune of one billion euro over the next decade. A similar programme - worth one billion dollars a year - was launched four years ago by the United States, while in 2017, China began work on the world's largest quantum technologies research centre.

Among the leading centres developing quantum technologies are also Polish laboratories and research centres. In fact, the history of achievements of Polish scientists working in this field is long and includes some of the cornerstones of quantum technologies, such as entanglement heralding or a universal method for its detection with the help of so-called entanglement witnesses.

Currently, scientists supported by programmes of the Foundation for Polish Science with funds from the POIR are working on key problems related to quantum technologies and are often at the global forefront.

A world without eavesdropping

All the world's secrets - this is what is at stake in the research conducted by Dr hab. Marcin Pawłowski from the University of Gdańsk. His team is working on technologies to ensure complete confidentiality of data sent over computer networks. "We even made ourselves sweatshirts saying 'Special Quantum Cybersecurity Unit'," the researcher says with amusement.

Cyber security experts, however, do not feel like laughing. They know that a serious problem is imminent. Everything points to the fact that the data encryption methods used today may become useless in a few years. This is why the development of new, 100% secure communication security methods has become a task of the utmost importance.

"Quantum cryptography, unlike all others, is mathematically proved to be entirely secure," explains Dr Pawłowski. His team, as part of a grant obtained from the FIRST TEAM programme of the Foundation for Polish Science, has already developed a device that uses the rules of quantum mechanics. Apart from encrypting information in a way that is impossible for an outsider to break, it also performs self-tests to detect interception attempts and faults that could lead to insufficiently strong encryption.

"We can imagine that we are talking on Chinese telephones over the American network, but neither the Americans nor the Chinese will be able to eavesdrop on us," explains the scientist. "The data encryption terminals available on the market today are not 100%

Dr hab. Marcin Pawłowski

secure, because there is always the possibility that their developers have built in a 'back door' through which they can view the data transmitted through them. The solution would be to control the entire process of building the device, including the surveillance of its every smallest component. In practice, however, even the largest superpowers would find it difficult to achieve this level of control."

The solution developed by the team from Gdańsk eliminates this problem and provides the possibility of encryption at a level that is basically unattainable today. "A device that can be plugged into a router is now ready. A device that would fit into a mobile phone is not ready yet, because the part needed for self-testing is relatively large, so its miniaturisation will probably take another five years or so," explains Dr Pawłowski, and adds: "We are also working on much more advanced problems, such as completely secure cryptographic key distribution and miniaturised quantum random number generators. In both cases, we already have patents and are starting to gain momentum."

In the future, of course, the quantum description of the laws of physics may be enriched with new, unknown rules, just as Newtonian physics was followed by quantum mechanics and the theory of relativity.

Quantum key to secrets

"Using quantum methods between two parties, a cryptographic key of any complexity can be created on demand," explains Prof. Marek Żukowski, who is also working on quantum methods for securing communications. A cryptographic key is a sequence of bits allowing data to be encrypted and decrypted. Absence of the correct key makes the data undecipherable. The problem in this case could be the interception of the key by an unauthorised person, but there is also a solution for that. "By creating two copies of the key using quantum techniques, no one can eavesdrop on it, because the copies are created and not transmitted," emphasises the professor.

The International Centre for Theory of Quantum Technologies (ICTQT) created by Prof. Żukowski and supported by the FNP within the framework of the International Research Agendas programme with the amount of PLN 35 million from the POIR is one of the leading centres developing the scientific basis for quantum technologies. In 2013, the professor himself was awarded the FNP Prize, considered to be the most important scientific award in Poland. A strategic partner of ICTQT is the IQOQI-Vienna science centre, established by Anton Zeilinger. Marek Żukowski has been collaborating with Zeilinger since 1990. The most important results of this collaboration in the 1990s were discussed in the part of the Nobel Prize laudation dedicated to his achievements.

The ICTQT team has also patented random number generation technologies. Random number generators are one of the cornerstones of conventional cryptographic technologies, which rely on them to create hard-to-break keys. The generators built so far had an important limitation: the numbers were never really random, and by knowing or working out the control algorithm, the outcome of the generator could be predicted in advance. This makes systems based on such solutions likely to fail. Only quantum generators guarantee the complete randomness of numbers, as this randomness is guaranteed by the laws of nature written in mathematical formulas.

In the future, of course, the quantum description of the laws of physics may be enriched with new, unknown rules, just as Newtonian physics was followed by quantum mechanics and the theory of relativity. Therefore, the team of Prof. Paweł Horodecki, who as a co-applicant of the project participated in the process of es-

Prof. Paweł Horodecki

tablishing ICTQT, examines, among others, quantum resistance of cryptographic key generation and randomness against possible new physical phenomena. Researchers have recently shown that moderate quantum control guarantees simple and secure key bit generation for three users, even if a hypothetical intruder would have access to devices operating under a certain class of laws of physics that we do not yet know.

“Thanks to the work of recent Nobel laureates, it is known that quantum entanglement precludes the existence of individual particle properties prior to measurement of this property and its derivatives make quantum mechanics surprisingly powerful when it comes to cryptography, as if it transcended its laws,” Prof. Horodecki concludes.

Today, thanks largely to support from the structural funds, we have nothing to be ashamed of when it comes to our laboratories. We are able to conduct research at the same level as teams from Western Europe, the USA or China.

From the universe to the inside of the brain

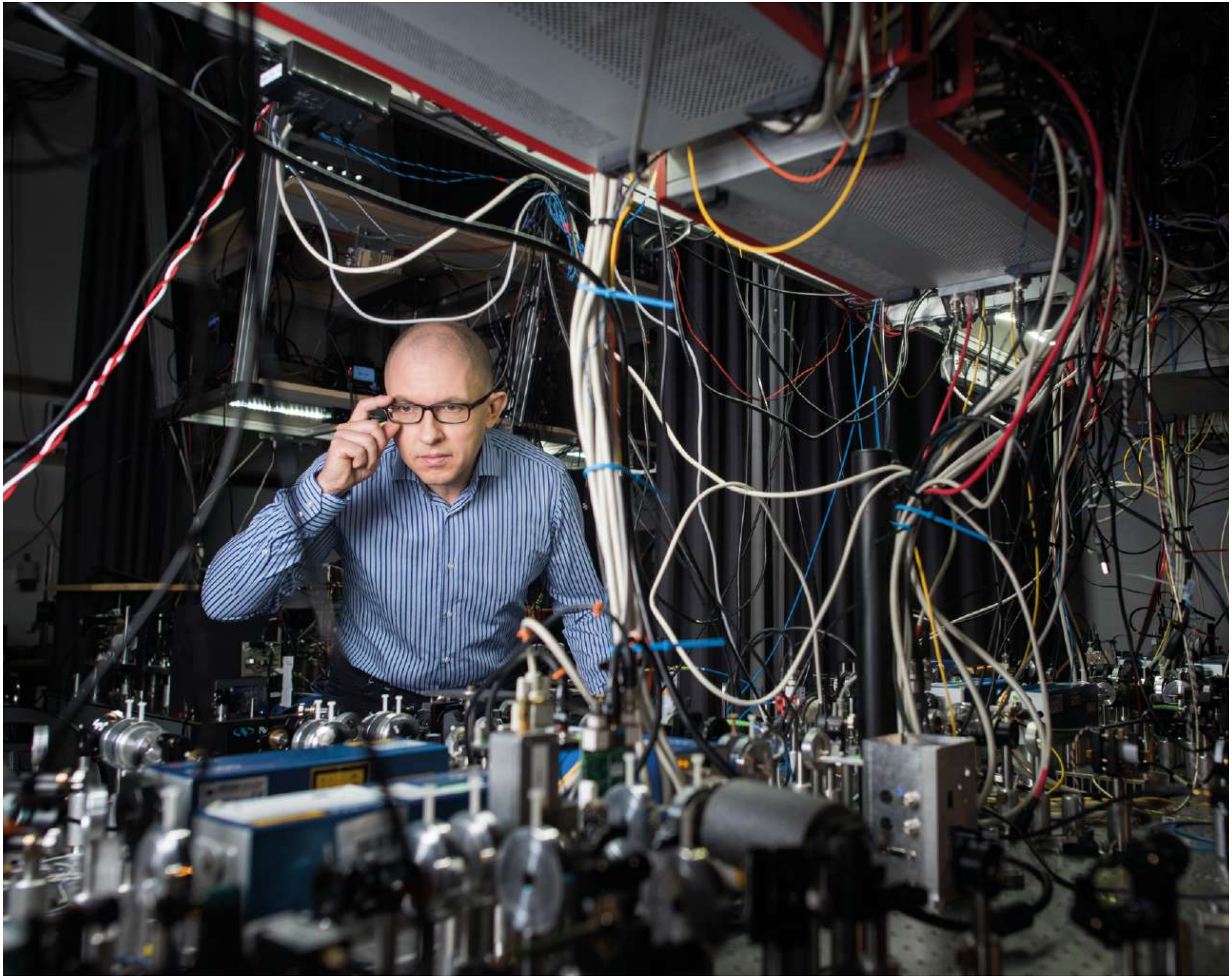
Established by Prof. Konrad Banaszek, the Centre for Quantum Optical Technologies (QOT) at the University of Warsaw is one of Europe’s leading centres for quantum technologies. QOT, of which the University of Oxford is a strategic partner, has been funded by the FNP with PLN 35 million within the International Research Agendas programme from POIR funds.

“Poland has always been strong in mathematics or theoretical physics. This provided a very good basis to deal with quantum information theory,” Prof. Banaszek explains. “Today, thanks largely to support from the structural funds, we have nothing to be ashamed of when it comes to our experimental laboratories. We are able to conduct research at the same level as teams from Western Europe, the USA or China.”

There are five teams operating within QOT. Director of the Centre, Prof. Banaszek leads a team working on the use of quantum technologies in optical communications. It is intended to work even at distances as great as those separating the Earth from the other planets of the Solar System. “At the moment, the bottleneck in the exploration of other space objects is the amount of data that can be transmitted to Earth. Most communications are based on radio networks. However, it is not possible to modulate such signals very quickly because the frequency of the carrier waves is relatively low, and at the same time they are subject to diffraction and only a small fraction of them reach the Earth. Switching to optical frequencies would allow the beam to be better targeted and more information to be encoded in it.” says Prof. Banaszek, adding: “Going beyond conventional technologies will allow the development of small, simple and efficient transmitters to increase the amount of data transmitted.”

Operating within QOT, the quantum-optical devices laboratory, led by Dr Michal Parniak, is working on the use of cold-atom technology, particularly rubidium atoms. Due to their specific properties, they can be used to record and process information. According to the researchers, in the future, such solutions could be used to build “network cards” for quantum computers, enabling these devices to communicate with each other. The same technology could also allow the construction of high-precision sensors to be used, for example, for biomedical research or fast wireless connectivity.

In turn, Dr Wojciech Wasilewski’s laboratory at QOT is working on technologies that could be used to build real quantum computers in the not too distant future. Among other things, the team has created quantum record memories and is working on quantum processors that process such stored information.



Prof. Konrad Banaszek

Led by Dr Jan Kołodyński, the Quantum Information and Inference Laboratory focuses on using quantum effects to improve measurement sensitivity and build the next generation of sensors. They could, for example, significantly simplify neurological examinations. The quantum sensors could operate at room temperature where complex and expensive devices requiring cooling to liquid helium temperatures are used today, enabling more accurate examinations. More precise sensors can also help with measuring the gravitational field, and this in turn can be relevant, for example, when searching for raw material deposits or predicting volcanic eruptions. The work of Dr Kołodyński's team has been published by "Nature Communications", among others.

Furthermore, another prestigious magazine, "Physical Review Letters" recently published the results of the work of the fifth QOT team, led by Dr Alexander Streltsov. Scientists have demonstrated that so-called complex numbers, often considered a purely mathematical creation, are an essential component of quantum mechanics, and that the formulation of quantum mechanics cannot explain all quantum phenomena without them.

The spectrum of quantum computers

Advances in quantum computing are putting pressure on researchers who are working on quantum cryptography. After all, the creation of a true quantum computer could render all conventional cryptography essentially useless – a true quantum computer will be able to instantly break ciphers that ordinary computers would not crack for centuries.

"When quantum computers appear, all existing cryptography goes into the bin. We will have to change the cryptographic systems in hundreds of billions of devices," explains Dr Pawłowski, adding: "In addition, the ciphers can be cracked later, that is, the communications can be recorded now and read out when the right technology emerges. If someone recorded, for example, an encrypted telephone conversation between Vladimir Putin and Emmanuel Macron, it will soon be possible to simply listen to it after the advent of the quantum computer".

When quantum computers appear, all existing cryptography goes into the bin. We will have to change the cryptographic systems in hundreds of billions of devices.

However, quantum computers themselves are still far from perfect. Despite all the big talk, there is still no device that can be called a full-fledged quantum computer. Many obstacles stand in the way. "What is available at the moment is rather an attempt to show in a relatively small system that quantum mechanics does indeed allow certain operations to be accelerated," Prof. Marek Kuś explains. Supported by a FNP grant from the POIR within the TEAM-NET programme, his team, while developing the theoretical basis for building quantum computers, focuses on testing software and creating algorithms to improve their operation.

Today, one of the fundamental problems with the design of quantum computers is that the basic units of which such devices are composed, the so-called qubits, quickly lose their quantum properties. And this is often before they can perform any useful calculations. "Quantum systems tend to become more and more 'classical' in their interaction with their environment. Meanwhile, the computer has to interact with the environment because we have to get the information out of the computer. This is the main theme of our research. We want to answer how, with the current resources, to stabilise the qubits, i.e. prevent their so-called decoherence or at least limit its disastrous impact," Prof. Kuś explains.

The quantum computer is intended to operate on a completely different principle to modern microprocessor-based computers.

Prof. Marek Kuś

While conventional computers operate with bits, i.e. information stored with electrical charges interpreted as zeros and ones, a quantum computer relies on the aforementioned qubits, which are not simply zeros or ones, but can be zeros and ones at the same time thanks to so-called superposition. Instead of analysing the data sequentially, superposition allows two qubits to analyse four scenarios simultaneously and three qubits to analyse eight. The power of the device increases exponentially as the number of qubits increases. Quantum computers are no better than traditional computers for all uses - traditional microprocessors are at least as good for browsing the Internet or running spreadsheets, but when it comes to analysing large data sets or optimisation problems, they are supposed to be able to run calculations thousands of times faster. And this gives hope for great progress in many areas.

“If we have several options for implementing a given process, we have to determine which is the most advantageous in terms of resources or time,” says Prof. Kuś, emphasising that both technological and purely scientific problems are involved: “A good example is the management of traffic in a city or air traffic over the territory of a country. Normal computers cannot keep up with analysing this data in real time.”

Humanity produces around 2.5 exabytes of data every day – that’s 2.5 billion terabytes. Analysing all this information with conventional computers is simply not possible. Only quantum computers can help process such large amounts of data, which can benefit, for example, better management of the economy or public health. For now, however, it is a matter of the future. A true quantum computer should have at least several thousand qubits to be able to process useful amounts of data. The largest machines in existence today have a maximum of 250 qubits. IBM announces that it will create a thousand-qubit quantum computer within two years.

Not just computers

Rather than creating a “quantum microprocessor”, i.e. a universal machine that can be used for many different types of computation, Prof. Magdalena Stobińska’s team is focusing on designing quantum circuits designed to perform specific tasks. “We are involved in quantum computing, for example transforms, which are particularly well suited to data analysis and quantum simulations that enable us to predict the existence of new interesting materials,” Prof. Stobińska explains. Her team was awarded an POIR-funded FNP grant within the FIRST TEAM programme and collaborates with a number of centres around the world, including NASA and the European Space Agency (ESA). “We are collaborating with the ESA on the usage of hybrid neural networks to process multidimensional images from Earth observation satellites,” the researcher explains.

Prof. Stobińska emphasises that contacts with other research centres, including Oxford University, Imperial College London and Sorbonne, but also with business, play a huge role in her research. “Interdisciplinarity and intersectionality are of key importance and I care a lot about them. Collaborating with business opens doors and lets in a lot of fresh air and lets you apply research to real-world problems,” the researcher says.

The distributed quantum protocols developed by the Warsaw team will soon be used in long-distance metrology, quantum communication and computing. The combination of photonics and nanotechnology should also open the door to super-sensitive infrared cameras or low-cost precision chemical or biological sensors that could, for example, monitor pollution.

Prof. Magdalena Stobińska

Quantum peeping at nature

Dr Radek Łapkiewicz's team from the Faculty of Physics at the University of Warsaw, winner of the FIRST TEAM programme of the Foundation for Polish Science, uses quantum technologies to peep into nature in its smallest details. The solution they have developed makes it possible to break down barriers that not long ago seemed to be the absolute limits of our research capabilities. "Traditional fluorescence microscopy has limited resolution. This is known as the diffraction limitation, which means that we are unable to distinguish between two objects that are closer than about half the wavelength of light, which is usually around 250 nm," Dr Łapkiewicz explains. "By measuring the correlation of photon pairs emitted from the sample, we can improve the resolution of the microscope twofold. It turns out that even small improvements in resolution can be of practical importance, for example enabling the characterisation of the shapes of dendritic spines, which play a key role in learning and addiction processes."

By measuring the correlation of photon pairs emitted from the sample, we can improve the resolution of the microscope twofold.

The use of quantum effects in biological imaging is a real breakthrough. Previous quantum techniques used in imaging required the preparation of complex light states with which to illuminate the sample. The technique developed by the Quantum Imaging Laboratory team at the University of Warsaw's Faculty of Physics together with the teams of Prof. Yaron Silberberg and Prof. Dan Oron from the Weizmann Institute of Science in Israel exploits the quantum properties of the light emitted by the sample itself.

There are a number of microscopic techniques that offer resolution significantly beyond the diffraction limit, but these usually require significant modifications to the experimental systems or special sample preparation. The technique introduced by the Quantum Optics Laboratory team at the University of Warsaw's Faculty of Physics together with teams from the Weizmann Institute of Science in Israel is cheaper and much easier to use. Importantly, it is compatible with existing microscopes: one only needs to replace the detector in the microscope with a miniature single photon sensitive camera (single photon avalanche diode array) to gain significant improvement in observational capabilities. "We aim to apply our knowledge and experience to solve practical problems in bio-imaging. We interact a lot with biologists and we build tools that will enable them to collect data that they would not get using commercially available equipment," says the physicist, adding: "It is also interesting to note that although we are focusing on applications, we are using fundamental properties of light such as the indivisibility of a single photon."

Clocks and earthquakes

Dr hab. Michał Zawada, Professor at the Faculty of Physics, Astronomy and Informatics at the Nicolaus Copernicus University in Toruń, is also seeking answers to the big questions using quantum technologies. The winner of the TEAM FNP programme has created a global network consisting of super-precision instruments to measure the most puzzling astronomical phenomena. These are optical atomic clocks, 40,000 times more precise than conventional atomic clocks.

"Every clock has two most important parts, one obvious and one not so obvious. The obvious one is the pendulum. The non-obvious one is a clockmaker that determines how many swings equal one second," Dr Zawada explains. "In an optical atomic clock, atoms are the clockmaker and laser light is the pendulum."

The precision of optical clocks is so great that any disturbance in their operation allows them to detect other phenomena, e.g. a clock located in Paris can easily detect waves hitting the shore

Dr Radek Łapkiewicz

of the English Channel. The interconnection of atomic clocks distributed worldwide could open up entirely new possibilities for researchers on both the macro and micro scales. Dr Zawada believes that such measurements could help in the search for new physics beyond the limitations of the current standard model, such as the variability of physical constants or the search for dark matter. However, they could also have much more “down-to-earth” uses, for example in the work of geologists, who predict earthquakes or volcanic eruptions using a super-sensitive clock network.

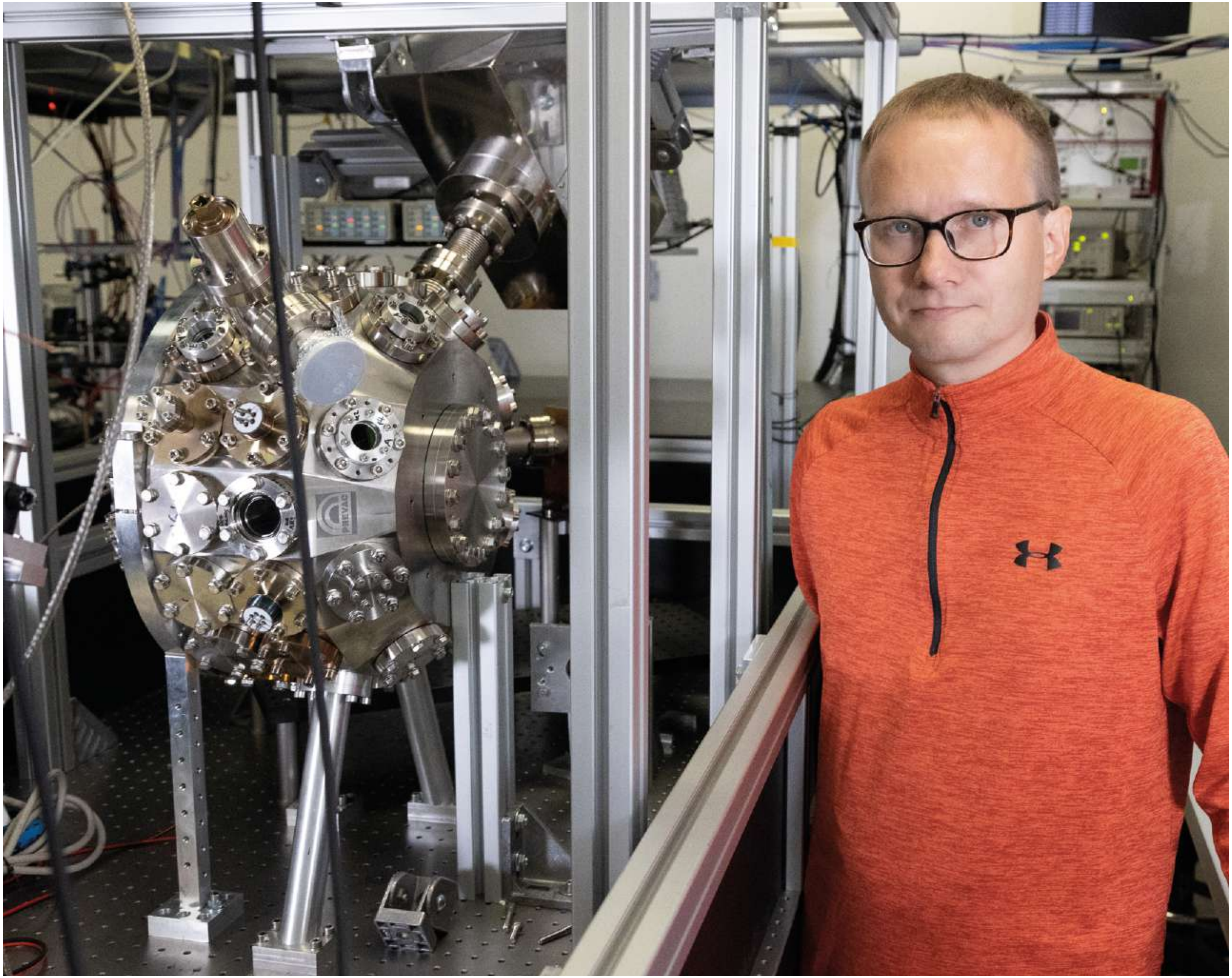
Great hopes, great problems

We have been waiting for a breakthrough in quantum technologies for decades and there are many indications that it is finally approaching. After all, the advances made in other technologies in the last two decades have enabled engineers to efficiently manipulate matter on a scale that until recently seemed completely impossible.

“Quantum physics works at the level of single elementary particles and technology has had to make a lot of progress for us to be able to take full advantage of it,” explains Dr Pawlowski, adding: “Erwin Schrödinger said that single-particle experiments are like having an ichthyosaur in the zoo. We can speculate about it, but it will never happen. Meanwhile, we are now able to do anything with a single particle. Biology is also moving forward, so who knows, we might get an ichthyosaur too?”

There is still a great deal of work ahead for researchers. Especially in front of those who focus on laying the foundations for quantum computers. “I think we are still missing a ground-breaking idea,” Prof. Kuś believes. “There are several technological ideas on how to construct such a computer and there are two approaches to the problem: one related to the study of super-cold matter, allowing individual atoms to be placed in a network, and the other, an optical one, involving the use of laser light. But which one will prevail, no one knows today.”

What is certain, however, is that in communications, computing and super-modern measurement techniques, quantum technologies will soon become an indispensable tool for researchers and engineers. And Polish scientists are already making great steps towards a quantum future.



Dr hab. Michał Zawada

Summary of activities

Since 2016, the Foundation for Polish Science has implemented programmes under: Measure 4.3 “International Research Agendas” and Measure 4.4 “Increasing the human resource potential in R&D sector” with funds from the POIR

FNP International Research Agendas

Measure 4.3 “International Research Agendas”

The aim of the IRAP programme is to create new research units (organisational and legal structures) in Poland, headed by eminent scholars from all over the world, in which teams composed of foreign and Polish scientists representing various scientific specialisations carry out research and development work at the highest world level. The specialised centres of excellence established with the support of the FNP should follow world best practice in terms of: identifying research programmes and themes; personnel policy and R&D management; commercialisation of R&D results.

The IRAP programme was co-financed under Axis IV of the POIR, Measure 4.3. Calls for proposals ran from 2015 to 2018. Funding was granted through a competitive basis.

Implementation of the International Research Agendas programme[1]

PLN 502,029,620 Total POIR funding for grant and scholarship payments under Measure 4.3

12 Total number of completed competitions

14 Total number of projects

159 Total number of scholarship recipients (students and PhD students)

17 Total number of foreign strategic scientific partners

419 Number of publications in international journals to date

232 (51%) Poles involved in the project (PhD students, postdocs, team leaders)[2]

226 (49%) Foreigners involved in the project (PhD students, postdocs, team leaders)[3]

[1] Data as at March 2023.
[2] Data as at June 2023.
[3] Data as at June 2023.

First Team

Homing

Powroty/Reintegration

Team

Team-Net

Team-Tech

Measure 4.4 "Increasing the human resource potential in R&D sector"

The Foundation for Polish Science acted as the Implementing Body of the POIR (under the implementation of Measure 4.4). It coordinated the implementation of the following programmes: FIRST TEAM, HOMING, POWROTY/REINTEGRATION, TEAM, TEAM-NET, TEAM-TECH (together with Core Facility and Core Facility Plus competitions).

The programmes were implemented under Measure 4.4 "Increasing the human resource potential in R&D sector" of the POIR 2014–2020, Axis IV: Increasing scientific and research potential.

Summary of programme implementation under Measure 4.4 "Increasing the human resource potential in R&D sector" [4]

PLN 763,562,072* Total amount of all project agreements concluded within the programmes under Measure 4.4 of the POIR

*Including own contribution

1,379 Total number of applications

34 Total number of completed competitions

227 Total number of projects

1,636 Total number of scholarship recipients (students and PhD students)

96 Total number of national economic partners

454 Total number of foreign scientific partners

2,247 Number of publications in international journals to date

1,032 (81%) Poles involved in the project (PhD students, postdocs, team leaders)

247 (19%) Foreigners involved in the project (PhD students, postdocs, team leaders)

[4] Data as at June 2023.

FNP First Team

The aim of the FIRST TEAM programme was to develop human resources in the R&D sector by supporting the first independent research teams run in scientific units or enterprises in Poland by people with a doctoral degree who are at the early stages of their scientific career and are working in the most innovative areas of research.

Calls for applications under the FIRST TEAM programme ran from 2016 to 2018. Funding was granted on a competitive basis.

Implementation of the FIRST TEAM programme[5]

- **PLN 146,646,452*** – Total amount of all project agreements concluded within the programme
  *Including own contribution
- **507** – Total number of applications
- **5** – Total number of completed competitions
- **54** – Total number of projects
- **277** – Total number of scholarship recipients (students and PhD students)
- **12** – Total number of national economic partners
- **109** – Total number of foreign scientific partners
- **495** – Number of publications in international journals to date
- **188 (74%)** – Poles involved in the project (PhD students, postdocs, team leaders)
- **67 (26%)** – Foreigners involved in the project (PhD students, postdocs, team leaders)

[5] Data as at June 2023.

Homing

The aim of the HOMING programme was to develop human resources in the R&D sector by financing ground-breaking postdoctoral internships carried out in research units or enterprises in Poland by young PhDs from abroad or researchers of Polish origin returning to Poland.

Calls for applications under the HOMING programme ran from 2016 to 2018. Funding was granted on a competitive basis.

Implementation of the HOMING programme[6]

PLN 41,315,705* – Total amount of all project agreements concluded within the programme

*Including own contribution

228 – Total number of applications

5 – Total number of completed competitions

51 – Total number of projects

135 – Total number of scholarship recipients (students and PhD students)

8 – Total number of national economic partners

95 – Total number of foreign scientific partners

235 – Number of publications in international journals to date

84 (84%) – Poles involved in the project (PhD students, postdocs, team leaders)

16 (16%) – Foreigners involved in the project (PhD students, postdocs, team leaders)

[6] Data as at June 2023.

Powroty/Reintegration

The aim of the POWROTY/REINTEGRATION programme was to develop human resources in the R&D sector by financing innovative postdoctoral internships carried out by young PhDs (regardless of their nationality) returning to research work in research units or enterprises in Poland, after a break due to parenthood or work outside the field of science.

Calls for applications under the POWROTY/REINTEGRATION programme ran from 2016 to 2018. Funding was granted on a competitive basis.

Implementation of the POWROTY/REINTEGRATION programme[7]

PLN 17,367,183*
*Including own contribution
Total amount of all project agreements concluded within the programme

117 Total number of applications

5 Total number of completed competitions

19 Total number of projects

56 Total number of scholarship recipients (students and PhD students)

8 Total number of national economic partners

35 Total number of foreign scientific partners

80 Number of publications in international journals to date

32 (91%) Poles involved in the project (PhD students, postdocs, team leaders)

3 (9%) Foreigners involved in the project (PhD students, postdocs, team leaders)

[7] Data as at June 2023.

FNP Team

The aim of the TEAM programme was to develop human resources in the R&D sector by supporting ground-breaking team projects led by eminent scholars from all over the world (regardless of their nationality) in research units or enterprises in Poland, working in the most innovative areas, together with a foreign partner. The support has enabled people starting out in their research careers (students, PhD students or young PhDs) to gain experience.

Calls for applications under the TEAM programme ran from 2016 to 2018. Funding was granted on a competitive basis.

Implementation of the TEAM programme[8]

PLN 211,046,012* – Total amount of all project agreements concluded within the programme

*Including own contribution

304 – Total number of applications

5 – Total number of completed competitions

55 – Total number of projects

329 – Total number of scholarship recipients (students and PhD students)

19 – Total number of national economic partners

161 – Total number of foreign scientific partners

655 – Number of publications in international journals to date

286 (78%) – Poles involved in the project (PhD students, postdocs, team leaders)

79 (22%) – Foreigners involved in the project (PhD students, postdocs, team leaders)

[8] Data as at June 2023.

FNP Team-Net

The aims of the TEAM-NET programme, which was launched in 2018, were to enable large-scale interdisciplinary research in Poland, to strengthen supra-regional cooperation between research units and to build competence in the use of available research infrastructure or the development of new technologies and research services.

The programme ensured the continuation of previous activities of the Foundation for Polish Science in the field of the development of human resources in the R&D sector by supporting team projects carried out by experienced scholars from all over the world, researchers at early stages of their career development including post-doctoral internships, as well as young PhDs setting up their first research teams.

The call for applications under the TEAM-NET programme ran in 2018. Funding was granted through a competitive process.

Implementation of the TEAM-NET programme[9]

- **PLN 204,361,158*** – Total amount of all project agreements concluded within the programme
  *Including own contribution
- **39** – Total number of applications
- **1** – Total number of completed competitions
- **11** – Total number of projects
- **596** – Total number of scholarship recipients (students and PhD students)
- **233** – Number of publications in international journals to date
- **258 (82%)** – Poles involved in the project (PhD students, postdocs, team leaders)
- **57 (18%)** – Foreigners involved in the project (PhD students, postdocs, team leaders)

[9] Data as at June 2023.

Team-Tech

The aim of the TEAM-TECH programme was to develop human resources in the R&D sector by supporting team projects headed by scholars with outstanding experience in the implementation of research results in economic practice (TEAM-TECH competition) or in the provision of research services or the operation of test equipment for business or other recipients, including other scientific and research units (Core Facility and Core Facility Plus competitions).

The support should enable early-career researchers (students, PhD students or young PhDs) to gain experience in the development of a technology, process or innovative product (TEAM-TECH competition) or in the design and development of research services using advanced test apparatuses (Core Facility and Core Facility Plus competitions).

Calls for applications under the TEAM-TECH programme ran from 2016 to 2018; under the TEAM-TECH Core Facility programme from 2016 to 2018; under the TEAM-TECH Core Facility Plus programme from 2017 to 2018. Funding was granted on a competitive basis.

Implementation of the TEAM-TECH programme[10]

PLN 142,825,562*	Total amount of all project agreements concluded within the programme
184	Total number of applications
13	Total number of completed competitions
37	Total number of projects
243	Total number of scholarship recipients (students and PhD students)
49	Total number of national economic partners
54	Total number of foreign scientific partners
549	Number of publications in international journals to date
184 (88%)	Poles involved in the project (PhD students, postdocs, team leaders)
25 (12%)	Foreigners involved in the project (PhD students, postdocs, team leaders)

*Including own contribution

[10] Data as at June 2023.

European Funds in the activities of the Foundation for Polish Science

In 2023, the Foundation for Polish Science will complete the implementation of the POIR. The activities launched in 2015 made it possible to supply Polish science with over PLN 1.2 billion.

While the POIR aimed mainly to stimulate the innovativeness of the Polish economy, the Foundation assumed that innovation is based on the development of high-quality research, education of research staff, and the development of cooperation between the academic sector and enterprises. As a result, POIR financed innovative projects and teams, in which young researchers developed under the supervision of outstanding scientists with significant achievements in the world and in cooperation with other research groups or business partners.

As part of the “Increasing the human potential in the R&D sector” (Measure 4.4 POIR), V supported over 2350 scientists. In turn, the International Research Agendas (Measure 4.3 POIR) enabled the creation of 14 independent research units that address essential social and civilization problems. These institutions attract scien-

Dr Marta Łazarowicz-Kowalik, Deputy President of the FNP Board, responsible for the Foundation’s evaluation activities tists from all over the world and cooperate with companies.

Experience and resources

Based on over 30 years of experience, the Foundation undertook the difficult task of using the structural funds of the European Union for the development of research in Poland. The Foundation has been supporting science since 1991, gaining experience in navigating a dynamically changing legal, economic, and social environment. During the last 30 years, the needs of science in Poland have changed. By cooperating with researchers, the Foundation has responded to their needs and adapted its programmes accordingly.

Following the motto "support the best so that they can become even better," the Foundation has consistently awarded funds on a competitive basis, relying on the assessment of the applicants' achievements provided by other researchers. After years of conducting various competitions, the Foundation established a robust expert base. It consists of over 18 thousand active experts, around five thousand of whom have foreign affiliations. Such cooperation fosters high competencies and an international perspective in project assessment, allowing to avoid conflicts of interest.

After years of conducting various competitions, the Foundation established a robust expert base. It consists of over 18 thousand active experts, around five thousand of whom have foreign affiliations.

Years of experience in conducting and improving grant competitions resulted also in carefully elaborated procedures and standards of operation, concerning, among other elements, the quality of reviews and expert evaluations and the consideration of appeals. The Foundation's place in the system supporting science in Poland stems from the trust of the research community, which in turn, relies on FNP's high standards of operation. The Foundation developed its principles of operation in close cooperation with the scientific community and modeled them on the best practices used by international grant-making institutions. To increase the transparency and reliability of its activities, the Foundation actively cooperates with foreign and international organizations (e.g. Science Europe, Philea Research Forum, and, most recently, the Coalition for Advancing Research Assessment CoARA). Moreover, the Foundation is a member of the Global Research Council, which gathers the most important and largest science funding organizations in the world.

At the same time, as in other countries, the Foundation's standards are changing in response to new expectations towards scientists, research institutions, and research funders. The understanding of good practices in the context of evaluating projects and scientific achievements is evolving. There are now higher requirements for transparency of recruitment processes and grant competitions, discrimination prevention, researcher's social responsibility, research results management, and open accessibility to these results. Furthermore, our legal and institutional landscape is also shifting.

The Foundation has formulated and, when necessary, enhanced codes of ethics applicable to its own staff ("The Code of Ethics of the Foundation for Polish Science")[1] and scientists participating in competitions and programmes ("The Code of Ethics for Beneficiaries and Candidates in Programmes of the Foundation for Polish Science").[2] The Foundation also provides mechanisms to intervene in the event of potential breaches of the rules of the codes or suspicions of fraud (zglosnaduzycie@fnp.org.pl). Moreover, the Foundation has also developed the Equality and Diversity Policy,[3] and it is working to formulate a well-considered position on Open Science.

In 2012, In recognition of these efforts, the Foundation was the first institution in Poland awarded the HR Excellence in Research logo by the European Commission for implementing the principles of the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers.[4] These principles concern ethical issues and professional responsibility; recruiting and evaluating researchers and providing them with appropriate working and training conditions. As an institution implementing the principles of the Charter and the Code, the Foundation is regularly subject to self-evaluation and external evaluation by experts from the European Commission.

As an institution supporting science, the Foundation attaches great importance to self-reflection and critical analysis of its own activities. Like the researchers we support, we take risks by facing challenging tasks. This is how we understand our role in the system supporting science in Poland. We initiate and test solutions that large state agencies later implement on a larger scale. To fulfill this role, we diligently analyze the course and effects of our activities by conducting evaluation studies that support the process of building the Foundation's programme strategy.[5]

Tackling new challenges

Based on a careful analysis of the environment's needs, the Foundation identifies new tasks ahead of it. For example, initially, in the 1990s, the tasks included interventional investments in research infrastructure. Over time, the Foundation has focused on supporting individual scientists and research teams. Because the system of financing science in Poland has been divided into a separate stream of funding basic research (the National Science Centre, NCN) and applied research (the National Centre for Research and Development, NCBR), the Foundation has been trying to bridge the gap between these two institutions and support scientists working at the interface of basic research and applied research and help them overcome barriers in the implementation of research results.

Our help in overcoming bottlenecks in the research system also included supporting researchers at the most critical moments in their careers, such as forming their first research team or returning to research activities after a parenthood-related break. We have dedicated special programmes to both of these areas. BRIDGE, BRIDGE BIS, and POWROTY/REINTEGRATION enabled the best scientists who were raising children or taking breaks in their research careers for various reasons to return to intensive scientific work. In turn, thanks to the FOCUS and FIRST TEAM programmes, outstanding young researchers were able to form their first teams. The evaluation of our activities shows that these programmes not only helped the laureates develop their careers but also attracted professionals from abroad to Poland and reaffirmed the decision of many scientists to stay in our country.

Attracting researchers to Poland has become an important goal for the Foundation, which we achieve primarily through EU structural funds. Poland's EU membership has not only created great development opportunities for our scientists and science but has also caused an outflow of talented researchers abroad. The Foundation has always wanted our researchers to have a chance to gain education and experience in the world's best centers (e.g. the KOLUMB programme served this purpose). However, when trips abroad became relatively easy to finance from other sources, the Foundation focused its efforts on attracting scientists from abroad to Poland, increasing the attractiveness of research work in our country, and building world-class scientific centers in the country. We will elaborate on the effects of these actions further.

The Foundation has also set itself the task of building a "critical mass" in the field of selected research topics and conducting groundbreaking research in Poland. Apart from funding individual researchers, the Foundation provided grants for teams, consortia of research teams (TEAM-NET), and centers of excellence (IRAP). We want to achieve synergy and strengthen the share of research conducted in Poland in international science, while increasing the inflow of European funds, the prestige of Polish science, and the attractiveness of work in our country.

Structural funds

Innovative Economy Operational Programme

Addressing the above challenges would not have been possible without European funds.

The Foundation began to finance its activities from EU structural funds first in 2007, when it became the beneficiary of the Innovative Economy Operational Programme (POIG).[6] This allowed for the implementation of six new programmes (TEAM; International Doctoral Projects Programme; VENTURES, WELCOME; PIER; HOMING PLUS) with a total budget of PLN 421 million. For the Foundation, this meant a huge conceptual and organizational challenge. These programmes resulted in 448 individual laureates, 2248 stipendees employed in their projects, and 179 foreign scientists who started working in Polish laboratories.

Another source we used to support Polish scientists was the Human Capital Operational Programme.[7] In addition to grants, we wanted to offer non-financial support that would help scientists improve their competencies so that they could conduct research more effectively and use its results, among other elements, by cooperating with enterprises. We heard about the need for this type of support for a long time. Moreover, the evaluations of the Foundation's programmes pointed to the importance of improving various skills for the development of both scientists themselves, projects, teams, and entire research institutions. The SKILLS project (2011–2015) aimed to increase the skills of project participants in the field of research management, interdisciplinary cooperation, scientific communication, dissemination of science, and entrepreneurship. The activity included various modules: training, mentoring, coaching, internships, and competitions in the field of science popularization and communication with the public; hence programmes such as eNgage, INTER, and IMPULS. The latter concerned primarily the development of scientists' entrepreneurial competencies. The evaluation study of the SKILLS project confirmed the deficit of soft skills in the research environment and the great usefulness of the Foundation's activities. Participants assessed all proposed forms as very useful and unique with mentoring and coaching being the most important. Therefore, the SKILLS project was an innovation not only in the Foundation's operation but also in the broader context of the science system in Poland, providing an opportunity to test new tools to support researchers.

We achieved the highest level of teams' internationalization in Poland. About 40% of research group leaders, 56% of early career researchers, and 54% of doctoral students implementing projects come from abroad.

Based on this experience, in 2016, the Foundation launched programmes financed by the POIR to support R&D sector staff (Measure 4.4) and create centers of scientific excellence in Poland (International Research Agendas, Measure 4.3).

POIR

International Research Agendas (4.3)

The International Research Agendas programme (IRAP) aims to create new research units in Poland, led by outstanding scientists who are world authorities in their fields. We wanted their interdisciplinary and international teams to conduct scientific research and development work at the highest level. In addition to high-quality research, the IRAP units wanted the scientists to introduce best practices in Poland in the field of identifying research programmes and topics, personnel policy and management of R&D works, and the commercialization of R&D results.

To achieve the highest quality of results, the Foundation supported only projects implemented in strategic partnership with renowned international centers, which excel in selected research areas. International scientific committees consisting of eminent representatives of science from around the world supervised the quality of research and organizational culture of IRAP units.

The Foundation established 14 centers of excellence under the IRAP. It established 71 research teams, employing, among other people, five ERC laureates, which is the most prestigious European grant. In total, 17 individuals from the top 2% of global scientists in their respective fields (as per Stanford University[8]) engaged in work with IRAP units. They supervised the research of 75 early career researchers and 91 doctoral students. We recruited three Nobel Prize winners and representatives of leading research organizations from Europe and the USA (e.g. Princeton University, Oxford, Edinburgh, Sheffield, Uppsala, UCL, and institutes such as EMBL, Max-Planck, IQoQi) to participate in the international committees, which supervise the recruitment and substantive shape of individual research agencies. We achieved the highest level of teams' internationalization in Poland. About 40% of research group leaders, 56% of early career researchers, and 54% of doctoral students implementing projects come from abroad.

Another direct benefit of the IRAP is the promotion of three units that have obtained funding from the Teaming H2020 programme. The Foundation created the International Research Agendas programme as a complement to the Teaming for Excellence programme announced by the European Commission under Horizon 2020. It provided the national contribution necessary to participate in the Teaming competition. IRAP brought significant funding to three Polish units, with each receiving an unprecedented amount of EUR 15 million – more than 51% of Poland's funds from Horizon 2020 in the Spreading Excellence and Widening Participation pillar.

Increasing the human potential in the R&D sector (4.4)

The programmes financed under this measure, namely HOMING, POWROTY/REINTEGRATION, FIRST TEAM, TEAM, TEAM-TECH, TEAM-NET, and TEAM-TECH Core Facility/ TEAM-TECH Core Facility Plus – enabled the creation of 275 teams that recruited 413 early career researchers and 591 doctoral students. Among the team leaders, there were 13 ERC grant winners. As in the IRAP, the Foundation placed great emphasis on the application of high recruitment standards, including open international competitions. The analysis of 1174 applications received by teams created under the programmes showed that as many as 60% of applications came from abroad and candidates were affiliated in 63 countries. The interest of candidates from abroad in research work in projects supported by the Foundation clearly increased at later career stages. In the case of students, it was 27%, but in the case of doctoral students and early career researchers – 67% and 72% respectively. The results of the analyzed competitions indicate that 71% of accepted scholars were previously affiliated in Poland. The remaining 28% came from abroad, some of them being Poles returning from abroad. Our winners declare that the employment of foreigners had a positive effect. The majority of respondents agreed with the statements: "A foreigner in a team brings new knowledge and other ways of doing things. This positively impacts the team's work;" "A foreigner in the team brings contacts that facilitate international cooperation in the future;" and "Scientific groups employing foreigners are seen as more prestigious." At the same time, respondents openly talk about barriers to recruiting foreigners. These include problems with bureaucracy, especially for people from outside the EU, and also the perception of Poland as not a very attractive country for scientific research. This underscores the value of the high internationalization degree of teams implementing projects under Measure 4.4 of POIR. Foreigners accounted for 8% of research group leaders, 22% of doctoral students, and 23% of early career researchers.

COVID-19

The implementation of the measure "Increasing the human potential in the R&D sector" coincided with the COVID-19 pandemic, which made it much more difficult to recruit research teams, conduct research, and handle grants. The Foundation used all legally available possibilities to extend the duration of projects and monitored the pandemic's impact on their implementation and the research work of funded teams. A total of 42% of the surveyed scientists declared that the pandemic had affected their health situation and 7% noticed a clear decline in their health condition. Most of the difficulties concerned delays in the projects' implementation, which to a large extent affected 51%. Noteworthy, the pandemic's impact depended on the maturity of the project, the type of conducted research, access to research equipment, and the degree of dependence on partners. At the time, a big obstacle was especially to involve new employees from abroad and continue the partnerships.

We focused not only on the practical, commercial implementation of research results but also on increasing the awareness and skills of scientists in this area.

Despite these adversities, the projects we supported managed to implement almost all previously assumed plans. Some of the funded teams also undertook additional research tasks related to the pandemic and cooperation in this area. We could entrust these tasks to well-functioning groups of scientists carefully selected under POIR competitions. For these additional research tasks related to COVID-19, the Foundation allocated approx. PLN 15 million. Moreover, the Foundation participated in battling the pandemic by initiating and conducting public debates with scientists on COVID-19 and vaccination. These debates are available on our website (www.fnp.org.pl).[9]

Impact on the innovative economy

A high level of scientific research and research and development works determines the economy's innovativeness. However, to actually create it, additional support is necessary. As part of POIR, the Foundation has broadly approached the understanding of R&D staff, without limiting its field of view to academic institutions. We offered the projects not only to research units but also companies. Cooperation with enterprises was a desirable and in some programmes even a necessary element.

We wanted the research financed by the Foundation to become the basis for the development of new technologies and be subject to commercialization. Hence, we ensured the security of intellectual property. Thus far, projects implemented as part of "Increasing the human resources potential of the R&D sector" have brought 67[10] patent applications of supra-local (regional or international) scope. In the case of International Research Agendas, there are already 30[11] applications. We focused not only on the practical, commercial implementation of research results but also on increasing the awareness and skills of scientists in this area. According to a survey addressed to all leaders of teams financed from POIR funds, only 15% of respondents have not filed or are not planning to file a patent application under the project. Another 45% of respondents have already applied or are in the process. Furthermore, 41% of respondents plan to apply. Of course, patenting activity varies from programme to programme. In programmes designed for technology transfer (e.g. TEAM-TECH), researchers apply for patent applications in the case of most projects. Respondents who have filed applications or are in the process most often motivate this with the desire to protect intellectual property before the results are disclosed (85.7%), belief in the results' commercialization potential (79.8%), and the need to demonstrate the indicators of the programme's implementation (68.9%). Scientists apply for national, regional, or international protection primarily because of the commercialization potential, the scale of inventiveness, or the significance of the invention and international cooperation with an economic partner. Choosing the right protection area requires prudence and a strategic approach of the entire institution. Application is not always necessary for effective service or technology implementation.

We are aware that a patent application does not yet imply commercialization. According to our survey, when team leaders see commercialization potential, they are more likely to talk to entrepreneurs, analyze the market, cooperate with entrepreneurs, or build a prototype. As the respondents emphasize, in addition to potential commercialization, the benefit of those patent applications that aim to demonstrate programme's implementation is the acquisition of experience and valuable skills in this field, which increases the chances of fruitful cooperation with business or developing one's own business potential, as well as satisfaction and a greater sense of research work's purpose. To achieve the objectives of programmes financed from the POIR funds, it is crucial to draw scientists' attention to the practical application of their results. As one of the leaders of the supported teams put it: "Regardless of the final commercial outcome, the requirement to file a patent application or even just consider the functional context of the results is valuable. It forces scientists to look for a purpose and motivation for their research."

As part of supporting good practices in the field of conscious management of research results, the Foundation expects IRAP units to develop plans for the management of laboratory data, which serve not only to reliably and transparently document the results but also to ensure their confidentiality and informed sharing as part of the undertaken path of cooperation or commercialization.

We will continue to develop centers of scientific excellence under the IRAP FENG to increase the ability of Polish science to generate research results that will be significant on a global scale.

We want the researchers educated in our projects to bring awareness of their work's significance to Polish science and have the know-how to turn it into innovation. According to a survey conducted in 2023, the vast majority of young scientists who participated in programmes financed by the POIR (86% of doctoral students and 95% of early career researchers) continue their research. Concerning their professional future, they are clearly open to various other career options: 14% focus on scientific work, while 42% want to work in research but do not exclude other opportunities, 11% hope to use their research experience to obtain an attractive job outside science, 11% want to combine research work with work in another sector, and 7% would prefer to implement research results.

For years, the Foundation has been monitoring the career development of the researchers it supports and the results they have achieved. In terms of the population of POIR beneficiaries, the survey results clearly deviate from the previous trend, when respondents declared almost exclusively the desire to continue their scientific career. This may be due to many reasons related to, among other elements, chances for stable employment or the attractiveness of scientific work. A possible reason for the new trend is the greater possibilities of using research experience, e.g. in the economy. Importantly, individuals who leave their scientific careers, who are very few, still value the experience gained from projects. Among them, 47% believe this experience is important to employers, and 38% apply their subject knowledge and research skills in their jobs.

European Funds for Smart Economy (FENG)
In 2023, we started to implement programmes financed by the FENG. Previous activities taught us to better diagnose the commercialization potential of projects and research teams. We also improved our understanding of the barriers to implementing research results and strive to provide more precise support tailored to these needs.

The planned FENG activities concentrate on identifying, verifying, and realizing the commercial potential of research. They also aim to foster collaboration between academia and industry as well as enhance early career researchers' abilities to research economic relevance and develop their careers. The Proof of Concept (PoC) programme will enable R&D, which aims to verify the research hypothesis and the implementation potential of research results. The TEAM-NET programme will aim to introduce an innovative product, service, and technology to the market as a result of cooperation between research teams in selected strategic areas. The PRIME programme will strive to build team competencies in the field of entrepreneurship and support academic spin-offs in the first year of their operations.

We will continue to develop centers of scientific excellence under the IRAP FENG to increase the ability of Polish science to generate research results that will be significant on a global scale. The support will cover funding for industrial research and experimental development. We will also continue to help young researchers create their first teams and develop their potential in Poland to make our country an attractive place for outstanding scientists from around the world and to increase the competitiveness of Polish science, including the quality of applications submitted to ERC calls and other prestigious international grants (the FIRST TEAM programme).

In subsequent financial perspectives, the Foundation's role has been changing (from the beneficiary, through the implementing institution, to the intermediary). This brings further organizational challenges both for us and the scientists we support. We understand the procedural and bureaucratic difficulties faced by our staff, researchers, and institutions implementing projects financed from structural funds. However, above all, we always try to represent the voice of the research community and serve Polish science.

Dr Marta Łazarowicz-Kowalik
Deputy President of the FNP Board, responsible for the Foundation's evaluation activities

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[9] Foundation for Polish Science, "FNP supports the fight against COVID-19," https://www.fnp.org.pl/category/aktualnosci/fnp-covid-19/ (accessed: July 28, 2023).

[10] Data as of June 2023.

[11] Data as of July 2023.

Webinar map. How European Funds support research and innovation

During the series of meetings, prominent scientists presented the latest research results in the field of green energy, medical diagnostics and new materials. Achievements in the fight against COVID-19 and research services offered to business were also presented. The participants of the webinars included the experts contributing to this publication. The videos complement the knowledge of the topics addressed in the publication, whereas online discussions allow exploring them even deeper. The events took place in December 2022.

Click the image to watch a YouTube video.

▲ **Energy and ecology. Scientific solutions for a better climate.** How do European Funds support research and innovation?

▲ **Understand, diagnose, cure. Research supporting medical diagnostics.** How do European Funds support research and innovation?

▲ **Research services for business.** Presentation session on the results of selected TEAM-TECH Core Facility projects

▲ **How do European Funds support the fight against COVID?** Research results of the Foundation for Polish Science laureates

▲ **From nanoscale to megastructures. Materials of the future are already being developed in Polish laboratories.** How do European Funds support research and innovation?

The research presented during a series of webinars was co-financed by the European Union under the European Regional Development Fund under the Smart Growth Operational Programme.

Programmes:
International Research Agendas, FIRST TEAM, HOMING, POWROTY/REINTEGRATION, TEAM, TEAM-NET, TEAM-TECH, were co-financed by the European Union under the European Regional Development Fund under the Smart Growth Operational Programme.

European Funds
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