Skolkovo Institute of Science and Technology

creating together

# Skoltech Annual Report

'22

# About the Report

Skoltech Annual Reports have been released from 2017 to share results of performance under the Strategy with stakeholders and wider audience. The content of Reports is presented in a way to correspond with the strategic goals and initiatives, also accounting for recommendations of the collegial governing bodies. Pursuant to Skoltech Charter, Annual Reports are approved by the Board of Trustees.

The Report 2022 overviews a new chapter in Skoltech story. This is a snapshot to the testing, however successful year, when accomplishments came alongside with complex decision-making on all organizational levels. To adapt to the new challenges, which changed dramatically and immediately regular models and activities, Skoltech stayed together, continuing to Create Together, thanks to commitment of every team and every employee.

The statistical data in the Report 2022 is indicated as of 30 December 2022 unless stated otherwise, while the financial results 2022 are reported conditionally, subject to the independent Auditor's opinion.

All Annual Reports are released in a corporate design, developed by the Brand and Marketing and Institutional Development teams under inspiration of Avant-Garde elements as symbols of pioneering approaches and dynamics. The Report 2021, devoted to Skoltech 10th Anniversary, was awarded by RAEX Analytics, which is the largest national rating agency, with 5* certificate for quality of design and content. The present Report will be also submitted to RAEX annual call for corporate reporting.

# Content

# Introduction

# Message from the Chairman of VEB.RF

**The Skolkovo Institute of Science and Technology fully fulfils its mandate – to design and implement own technologies, develop and transfer competencies in the most important areas for Russia.**

The contribution to ensuring technological sovereignty and transformation of the national economy is the priority agenda for the VEB.RF Group. In this paradigm, the Skolkovo Institute of Science and Technology fully fulfils its mandate – to design and implement own technologies, develop and transfer competencies in the most important areas for Russia: Artificial Intelligence, 5G, Energy Technologies, Advanced Materials, Hydrocarbon Recovery, Genetics and Agrotechnology, Engineering.

National companies of a high-tech sector as well as governmental authorities rely on Skoltech expertise in defining directions of national research and technology agenda for the coming years as well as long-term perspectives. With Skoltech involvement, the Russian Federation Government developed concepts and roadmaps in a number of priority areas.
Some technology solutions were designed from scratch and transferred to the industry for further scaling.

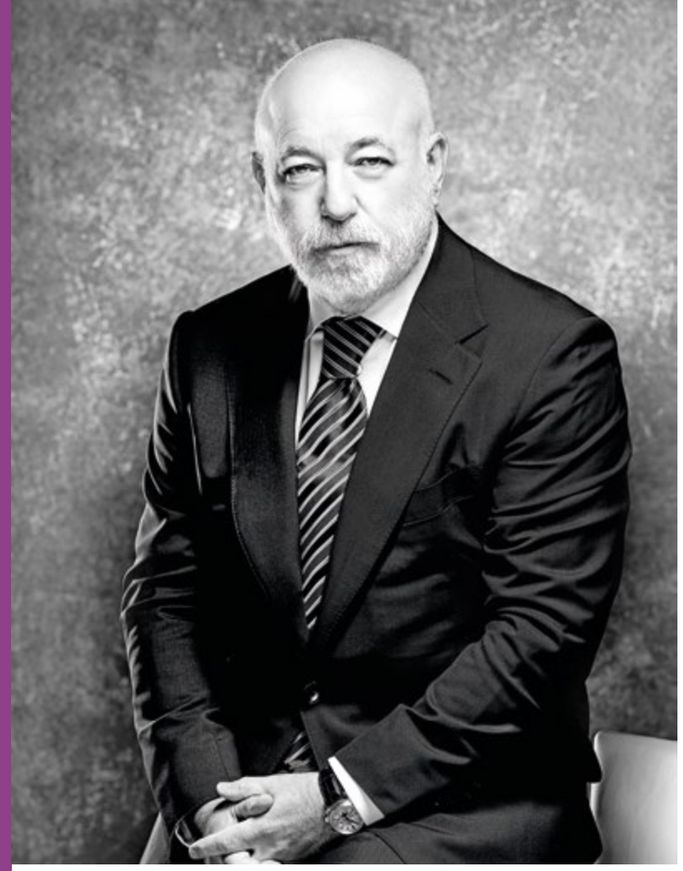
Skoltech is a team of professionals, committed to searching innovative approaches, which nowadays become more important than ever.

The Institute continues to provide Russia with high-level specialists in the most demanded areas. I am sure that in the new conditions Skoltech will pay a significant role, acting as advanced science and technology task force of the whole system of the organizations of development in VEB.RF Group.

**Igor Shuvalov,**
**Chairman of VEB.RF**

# Message from the Chairman of the Board of Trustees

**Today, Skoltech is not only a bridge between science and the market, but an institution with a coherent R&D program implemented through a large portfolio of applied projects and backed up by an extensive industrial network and technology solutions that have already found demand with the industry.**



I have always believed Skoltech to be the cornerstone of the Skolkovo Innovation Ecosystem that aims to bridge the gap between fundamental science and commercialization of technologies with a view to bringing up a new generation of scientific entrepreneurs. Today, in 2023, Skoltech is not only a bridge between science and the market, but an institution with a coherent R&D program implemented through a large portfolio of applied projects and backed up by an extensive industrial network and technology solutions that have already found demand with the industry. The Skoltech community has become a cradle of active entrepreneurs who breathe life into technology startups in Skolkovo and beyond.

The year 2022 was the year of unprecedented challenges and uncertainties. Yet, Skoltech demonstrated resilience of its model, commitment to the strategy and expectations of its stakeholders, with excellent performance visible not only through quantitative indices but rather through the continuous breakthroughs in research and technologies. We have taken all necessary decisions to retain our core academic staff, align our technology agenda to the changing needs of the national economy, and revise our international strategy.

The turning point for us in 2022 was the termination of Skoltech-MIT partnership. I am personally very grateful to Prof. Rafael Reif for our mutually beneficial collaboration through all these years, back from when Skoltech was merely a concept laid down in a pdf presentation until Skoltech's recognition as one of the world's top young universities.

Today, Skoltech is a globally recognized brand in science, technology, engineering, and innovations. We are well integrated in the international university community and we are committed to further development of our collaboration with leading universities all over the world. We play an integral role on the international scientific and technology arena.

In 2023, we will definitely continue to face uncertainties. Yet, on the other hand, there are new great opportunities ahead, and Skoltech has a proper strategy and a dedicated team in place to take full advantage of these opportunities and deliver excellent results.

**Viktor Vekselberg,**
**Chairman of the Board of Trustees**

# Message from the President

**We did not change our foundation principle: Targeting Excellence Today to Impact Tomorrow. Numerous examples of excellence in research and technology development, teaching and learning, creating IP and startups, demonstrate that Skoltech vision, model and strategy are working.**

The year was undoubtedly one of the most challenging in my whole Presidency. We faced challenges we could not forecast – a rapidly increasing international isolation, symbolic termination of multi-year collaboration with Skoltech founding partner, MIT, unprovoked SDN sanctions, leaves in the academic leadership and resignations in the Board, cancellations of R&D projects. Even routine finance and procurement operations became a quest.

Today, we look back to 2022 as a successful year and it is my honour to present the Annual Report. We managed not only to achieve KPIs, but, what is more important, we did not change our foundation principle: Targeting Excellence Today to Impact Tomorrow. Numerous examples of excellence in research and technology development, teaching and learning, creating IP and startups, demonstrate that Skoltech vision, model and strategy are working.

How was it possible to achieve such results in 2022? First and foremost, these are our talented and professional people, motivation and commitment to what we are doing – for our students, partners, our country and the world. I would like to thank every member of Skoltech community for making it possible.

Our aspiration to excellence is embedded into academic culture and core frameworks, starting from faculty appointment and promotion. Let me remember our esteemed colleague, Prof. Igor Krichever, passed away recently. This is the incredible loss for Skoltech and far beyond – the international community of mathematicians. Chairing the Appointment, Promotion and Tenure Committee for more than five years, Prof. Krichever brought the highest standards to the core policies. In memory of the outstanding contribution, the Center for Advanced Studies was awarded with Prof. Krichever's name.

We entered 2023 with a firm commitment to the vision – to be one of the best science and technology universities in Russia and the world, committed to excellence. And we will succeed.

**Alexander Kuleshov,**
**President**

# About Skoltech

# Purpose

## Our Mission – Why we are

Skoltech facilitates economic and societal development by academic and technology excellence and entrepreneurial spirit.

## Our Vision – What are our aspirations

Skoltech was founded as a new model international graduate university with the vision to be one of the best science and technology universities in Russia and the world, renowned for excellence and impact. This vision is grounded on a fusion of aspirations.

Skoltech pursues research in advanced areas of crucial importance for Russia and the world, being committed to excellence in results. The organizational model supports both curiosity-driven and problem-driven research that brings novelty and impact to society. This allows to be dynamic and responsive to changing environment.

Skoltech distinguishing feature is Entrepreneurship and Innovation. Born as a Triple Helix university, Skoltech weaves innovation into research and education, supporting entrepreneurial problem solvers to explore, develop and launch new solutions.

Skoltech has a strong international outlook, attracting students and researchers from abroad, conducting projects with international partners.

Skoltech is a young university built from scratch. Our people are pioneers, passionate about opening new frontiers in everything they do.

# Our standing – Who we are today

Eleven years after foundation, Skoltech is well-positioned in the national and international landscape, staying committed to the mission and vision.

Skoltech operates 15 Centers, encompassing a broad span of topics in Artificial Intelligence and Telecommunications, Life Sciences and Agro, Engineering and Advanced Materials, Energy Efficiency and Energy Transition, Photonics, Advanced Studies. The Centers bring together strong teams to pursue curiosity-driven and problem-driven research.

Skoltech has gained international reputation. For several years in a row, the Institute retains leadership in the prestigious international rankings of Nature Index and Research.com.

Providing high-quality STEM education, Skoltech remains attractive for thousands of applicants from Russia and abroad, enrolling only 3% of talented and ambitious students. The holistic educational model proved its success in training leaders, capable to make difference, think and act globally. Hundreds of Skoltech graduates started careers in top companies and research institutions in Russia and abroad.

Leveraging expertise in technology intense areas, strong connections to industry and government policy makers have been established. Each year, Skoltech conducts hundreds of technology oriented projects. Being a trusted knowledge partner, Skoltech provides expertise for the national level science and technology concepts and roadmaps.

As the intellectual core of the Skolkovo Innovation Center, Skoltech faculty, researchers, students and alumni founded 148 startups, including 85 companies that received a status of Skolkovo residents. Mutually beneficial partnership with Skolkovo Gymnasium is in place: each year faculty and researchers share science advancements with pupils through seminars and workshops.

On top of the research and technology outputs, Skoltech delivers a program for wider community in Moscow and far beyond through open lectures, interviews, masterclasses, and site tours.

Today, Skoltech remains well-positioned to continue a growth path thanks to continuous transformation towards new sustainable models and approaches.

## 2011

Skoltech founded as a private graduate research university with English as a working language

Capacity building agreement signed with MIT

MIT Ford Professor of Engineering, Ed Crawley, appointed as President

## 2012

First faculty hired and a pilot group of MSc students enrolled

First three Centers for Research, Education and Innovation approved by the Board of Trustees

Center for Entrepreneurship and Innovation established

## 2013

Start of campus construction marked with the official ceremony

Long-term strategy supported by stakeholders

First student startup gained Skolkovo residency (Sadko Mobile)

## 2014

Faculty recruitment process transferred from MIT to Skoltech

Educational programs delivered in Biomedicine, Energy, IT, and Space

More than 65% of students involved in startup projects

## 2015

First technology transfer license signed with Quantum Systems

First commencement ceremony held with participation of RF Prime Minister Dmitry Medvedev

## 2016

Prof. Alexander Kuleshov appointed as President

Center for Advanced Studies (Krichever Center today) established

Academic Council and Committees established

## 2017

Laboratories in Oil and Gas, Additive Manufacturing, Photonics, Mass Spectrometry, Energy Storage and other areas opened

The Web of Science Rising Star of Citation Impact Award received

First PhD cohort successfully defended

## 2018

Relocation to the new campus started

Center for Neurobiology and Brain Rehabilitation (Zelman Center today) established

PhD Life Sciences program received international accreditation

## 2019

Skoltech named among top 100 world young universities in Nature Index ranking

Campus, designed by the world-renowned Swiss architects Herzog and de-Meuron, received Prix Versailles Award

## 2020

Number of alumni exceeded one thousand

Skoltech and MTS launched a 5G pilot zone in Skolkovo

Skoltech annual impact on the national economy counted as 20 bln Rub

## 2021

Skoltech 10th anniversary celebrated

Project Centers in technology intense areas established

Strategy 2021 – 2025 launched

## 2022

Year of institutional transformation and adaptation towards new challenges

# Strategy

In 2020, Skoltech mapped out the period of 2021 – 2025 with the Strategy approved by the Board of Trustees and Founders. In the Strategy, Skoltech aspires to have a leading role in the national technology agenda, and become the best STEM university in Russia for talented students of all three levels: bachelors, MSc and PhD.

Everything that Skoltech strives to achieve is underpinned by the core principle: Targeting Excellence Today to Impact Tomorrow. The Strategy cascades the goals through a number of initiatives in three thrusts: Excellence making impact, Educating leaders, and Strategic governance.

As the Strategy is a living document, several updates were introduced in light of the results and plans. The major amendments included changes in research and technology agenda, HR strategic framework, KPI system[1].

In the context of geopolitical challenges 2022, the Strategy remained unchanged. At the same time, adjustments were made on operational levels to find new ways for maintaining core activities.

The comprehensive Strategy revision is planned for 2023 to adapt to the changing circumstances and make the most of opportunities opening up.

The Strategy is available on Skoltech site.

[1] Approved by the Board of Trustees in December 2021.


Skoltech
Science
is here.

# Numbers at a Glance

# 2022

**15**
Centers in advanced areas of science and technology

**No.1**
in Computer Science, Genetics and Molecular Biology

Research.com[2]

**126**
papers in Nature Index journals and A* conferences

Per faculty ratio on par with top young international universities

**1293**
total employees headcount

**1028**
MSc and PhD students

**19%**
international students

**1718**
alumni in 48 countries

**103**
industry partners in R&D projects

**160%**
growth of income from professional education

**2.9**
bln. Rub external funding[3]

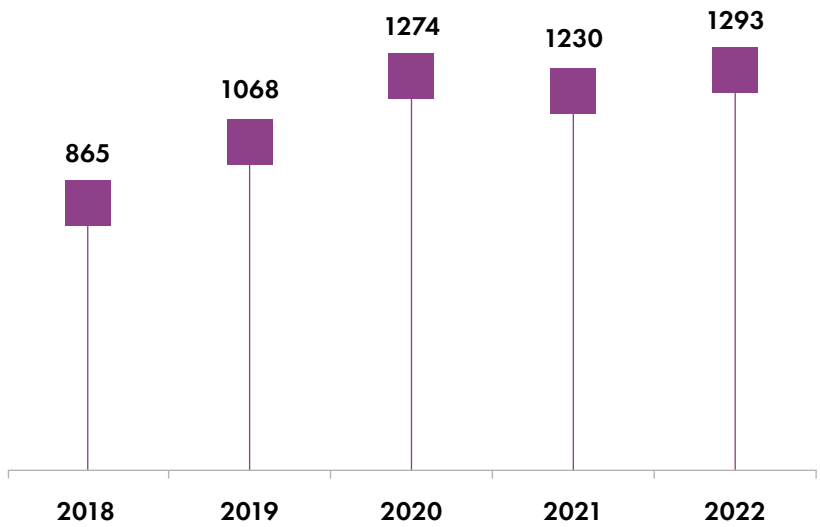
**148**
startups in Skolkovo and beyond

**134 000**
square meters world class campus

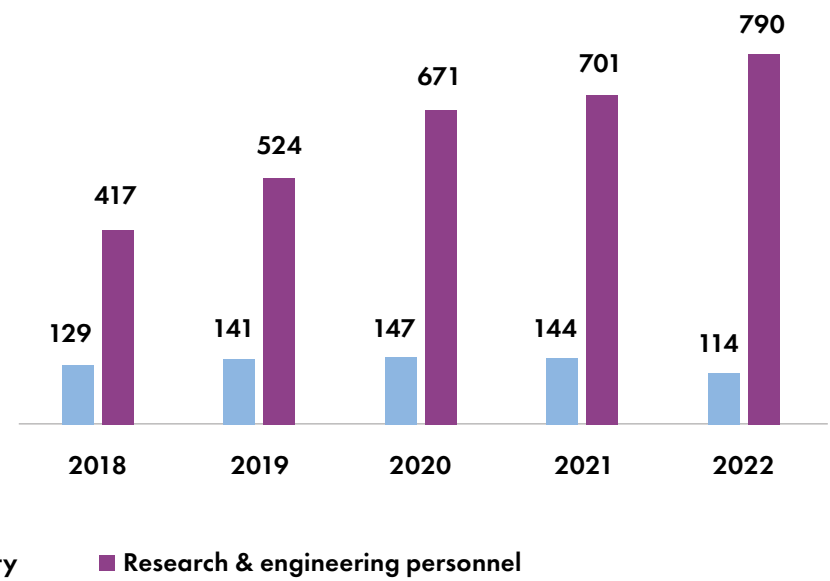
[2] Ranking for Russian universities.
[3] Committed sponsored research funding (R&D contracts, grants), professional education.

# Five Years at a Glance

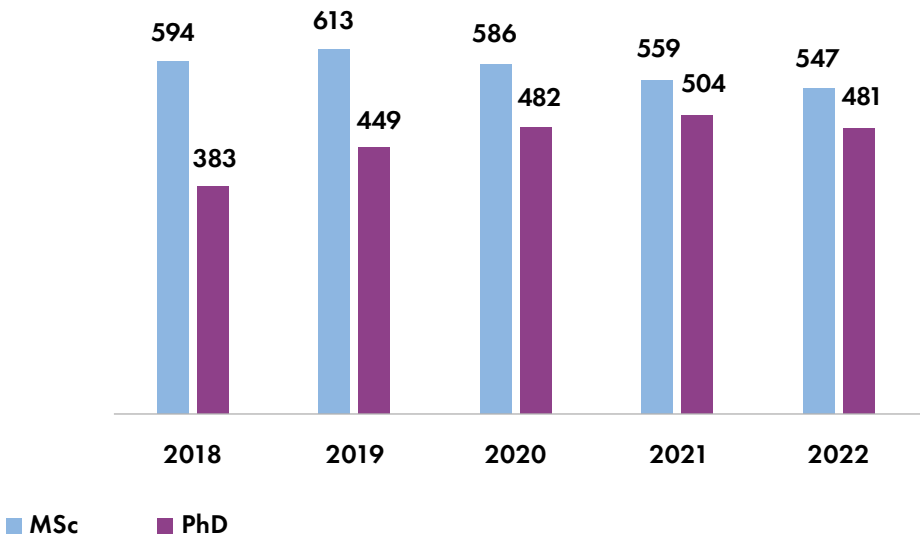
## All personnel



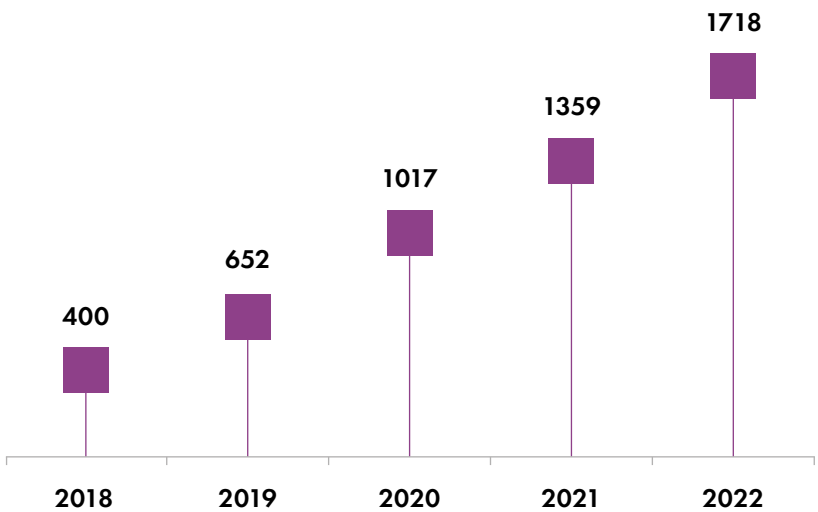

## Academic and engineering personnel



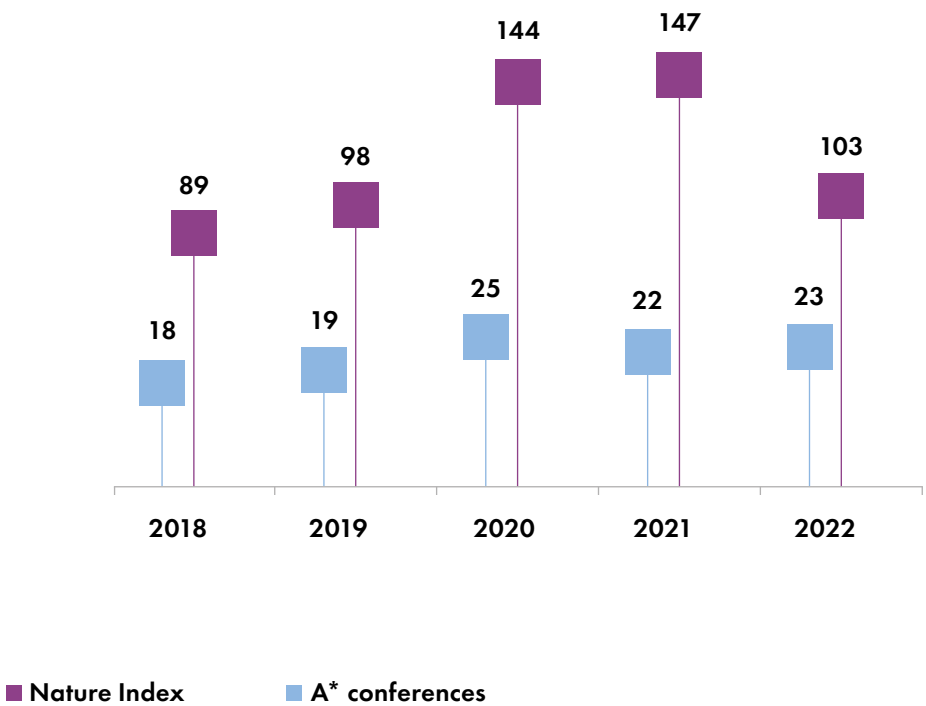
## Student cohort



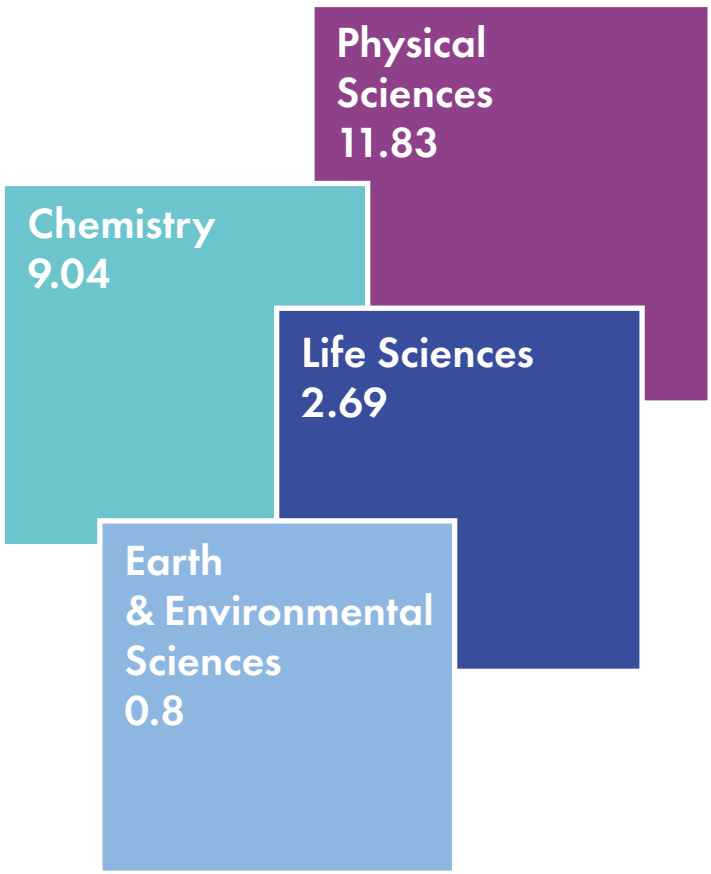

## Alumni (cumulative)



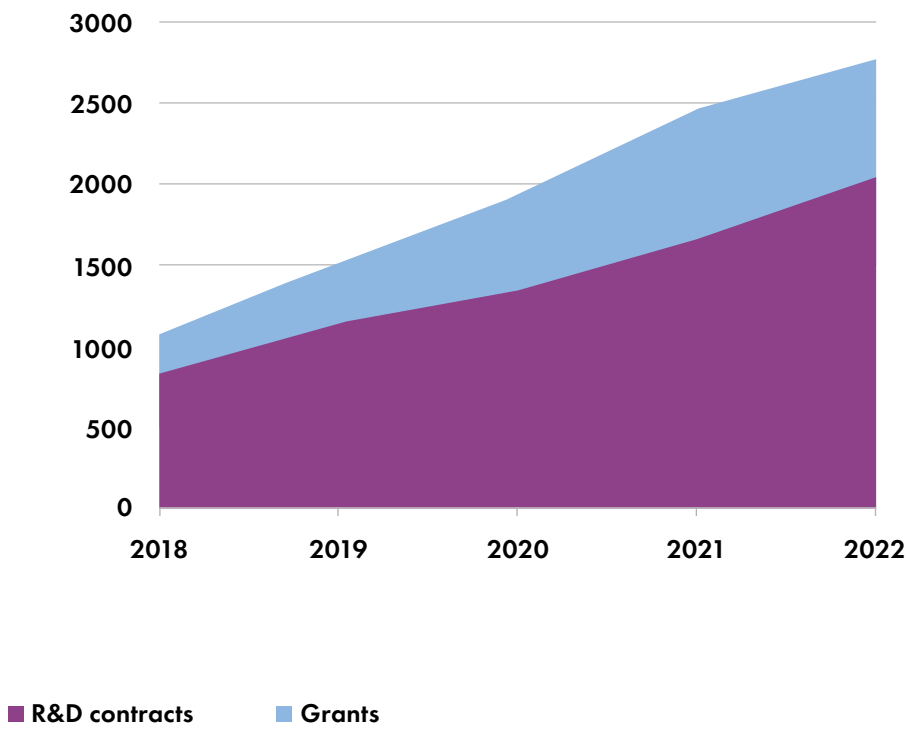
## Publications in Nature Index and A* conferences



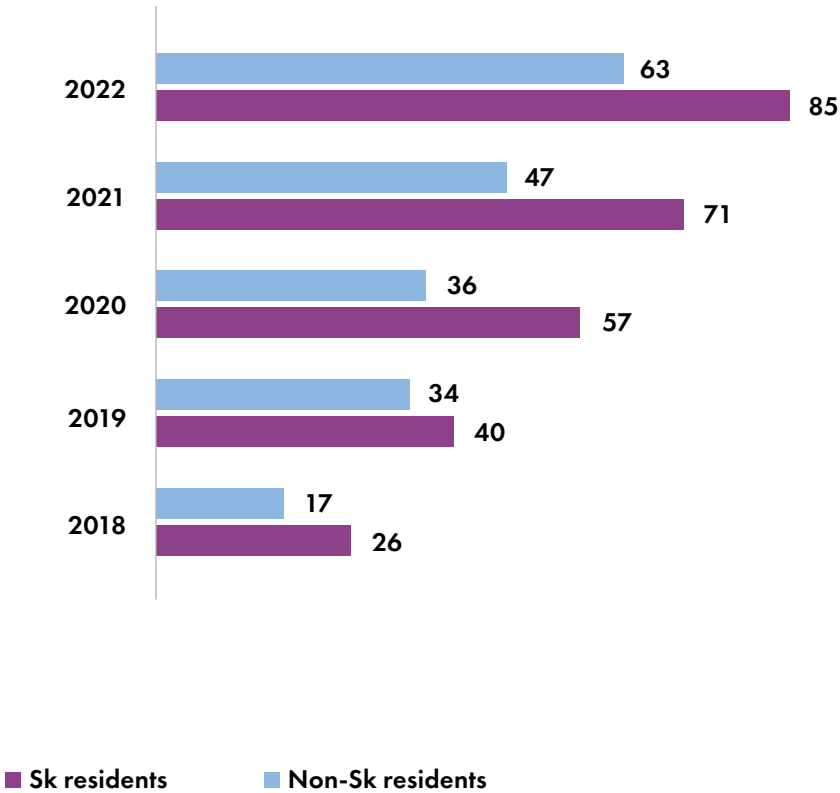
**Share in Nature Index publications (2022)**



## R&D contracts and grants (mln Rub)



## Skoltech associated startups (cumulative)



# Strategy Report

# Message from Senior Vice President for Development

**In times of uncertainties, real strengths become the absolute advantage. Our strength and greatest asset are people, a community of passionate professionals.**

A year of historic changes in the world, the 2022 brought Skoltech a deep sense of unease.

The incredibly turbulent environment made a reality the threats, risks and stress factors which we had imagined – and which we had not – in our Strategy. Instead of well-defined operational plans, Skoltech lived with the emergent strategy, dominated the whole year in Centers and administration.

In times of uncertainties, real strengths become the absolute advantage.

Our strength and greatest asset are people, a community of passionate professionals shaped during the decade – people who joined Skoltech years ago or just recently, those who just started career and those advancing to management positions.

Many of them made a choice to go with Skoltech. In some cases, this was not a simple choice. We value it.

Definitely, the year marked a new page of Skoltech story. In the Report you will read about advancement in many strategic initiatives – made by Skoltech people despite all pessimistic forecasts.
You will see how much our community evolved in addressing the challenges.
The results are remarkable and we are proud of them.

Looking ahead, *Brittle, Anxious, Nonlinear* and *Incomprehensible* will remain the keywords of global and local agenda.

To be adaptive and resilient, and to drive forward, we should be well focused on the meaning of what we pursue. Clear goals and creative approaches at all levels, teamwork in complex tasks, quantity and quality of internal communications to keep eye on the 'big picture' – these will be our priorities.

Let's go forward together.

**Alexander Safonov,**
**Senior Vice President**
**for Development**

# Context

The 2022 was a year when the Annual Report cannot ignore a challenging and unprecedented wider landscape. The big picture in Russia was influenced not only by global trends in the economy, technology and society, but also geopolitical tensions and restrictions.

A high volatility of human capital was observed during the whole year, and the outlook is still vague. HR agenda was dominated with actions to retain and support staff along with efforts to build organizational capacities to foresight, respond, and adapt. Recruitment was quite limited, also in terms of international staff.

The increasing fragmentation in the world cooperation influenced ongoing projects and plans on the governmental level. For example, Russian Science Foundation programs with Belgium, France and Germany were terminated, while new calls for joint research with EU partners were not announced.

Significant changes were observed in the national technology agenda. Federal funding was allocated for projects in areas of high importance for national sovereignty: Artificial Intelligence, Electronics, Advanced Materials, Scientific Instrumentation. Large high-tech companies were forced to revisit investment priorities, highlighting projects with TRL 6-9, to fill needs and gaps in technologies and equipment under sanctions.

The unprecedented loss of communication occurred with international research equipment manufacturers and consumables dealers. Limited access for US, European, Japanese and other equipment and services raised the urgency to search for alternatives to ensure stability of operations.

The educational landscape was characterized by a growing competition for talents, which was specifically strong between national universities and international peers. Various short-term programs, provided by IT companies in Russia and oversees branches, also influenced target audience of tech-oriented talents.

Several trends were observed in professional education segment, being traditionally strong in executive programs. National industry demonstrated a steady demand for engineering education and programs in technology intense areas. The demand is driven by the need to advance skills and knowledge related to new technology trends, and building effective partnerships with academia.

Against this challenging context, Skoltech remained well-positioned and focused, continuing to demonstrate excellent results.

# World Class Research

## Research Excellence

Skoltech goal is to conduct impactful research, attract sponsored research funding, attain leadership positions, exploit beneficial collaborations. This year, the standing as a world-class university was confirmed by a number of results.

It is a pleasure and pride to see Skoltech faculty among top 2% world most influential scientists of the Stanford / Elsevier study which accounts for career-long scholarly impact indicators in the field (citations, h-index, co-authorship).

**Prof. Andrzej Cichocki**

**Prof. Vladimir Drachev**

**Prof. Albert Nasibulin**

**Prof. Evgeny Nikolaev**

**Prof. Artem Oganov**

**Prof. Ivan Oseledets**

**Prof. Vladimir Terzija**

**Prof. Alexander Shapeev**

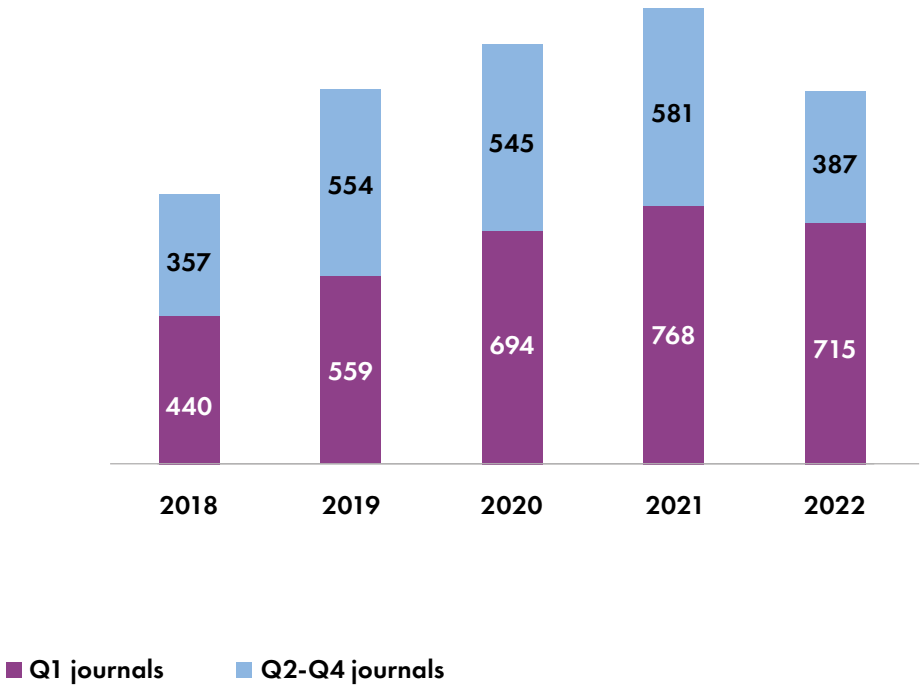
**Prof. Igor Shishkovsky**

**Prof. Keith Stevenson**

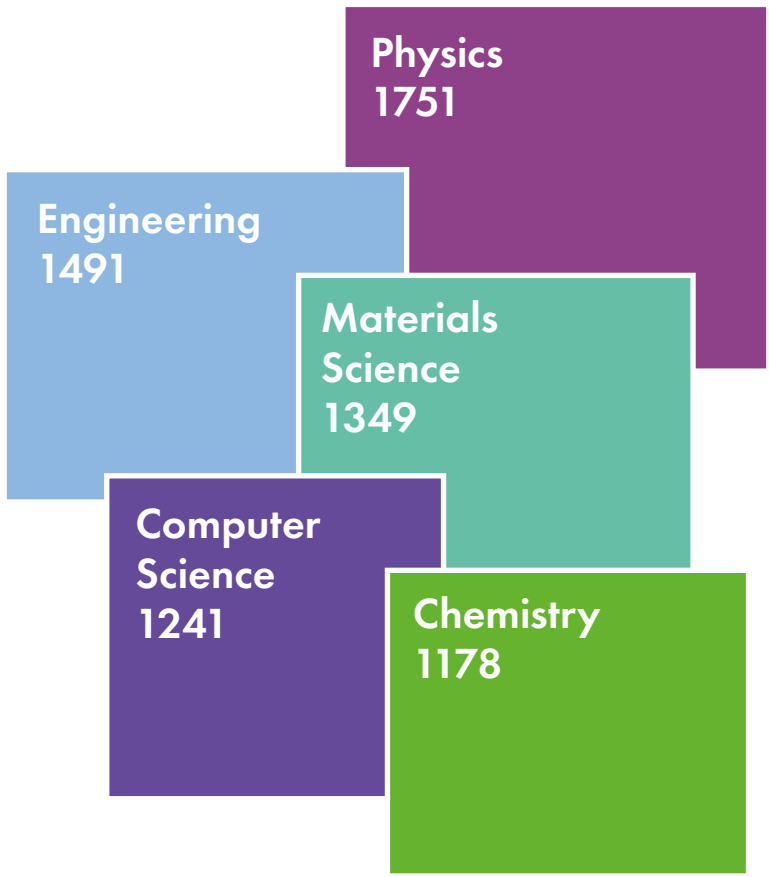
In recognition of research excellence, Prof. Artem Oganov, Prof. Andrzej Cichocki and Prof. Dmitry Chudakov were named as the Highly Cited Researchers by Clarivate. This prestigious award is given for scientists demonstrated significant and broad impact reflected in highly cited papers over the last decade (top 1% by citations for a field / fields).

The quality of Skoltech publication output confirmed excellence across a wide range of disciplines. The total number of papers slightly decreased compared with 2021, however the output metrics related to quality of journals remained. Despite restrictions evidenced in accepting papers to reputable international sources, 65% of papers were published in top-25% journals, while 103 papers appeared in Nature Index journals. 23 papers were presented at the top-level Artificial Intelligence conferences of A* class.

## Annual publication output



## Top fields (papers 2017-2022)




**53%**
papers
in international
collaboration

**1313**
international
partners
in publication output

**>1000**
authors
with Skoltech
affiliation

Data refers to the output 2022.

## International Rankings

While international rankings are not viewed as a comprehensive reflection of results, they remain one of indicators of how the Institute is perceived externally.

In 2022, Skoltech performed excellently continuing to retain leadership. The Research.com named Skoltech No.1 university in Russia in Computer Science, and Genetics and Molecular Biology, and No. 2 among all Russian universities after Lomonosov Moscow State University. The ranking does not account for universities size.

Considerable progress was made in the Academic Ranking of World Universities (ARWU), where Skoltech improved the position in Biological Sciences and entered the group of "201-300".

The position in QS ranking for Petroleum was maintained as in 2021 (101-150).

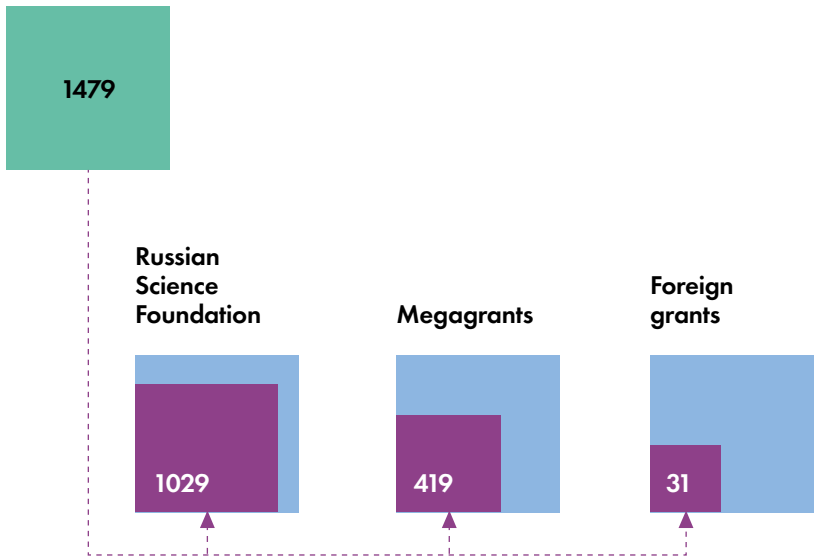
In the Nature Index Annual Institute's tables Skoltech appeared among top-5 universities in Russia in Life Sciences, Chemistry, Physics, Earth and Environmental Sciences.

## Grant Support

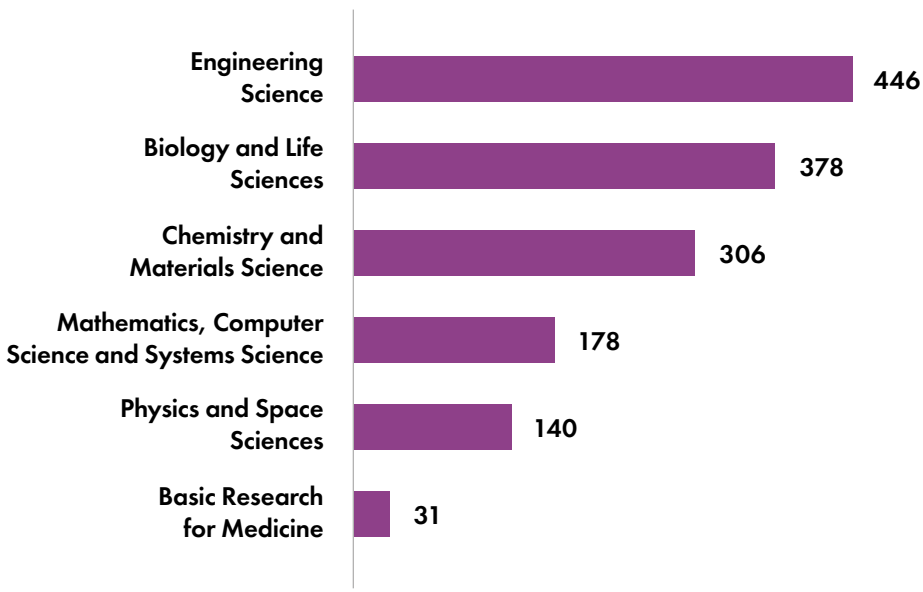
Skoltech continued to be successful in raising sponsored research funding. The total amount of new awards exceeded 500 mln Rub, primarily coming from the Russian Science Foundation (RSF).
The largest shares of awards were received by scientists in Life Sciences (44%), Engineering (19%) and Photonics (13%) Domains. In most cases, Skoltech won grants in the programs "Research groups" and "Young research groups".

The research projects with international partners, including Indian Institute of Technology Kanpur, Helmholtz Centre for Environmental Research, University of Science and Technology of China, INRIA, University of Stuttgart, Delft University of Technology, University of Tartu, University of Basel, Fudan University, were ongoing despite cancellations of several international programs by the RSF.

## Grant funding 2022 – 2025 per sources (mln Rub)




## Grant funding 2022 – 2025 per fields (mln Rub)



## International Agenda

The international agenda was under significant influence of global tensions and sanctions. More than 40 institutional agreements with universities and research centers in USA and Europe were terminated or postponed. Among the key losses is the termination of partnership with MIT, as well as a closure of the program with TUM.

Still, faculty-to-faculty collaboration was ongoing, bringing joint projects, publications, conferences. New opportunities evolved in the regions of BRICS, Asia and Middle East. Thus, negotiations were advanced with Indian partners, including the Council of Scientific and Industrial Research, University of Delhi, SRM Institute of Science and Technology, National Institute of Electronics and Information Technology. Target collaborations with partners in the Middle East and Asia were launched by a few Centers.

In 2023, Skoltech will continue to explore partnerships with China, India, Israel, Brazil. Joint laboratories are planned with the University of Fudan and University of Sharjah.

## Research Facilities

Skoltech research infrastructure is managed by the Research Facilities Center (RFC), responsible for its efficient use and operations. The RFC manages laboratory and research equipment database, access to facilities for the Centers and external clients.

The geopolitical context severely influenced a regular process of purchasing equipment from EU, USA and Japan. Many companies closed service centers and terminated contracts with engineers in Russia, thus significantly limiting capacities for proper and on time equipment maintenance.

To address these challenges, the RFC focused on searching alternative equipment to those no longer available in Russia. A lot of items were discovered in Russia, CIS, China and other countries, further analyzed and configured to Skoltech research needs. For items that were not possible to replace, such as the electron-beam lithography and transmission electron microscopy, equipment access agreements were signed with partners in Russia.

Quality management activities were further continued. In addition to regular inspection controls, the "Introduction to Quality Management System" course for project managers was delivered by the RFC team.

In 2023, the RFC will continue to implement measures to mitigate negative impact of sanctions. Thus, to address the problem of limitations, the special unit (Research Service Facility) will be established to supervise equipment maintenance, purchase of spare parts, installation of equipment.

# National Think-Act Tank

## Advisory Role

With a strong advisory expertise in a wide span of areas related to science and technology agenda, Skoltech continued to support governmental authorities in finding solutions related to strategic level concepts and plans. The expertise was delivered through membership in federal level working groups, expert committees, white books, development of concepts, roadmaps, analytical reviews in Artificial Intelligence, Wireless Technologies and Internet of Things, Quantum Technologies, Energy Transition, Space Systems, Biotechnologies and other fields.

The notable examples of the year include Analytical report on development of electric vehicles transportation in Russia[4], White Paper on analysis of Russia's prospective partners in science and technology (Iran, India, and Bangladesh) prepared by the Analytical Department on Science and Technology, participation in completing the White Book of Russian High Technologies (Annual report of the Government to RF President), preparation of the roadmap for development of a high-tech direction "Promising space systems and services" up to 2030.

A new governmental agenda in science and technology was addressed by contributing to the Federal project "Development of instrumentation for scientific research in civil sector": the concept and economic justification based on original assessment of laboratory analytical instruments market were developed.

The other directions of advising covered defining approaches to ensure Russia's technological sovereignty: analytical materials on breakthrough technologies, the conceptual model of movement towards technological sovereignty under sanctions[5].

Skoltech also participated in drafting a roadmap for development of scientific instrumentation, further considered in the Action Plan ("Roadmap") for development of domestic instrumentation[6].

[4] Available in a hard copy and at the Department's web page https://www.skoltech.ru/en/industry/scientific-industrial-policy-group.
[5] Dezhina, I. G., Ponomarev, A. K. (2022). Approaches to Ensuring Russia's Technological Self-Sufficiency. Science Management: Theory and Practice. Vol. 4, no. 3. P. 53–68. DOI: 10.19181/smtp.2022.4.3.5.
[6] Approved by the Deputy Prime Minister of the Russian Federation on September 14, 2022.

## R&D Programs

Skoltech continued to build collaborations with existing and new industrial partners in the areas of 5G/6G, AI, Electrochemical Materials, Photonics, Oil and Gas, Quantum Communications, Agro and Biotech, Advanced Materials.

Despite the geopolitical context, the highest ever amount of R&D funding was secured, demonstrating a 23% growth comparing with 2021. The other highlights include participation in the national level technology programs and advancement in industry cooperation programs.

To support implementation of the state policy towards national technological sovereignty, Skoltech significantly increased capacities, both in terms of expanding direct cooperation with technological leaders of system-forming sectors of the economy, and in launching large state programs with leading scientific and educational organizations and state authorities. A highlight example is the launch of the Federal project on scientific instrumentation, where Skoltech involvement is led by the Laboratory under Prof. Evgeny Nikolaev chair. The National Technology Initiative Center for Mobile Energy Storage Technologies was established to design solutions in the field of energy sources for electric vehicles, unmanned aerial vehicles, robotics and stationary energy.

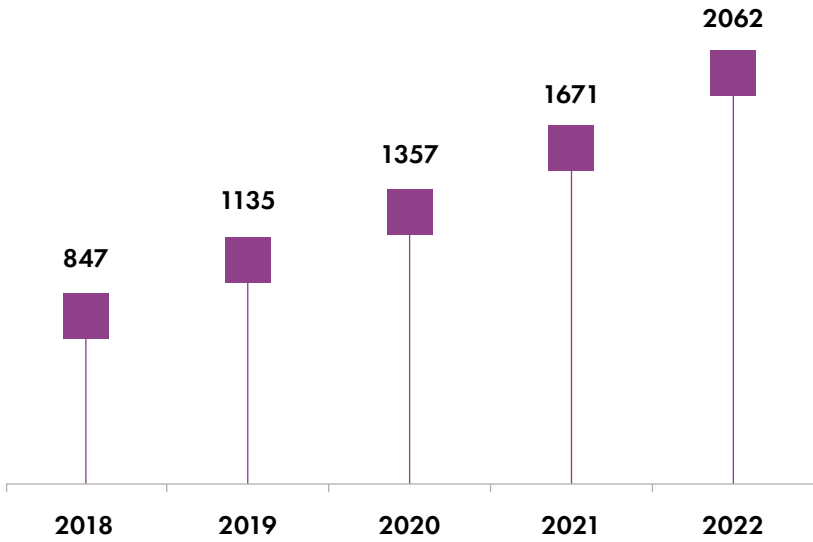
Cooperation with key industrial partners was expanded. Skoltech won the competition "Comprehensive support of scientific and technical projects and initiatives for implementation of the technological strategy 2023 – 2030" in priority areas of Gazprom Neft R&D Center, which is a basis for development and implementation of a medium-term technology program. Also, the first long-term contract for development of quantum algorithms and calculations for exploration tasks was signed with the Gazprom Neft Digital Transformation Directorate.

The agreement on long-term cooperation was signed in the frames of Gazprom Neft University League project. This will allow to significantly expand cooperation with companies and universities participating in the project.

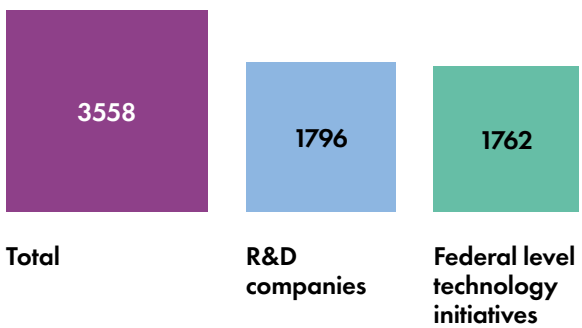
Foundations for launching long-term R&D programs were formed with Rosatom, RusHydro, LUKOIL, Gazpromneft-Zapolyarye, Hevel Group, EVRAZ, Russian Copper Company, Metalloinvest, Power Machines.

Strategic planning seminars were held with Acron Holding resulted in defining areas for joint projects: digital modeling of new chemical compounds for catalysis, AI application for geophysical modelling. Similar seminars were organized with EVRAZ: future cooperation will cover energy storage, development of coatings for structures to increase their durability and equipment elements. Such involvement of top companies makes it possible to continuously update Skoltech technological agenda, and also form a long-term basis for launching and implementing programs in the interests of national industry and state R&D policy.

## Annual R&D funding (mln Rub)




## R&D funding 2022–2025 (mln Rub)




Mass spectrometry is the most sensitive and accurate method of analyzing substances in various aggregate states. During last 30 years, Russia has been satisfying demand for mass spectrometers with characteristics required for critical technologies and research exclusively through import. Within the Ministry for Science and Higher Education program on scientific instrumentation, Skoltech, for the first time in Russia, designed a prototype of the ultra-high-resolution mass spectrometer for analysis of mixtures of volatile compounds. Currently, the testing is carried out to prepare a mass production of the device.

**Prof. Evgeny Nikolaev, Bio Center**

Skoltech Centers are the core units contributing to the Mission and Strategy. Centers' programs focus in research and technology excellence across six Target Domains, defined as long-term priorities.

The organizational model of the Centers support both curiosity-driven and problem-driven research that brings novelty and impact to society. The Centers for Research, Education and Innovation (CREIs) are balanced in all three components, while the Project Centers have been established as task forces for development of technologies that will have significant impact on the national economy.

# Centers' highlights

## Artificial Intelligence & Telecommunications

- **AI Center** — Prof. Oseledets
- **Applied AI Center** — Prof. Burnaev
- **Wireless Center** — Prof. Lakontsev

## Life Sciences & Health, Agro

- **Bio Center** — Prof. Gelfand
- **Neuro Center** — Prof. Khaitovich
- **Agro Center** — Prof. Gentzbittel

## Cutting-edge Engineering, Advanced Materials

- **Engineering Center** — Prof. Podladchikova
- **Petroleum Center** — Prof. Spasennykh
- **Materials Center** — Prof. Sergeichev

## Energy Efficiency & Energy Transition

- **Energy Center** — Prof. Abakumov
- **Energy Transition Center** — Prof. Osiptsov

## Photonics & Quantum Technologies

- **Photonics Center** — Prof. Lagoudakis
- **Physics Center** — Prof. Drachev
- **Applied Photonics Center** — Prof. Dorozhkin

## Advanced Studies

- **Krichever Center** — Prof. Marshakov

■ Project Centers

# AI Center

The Center for Artificial Intelligence Technology was established in 2021 within the Institute's transformation of research and technology agenda. The Center's strategy aims at creation, study and dissemination of AI technologies. The program is organized via laboratory structure, which reflects the core areas of research focus: Computational Intelligence, Tensor Networks & Deep Learning, Mobile Robotics, Natural Language Processing, Intelligent Signal and Image Processing, Multiscale Neurodynamics for Intelligent Systems, Mathematical Foundations of AI, Statistical Machine Learning, AI & Supercomputing, Medical Computer Vision, Quantum Algorithms for Machine Learning and Optimisation, Computational Imaging, AI for Materials Design. The Center is chaired by Prof. Ivan Oseledets.

**103**
faculty
and researchers

**129**
MSc and
PhD students
supervised

**78**
MSc and PhD
graduates

**59**
papers
in Q1 journals.
15 papers in A*
conferences

**360**
Mln Rub
R&D funding
(2022-2025)

**45**
projects
supported
by grants
and industry
funding

Artificial
Intelligence &
Telecommunications

**The other results included:**

- Presented the first data augmentation method based on optimal transport theory, with the generated data being guaranteed to belong to the original data manifold.

- Derived a new strong Gaussian approximation bound for the sum of independent random vectors, which established a new fundamental limit for practical applications of statistical learning theory.

- Developed an approach for synthetic generation of tube-shaped objects in chest X-rays using a generative adversarial network and Frangi-based regularization.

- Proposed a neural network-based regularization term to enhance Autofocusing, a classic optimization-based method to remove rigid motion artifacts in MRI.

- Proposed a new unsupervised approach to detect landmarks in images, validating on the task of human face key-points extraction.

- Developed a new analytic approach to study mini-batch stochastic gradient descent with momentum.

- Developed new deep neural networks and associated learning algorithms supporting biomedical diagnosis and/or performing super-resolution of images.

- Developed a method of machine-learning interaction of spins in iron, which opens possibilities of accelerated modeling of magnetic materials.

- Developed a new method to train tensor networks which are unstable and hard to fine-tune. Our method gains the stability of the tensor network, keep its robust and attain better approximation. The method was applied to compression of well-known CNNs.

- Developed a new data augmentation method applied to training train neural networks for brain computer interfaces.

With regards to overall industry program, it was influenced with SDN sanctions and fruitful collaboration with Philips, Huawei, Samsung and other international leaders were temporarily postponed. Nevertheless, a large number of industrial projects with Huawei successfully completed in 2022 for various topics of AI technology. As for the national companies, the main client Sber increased the portfolio of joint research projects, focusing on robotics and effective deep neural networks training and inference, while the Gazprom Neft started a long-term collaboration on Quantum algorithms and optimization.

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## Top publications

1. T. Yokota, H. Hontani, Q. Zhao and A. Cichocki, "Manifold Modeling in Embedded Space: An Interpretable Alternative to Deep Image Prior," in *IEEE Transactions on Neural Networks and Learning Systems*, vol. 33, no. 3, pp. 1022-1036, published in March 2022, doi: 1 0.1109/TNNLS.2020.3037923. (impact factor > 10) https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9281370 (already cited 20 times)

2. T. Wang, A. Bezerianos, A. Cichocki and J. Li, "Multikernel Capsule Network for Schizophrenia Identification," in *IEEE Transactions on Cybernetics*, vol. 52, no. 6, pp. 4741-4750, June 2022, doi: 10.1109/TCYB.2020.3035282 (IF>11)

3. Sozykin, K., Chertkov, A., Schutski, R., PHAN, A. H., Cichocki, A., & Oseledets, I. TTOpt: A Maximum Volume Quantized Tensor Train-based Optimization and its Application to Reinforcement Learning. In Advances in Neural Information Processing Systems.

4. Pautov, M., Tursynbek, N., Munkhoeva, M., Muravev, N., Petiushko, A., & Oseledets, I. (2022, June). CC-Cert: A probabilistic approach to certify general robustness of neural networks. In Proceedings of the AAAI Conference on Artificial Intelligence (Vol. 36, No. 7, pp. 7975-7983).

5. Bespalov, I., Buzun, N., & Dylov, D. V. (2022). BRULÈ: Barycenter-Regularized Unsupervised Landmark Extraction. Pattern Recognition

6. Talitckii, A., Kovalenko, E., Shcherbak, A., Anikina, A., Bril, E., Zimniakova, O., ... Dylov, D. V. & Somov, A. (2022). Comparative Study of Wearable Sensors, Video, and Handwriting to Detect Parkinson's Disease. IEEE Transactions on Instrumentation and Measurement

7. Towards high photon density for Compton scattering by spectral chirp" M. A. Valialshchikov, D. Seipt, V. Yu. Kharin, and S. G. Rykovanov, Physical Review A, 106, L031501 (2022) (Nature Index)

8. Velikanov, M., Kuznedelev, D., Yarotsky, D. A view of mini-batch SGD via generating functions: conditions of convergence, phase transitions, benefit from negative momenta, to appear in ICLR2023 (Core A*)

9. Kornilova, A., Faizullin, M., Pakulev, K., Sadkov, A., Kukushkin, D., Akhmetyanov, A., ... & Ferrer, G. (2022). Smartportraits: Depth powered handheld smartphone dataset of human portraits for state estimation, reconstruction and synthesis. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (pp. 21318-21329).

10. N. Kotelevskii, A. Artemenkov, K. Fedyanin, F. Noskov, A. Fishkov, A. Shelmanov, A. Vazhentsev, A. Petiushko, M. Panov. Nonparametric Uncertainty Quantification for Single Deterministic Neural Network, Neural Information Processing Systems, NeurIPS (CORE A*), 2022

11. Novikov, I., Grabowski, B., Körmann, F., & Shapeev, A. (2022). Magnetic Moment Tensor Potentials for collinear spin-polarized materials reproduce different magnetic states of bcc Fe. npj Computational Materials, 8(1), 13.

## Educating leaders

The Center implements two MSc educational programs: Data Science (DS) and Advanced Computational Science (ACS) and a PhD Computational and Data Science and Engineering (CDSE) program. Faculty delivered courses on NLA, Computational Imaging, Biomedical Imaging & Analytics, Deep Learning to Natural Language Processing, Introduction to Natural Language Processing, Theoretical Methods of Deep Learning, Scientific Computing, Perception in Robotics, Planning Alg. In AI and Robotic, Tensor Decompositions and Tensor Networks in Artificial Intelligence, Convex optimization and Applications. Among the courses with the highest number of students were Introduction to Data Science (Prof. Panov, 112 students), Deep Learning (Prof. Oseledets, 101 students), High Performance Python Lab (Prof. Rykovanov, 26 students), Scientific Computing (Prof. Yarotsky, 18 students).

Students' success was evidenced in multiple forms: papers, defenses, employment, awards and prizes. Select examples are highlighted below:

- **Assel Yermekova** (AI & Supercomputing lab, supervisor Prof. Rykovanov) won the best diploma award for MSc ACS program for her thesis on using ML in modeling plasma particle accelerators. She also won Skoltech academic mobility grant to visit DESY (Germany).
- **Fedor Noskov** (StatML Lab, supervisor Prof. Panov) – co-authored a CORE A* paper at NeurIPS 2022.
- **Lina Bashaeva** (Artificial Intelligence lab, supervisor

We have built an excellent AI team that has overcome challenges and achieved impressive results in 2022. Our team stands among the best in Russia and globally, with a proven track record of delivering cutting-edge projects, educating AI leaders, and publishing top-notch papers.

**Prof. Ivan Oseledets, Director of the Center**

Prof. Oseledets) co-authored a paper in the BMVC 2022 conference.

- **Nikita Kotelevskii** (PhD-3, supervisor Prof. Panov) – first author of two CORE A* papers at NeurIPS 2022.
- **Valialshchikov Maksim** (PhD-2, supervisor Prof. Rykovanov) – Q1 and Nature Index paper first author.
- **Pautov Mikhail** (PhD-3, supervisor Prof. Oseledets) – first author of Proceedings of the AAAI Conference on AI and first author of CORE A paper at NeurIPS 2022.
- **Illarionova Svetlana** (PhD-3, supervisor Prof. Oseledets – first author of two Q1 papers.
- **Fedotova Polina** (PhD-1, supervisor Prof. Ferrer) – a paper at IEEE 18th International Conference on Automation Science and Engineering (CASE).
- **Velikanov Maksim** (PhD-3, supervisor Prof. Yarotsky) – first author of two A/A* publications (AISTATS2022, ICLR2023)
- **Kuznedelev Denis** (PhD-2, supervisor Prof. Yarotsky) – co-author of two papers accepted for ICLR2023 (A*)
- **Konstantin Sobolev** (PhD-4) and Dmitry Ermilov (PhD-3) – first and 2nd authors of a Q1 paper.

As for the admission campaign 2022, a record amount of applications was received for both MSc programs. All programs kept a high selectivity, enrolling top talented and motivated candidates.

The professional education track included successfully designed and completed new course on "Transformers" for the Sber Corporate University.

## Innovation activities

The Laboratory of Computational Intelligence continued development of the Tensor Fields startup through a variety of lines: Skoltech translational research program, the RSHB startup support program and integration of the product into the platform "Svoyo Fermerstvo", membership in the Accelerator of the Moscow Innovation Cluster, submission of an application for the support program of the Government of the Russian Federation under Resolution 555. The Computational Imaging Lab' 'MedTech AI' startup addressed the challenges of medical image processing and conducted 3 active pilots with Moscow hospitals.

## Think-act tank role

The advisory expertise of the Center was delivered on a number of national level projects or initiatives, including Federal Program for AI centers creation (key expertise on Green AI topics), Moscow Region AI transformation together with Sber. Prof. Oseledets is a member of Scientific Council under the President of the Russian Federation, in 2022 appointed as Head of the Expert Council of the Institute of AI of Moscow State University.

## International collaborations

Despite the global tensions, the Center participated in top international conferences: NeurIPS, CVPR, IJCAI, MICCAI, EMNLP, ACL. Faculty were invited for PhD defenses in foreign universities, served as reviewers and editors of reputable journals, chairs in ICLR, NeurIPS, ICML, ACL etc. Joint grant proposals with top universities in China were prepared within RDF and Ministry for Science and Higher Education grant programs, valuable outcomes are expected in the near future.

## Professional and wider community engagement

Faculty gave talks and participated in numerous outreach events and brand promotion activities in media. The highlight examples are the AI Journey Conference, organized by Sber, where Prof. Panchenko and Prof. Shapeev were keynote speakers, while Prof. Oseledets was one of the members of discussion with Sber CEO German Gref and President of Russia Vladimir Putin. Several faculty (Prof. Rykovanov, Prof. Oseledets) participated in the Young Scientist Congress in Sochi discussing various applications of AI.


AIJ


Center of AI Technology Conference

# Applied AI Center

The Center was established in 2021 under the Federal Program "Digital Economy of the Russian Federation" (direction Artificial Intelligence). The main focus of research and technology agenda lies in creation and development of applied interpretable technologies and methods of AI and Machine Learning, creation of a software platform for solving urgent large-scale problems identified by national level strategies related to AI and Energy, including problems of multi-scale monitoring, control of climate related and environmental risks (ESG), optimization of management decisions to reduce carbon footprint, analysis and optimization of industrial processes, logistics, etc.
The Center is chaired by Prof. Evgeny Burnaev.

**5**
faculty

**>120**
Researchers and engineers

**98**
MSc and PhD students supervised

**26**
MSc and PhD graduates

**57**
papers, including 34 in Q1 journals, and 9 papers in A* conferences

**1,4**
Bln Rub sponsored research funding 2022 – 2024

**5**
applications for registration of exclusive rights to inventions

**3**
frameworks for AI developed

Artificial Intelligence & Telecommunications

## R&D highlights

The Center continued the program ramped up in 2021, achieving a number of R&D results:

- fundamental research in the field of Artificial Intelligence/ Machine Learning/Data Science, including Physics-Informed Machine Learning, Graph Machine Learning, Large-Scale Generative Modeling, Structural Data Statistics, Probabilistic Inference and Bayesian Neural Networks;
- creation of novel AI-based technologies and methods for Data Fusion with application to analysis Multimodal Remote Sensing and Biomedical data with implementation in the form of software libraries and frameworks;
- creation of novel methods in the field of Topological Data Analysis, Manifold Learning, Optimal Transport;
- creation of novel methods for 3D shape modeling, reconstruction and visualization;
- development of novel AI-methods and models for processing and analysis multimodal biomedical data (including neuroimaging and omics data) with further implementation in the form of AI-based software tools for clinical decision support systems;
- development of AI-powered Software Platform consisting of libraries and frameworks intended for solution to various applied problems such as fusion of Earth remote sensing data and instrumental measurements data for assessing the carbon balance of territories; for computational modeling of transport processes, physical and financial risks posed by climate change, modeling of ice conditions and other natural processes associated with oil production.

Select results were secured with IP:

- Patent "Method of determining the ultimate owners of companies by ownership data." The application submitted to the Federal Institute of Industrial Property and the Eurasian Patent Organization.
- Patent application "Method for predicting the spread of wildfires using data from remote sensing of the earth and neural networks" (submitted to Federal Institute of Industrial Property and the Eurasian Patent Organization).
- Registration of the computer program "Program for identifying the ultimate owners of companies by ownership data".
- Registration of the computer program "The EPIDETECT data processing program. Version 1.0"
- Registration of the computer program "The EPIDETECT data visualization program. Version 1.0"

## Think-act tank role

The Center is an active player in defining national level concepts in the field of AI, being a member of working groups, e.g. AI working group of the Digital Economy national program.

The developed methods and algorithms are used as a basis for creation of AI tools to address applied problems in science and technology sector. Thus, the AI software tools created in the Center were implemented in applied projects of key industry players:

- formation of a new direction of financial monitoring with due account of ESG risks when lending to industrial enterprises (for Sber),
- enhancing efficiency of analysis of corporate information through use of methods for training speed up and compressing large neural models (for Sber),
- development of a self-learning model of an oil and gas-bearing formation (for Gazprom Neft),
- development of a system for Arctic ice situation prediction (for Gazprom Neft),
- improving efficiency, reliability and scaling of an air quality monitoring systems (for CityAir),
- projects on OMICs data analysis for Moscow Department of Health with Skoltech Laboratory of Omics technologies.

The Center's objective is to address significant applied industry problems, including sustainable development, by leveraging the outcomes of fundamental AI research. In 2022, the Center achieved noteworthy progress in AI, specifically in optimal transport, manifold modeling, generative modeling, and 3D computer vision. These advancements were incorporated into mathematical algorithms and software products, leading to the development of new platform solutions that are currently utilized by major industrial corporations. The importance of the scientific outcomes and products generated by the Center is supported by grant funding from both Russian and foreign scientific foundations, as well as significant financing from industrial partners.

**Prof. Evgeny Burnaev, Director of the Center**

## Top publications

The following examples illustrate the scope and impact of the Center's research.

### A* conferences


1. Albert Matveev, Alexey Artemov, Ruslan Rakhimov, Gleb Bobrovskikh, Daniele Panozzo, Denis Zorin, Evgeny Burnaev. DEF: Deep Estimation of Sharp Geometric Features in 3D Shapes. ACM Transactions on Graphics (TOG), Siggraph, 2022.

2. Litu Rout, Alexander Korotin, Evgeny Burnaev. Generative Modeling with Optimal Transport Maps. ICLR, 2022.

3. Ruslan Rakhimov, Andrei-Timotei Ardelean, Victor Lempitsky, Evgeny Burnaev. NPBG++: Accelerating Neural Point-Based Graphics. CVPR, 2022.

4. Serguei Barannikov, Ilya Trofimov, Nikita Balabin, Evgeny Burnaev. Representation Topology Divergence: A Method for Comparing Neural Network Representations. ICML, 2022.

5. Evgenia Romanenkova, Alexander Stepikin, Matvey Morozov, and Alexey Zaytsev. 2022. InDiD: Instant Disorder Detection via a Principled Neural Network. In Proceedings of the 30th ACM International Conference on Multimedia (MM '22). Association for Computing Machinery, New York, NY, USA, 3152–3162. https://doi.org/10.1145/3503161.3548182.

6. Alexander Korotin, Vage Egiazarian, Lingxiao Li, Evgeny Burnaev. Wasserstein Iterative Networks for Barycenter Estimation. Neurips, 2022.


### Q1 Journals


1. Arsalidou, M., Skuratov, N., Khalezov, E., Bernstein, A., Burnaev, E., Sharaev, M., 2022. Effects of age, gender, and hemisphere on cerebrovascular hemodynamics in children and young adults: Developmental scores and machine learning classifiers. PLoS ONE 17, e0263106.

2. Bachurina, V., Sushchinskaya, S., Sharaev, M., Burnaev, E., Arsalidou, M., 2022. A machine learning investigation of factors that contribute to predicting cognitive performance: Difficulty level, reaction time and eye-movements. Decision Support Systems 113713.

3. Y. Shen, Z. Du, H. Fu, X. Chen, E. Burnaev, D. Zorin, K. Zhou, Y. Zheng. GCNDenoiser: Feature-preserving Mesh Denoising with Graph Neural Networks. ACM Transactions on Graphics (TOG) 41(1), 1-14, ACM, 2022/2/10.

4. N. Klyuchnikov, E. Artemova, M. Fedorov, I. Trofimov, M. Salnikov,

E. Burnaev. NAS-Bench-NLP: Neural Architecture Search Benchmark for Natural Language Processing. IEEE Access, 2022.

5. Timofey Grigoryev, Polina Verezemskaya, Mikhail Krinitskiy, Nikita Anikin, Alexander Gavrikov, Ilya Trofimov, Nikita Balabin, Aleksei Shpilman, Andrei Eremchenko, Sergey Gulev, Evgeny Burnaev, Vladimir Vanovskiy. Data-Driven Short-Term Daily Operational Sea Ice Regional Forecasting. Remote Sens., 14(22), 2022.

6. Kalinov, A., Osinsky, A., Matveev, S.A., Otieno, W., Brilliantov, N.V. Direct simulation Monte Carlo for new regimes in aggregation-fragmentation kinetics. Journal of Computational Physics. Том 467, 111439, 2022.

## Educating leaders

The Center is involved in delivery of MSc and PhD programs in AI & Telecommunications Target Domain, supervising students and involving them into applied research projects. Most notable success of the year was the Yandex Ilya Segalovich Award to PhD students Ruslan Rakhimov and Petr Mokrov.
Graduates 2022 demonstrated high competitiveness and started career in top companies (Sber, Yandex, Samsung, VK, Tinkoff etc.). Many decided to continue with the Center on junior research positions.

## Professional education

In addition to MSc and PhD programs, the Center delivers professional education. The "Introduction to Sequential Data Models" helped to improve competencies of technical specialists and project managers in analyzing time series of discrete events with use of Python, as well as applying machine learning methods to create predictive and generative models of event sequences.

The "Event Sequence Models" course immersed participants in discrete event time series with the use of Python, and application of machine learning methods to create predictive and generative models of event sequences. The Center also delivered select courses: "Sustainable development of the fuel and energy sector", a number of courses through the Moscow Technical School, which is a network of technological and industrial competence centers based on scientific and educational organizations in Moscow.

## International network

International visibility was ensured via attendance of key AI conferences, workshops and forums. Some examples:

Ruslan Rakhimov, Andrei-Timotei Ardelean, Victor Lempitsky, Evgeny Burnaev / NPBG++: Accelerating Neural Point-Based Graphics // **CVPR 2022**

Litu Rout, Alexander Korotin, Evgeny Burnaev / Generative Modeling with Optimal Transport Maps // **ICLR 2022**

Albert Matveev, Alexey Artemov, Ruslan Rakhimov, Gleb Bobrovskikh, Daniele Panozzo, Denis Zorin, Evgeny Burnaev. DEF: Deep Estimation of Sharp Geometric Features in 3D Shapes. ACM Transactions on Graphics (TOG), **Siggraph, 2022**

Alexander Korotin, Alexander Kolesov, Evgeny Burnaev. Kantorovich Strikes Back! Wasserstein GANs are not Optimal Transport? Neurips, 2022
Invited panel talks on **ICMV-2022, BICA-2022, CBAI-2022 conferences**.

At the 2022 Conference on Empirical Methods in Natural Language Processing (EMNLP 2022) Prof. Evgeny Burnaev presented a paper "Acceptability Judgements via Examining the Topology of Attention Maps". At Abu Dhabi AI Connect 2022, Prof. Evgeny Burnaev and Maxim Sharaev took part in Demo session with AI-based EpiDetect software prototype. Several networking meetings resulted in preliminary agreements on cooperation with Khalifa University, Qatar University, KAUST, Astana University.

## Professional and wider community engagement

The Center was visible in multiple conferences, workshops and summits. Some notable examples include X Anniversary Technology Conference (Startup Village 2022) and participation in the session "Useful Data. Unite, Analyze and Conquer" on trends that will define development of Data Science in Russia.

At the AI Journey, the largest online platform for discussing AI and ML technologies, Prof. Evgeny Burnaev and Saveliy Galochkin, jointly with Tatyana Saracheva, Head of the branch of the State Historical Museum "Pokrovsk (St. Basil's) Cathedral", presented a promising project on St. Basil's Cathedral: 3D computer vision for digital preservation of cultural heritage.

Talks were given at Computer Vision and Machine Learning Summit "Machines Can See" organized by VisionLabs, Summer School on Machine Learning in Bioinformatics organized by the HSE Faculty of Computer Science, AIRI Conference on AI at Sirius as well as large industry conference, including TNF Industry and Energy Forum, Conference on Digital Technologies in Hydrocarbon Production: Digital Transparency.

291 поле, 18 мая 2021г

335 полей, 16 августа 2021г


# Wireless Center

The Wireless Project Center was established in 2021 based on the merge of the 5G Center and IoT Center. The Center aims to strengthen Skoltech technology competencies in Wireless and IoT Technologies, to position the Institute as the intellectual and technological leader in national telecommunication and IT industries. The Center's strategy is organized in core areas: 5G development, 6G Research and Development, and Wireless technology perspective studies. The Center is chaired by Prof. Dmitry Lakontsev.

**103**
faculty, researchers and engineers

**23**
MSc and PhD students supervised

**13**
MSc and PhD graduates

**399**
Mln Rub sponsored research funding 2022-2024

**10**
R&D projects with Center's leading role

**7**
5G technologies delivered to industry (TRL 7)

Artificial Intelligence & Telecommunications

## R&D highlights

### 5G Development

The first pre-commercial version of 4G/5G base station with Open RAN architecture (TRL 7) was designed and tested in Skoltech pilot zone. The pre-commercial version of the complex solution for private 4G/5G networks with a base station and Non-Standalone core functionality (TRL 7) was tested both in Skoltech pilot zone and several companies. More than 10 partner tests were conducted with Mikran, IPG Photonics, T8, FSUE "Space communications" (GP KS), and other companies. The Center also successfully deployed 5G private network based on 5G base station and Core network software in NLMK Group. New contracts were secured, among the largest is the one with RZD ("Hardware and software system for secure data transmission in 4G/5G mobile networks using quantum key distribution technologies").

### 6G Research and Development

The applied research was conducted for high mm Waves/THz transceiver prototype architecture, detailed technical requirements generation and technology proposals for the transceiver elements (TRL 3) and 6G Intelligence architecture, detailed technical requirements generation, and technology proposals for technology elements (TRL 3).

### Wireless technology perspective research

resulted in AI-based algorithms for signal detection and decoding. Commercialization and licensing of solutions for building 5G private networks and the development of OpenRAN ecosystem were made. The IP portfolio reached 50 IP objects, including 14 developed in 2022. The patents were issued for RU module of base station and submitted for 6G transceiver. Software IP covered protocol stack programs, as well as system software of the transceiver module (RU).

Progress was also made in other topics:

### ViNR (Video over New Radio)

The ViNR technology was implemented, enabling high-resolution video calls without third-party applications. The service is provided in Skoltech 5G pilot zone. ViNR is one of the key 5G services alongside VoNR (Voice over New Radio), supports HD video communications and operates only in 5G standalone networks, such as the one deployed in 5G Skoltech pilot zone. Unlike conventional video applications (Skype, WhatsApp, etc.), ViNR does not require any add-ons on a user device.

### 4G/5G hardware and software

At the Microelectronics 2022 forum (Sochi, October 2-8, 2022), Wireless Center demonstrated an operating base station and a private 5G OpenRAN network. The solution runs on domestic software and hardware. The centralized unit (CU), the distributed unit (DU) and the network core are deployed on specialized servers of the national company Aquarius. At the same time, the solution can be run on any equipment available on the market. The transceiver (RU) was developed by Skoltech and manufactured by Eltex.

### 5G satellite connection

A 5G base station was connected to the network core via a satellite link. The Russian Satellite Communication Company and the Center tested a private 5G network running on Skoltech software and connected to a geostationary communications satellite. This is the first time that a Russian satellite was used for a 5G project. In future, the solution will help provide 5G services to users in remote areas.
The private OpenRAN 5G network solution was developed by Skoltech. The base station was connected to the network core via Express-80 using RSCC's facilities at Shabolovka Technical Center and Dubna Satellite Communications Center.

The tests that included transmission and playback of high quality 4K HDR, HLG and Dolby Vision video via the 5G network demonstrated the required service quality during the transmission of multimedia, voice and video via subscriber devices. This scenario will enable deploying private 5G networks in remote areas lacking connections to backbone networks, with a possibility to remotely connect base stations within the satellite footprint to the network core via RSCC's geostationary satellites.

### 5G drones

The test flights in the urban air mobility zone at Skolkovo involved a drone that carried a 5G data transmission and reception system which in the future will be part of the 5G-based digital airspace for drones. The tests included transmission of video and drone payload data streams over the 5G mobile network, with the drone's coordinates tracked using the network data. Besides that, the topological and altitude characteristics of the airspace with continuous 5G connectivity were recorded. The resulting multialtitude network coverage map will be a useful aid for further research. The tests confirmed that using 5G networks to support drones and the digital airspace opens up vast prospects for the development of domestic innovative products.

## Think-act tank role

The Center is the active contributor to the national agenda in 5G and IoT fields. One of the notable result of the year is the Center's core role in development of the roadmap "Modern and future mobile networks" up to 2030 where Skoltech is becoming one of the key executors. The Center was also involved in completing the White Book of Russian High Technologies, which is the annual report of the Government to the RF President.

The Center is represented in key professional associations, such as "Telecommunication Technologies", Association of Organizations for Development of Open Communication Networks "Open Network Technologies", Associations of Internet of Things Market Participants, as well as expert groups of the Ministry of Digital Development, Communications and Mass Media, Ministry of Industry and Trade, FSUE NIIR and other advisory bodies. Prof. Dmitry Lakontsev is a member of the Interdepartmental Expert Council under the Ministry of Industry and Trade that assigns the status to telecommunications equipment of developed and manufactured in Russia.

Advancements were made on the OpenRAN standards. Technical Committee 194 "Cyber-Physical Systems" submitted for public discussion the final document of main series of preliminary national standards for 4G/5G networks with an open architecture. Their adoption lays the foundation for the rapid development of the ecosystem of modern telecommunications equipment by national companies.

A preliminary national standard "Information Technologies. Open radio access network interfaces: E2 interface» is necessary for the full implementation of virtualization, automation and self-organization technologies in 4G/5G networks. The document describes the signaling protocol specification for the E2 interface, which links the base station elements (BBU, CU, DU) to the 5G/4G OpenRAN intelligent radio access network controller.

At the Federation Council exhibition, Skoltech presented its newest innovation: a 5G base station. This station is deployed in our 5G campus pilot zone. Our team is focusing on aiding in the replacement of 200,000 LTE base stations throughout Russia in the next five years. By June, or even earlier, samples of our cutting-edge LTE/5G platform should be ready for field tests. Working with renowned telecom operators and manufacturers in Russia, Skoltech has established itself as an industry leader in mobile technology over the past three years.

**Prof. Dmitry Lakontsev, Director of the Center**

## Top publications

The following publications illustrate the scope and impact of the Center's research outputs in 2022.

1. K. Andreev, P. Rybin and A. Frolov. Coded Compressed Sensing with List Recoverable Codes for the Unsourced Random Access. // IEEE Transactions on Communications. 2022, 70:12, pp. 7886-7898. DOI: 10.1109/TCOMM.2022.3216901.(Q1, IF 6.166)

2. J. Park, T. Kim, G.W. Kim, V. Bessonov, A. Telegin , I.G. Iliushin , A.A. Pervishko, D. Yudin, A. Yu. Samardak, A.V. Ognev, A.S. Samardak, J. Cho, Y. K. Kim. Compositional gradient induced enhancement of Dzyaloshinskii–Moriya interaction in Pt/Co/Ta heterostructures modulated by Pt–Co alloy intralayers. // Acta Materialia 241, 118383 (2022). DOI:10.1016/j.actamat.2022.118383. (Q1, IF: 9.209).

3. G. Paradezhenko, A. Pervishko, N. Swain, P. Sengupta, and D. Yudin. Spin-hedgehog-derived electromagnetic effects in itinerant magnets. // Physical Chemistry Chemical Physics 24, 24317 (2022). DOI:10.1039/D2CP03486G. (Q1, IF 3.945)

4. A.S. Kardashin, A.V. Vlasova, A.A. Pervishko, D. Yudin, and J. D. Biamonte. Quantum-machine-learning channel discrimination. // Physical Review A 106, 032409 (2022). DOI:10.1103/PhysRevA.106.032409. (Q1, IF 3.14)

5. A.S. Samardak, A.V. Ognev, A.G. Kolesnikov, M.E. Stebliy, V.Yu. Samardak, I.G. Iliushin, A.A. Pervishko, D. Yudin, M. Platunov, T. Ono, F. Wilhelm, and A. Rogalev. XMCD and ab initio study of interface-engineered ultrathin Ru/Co/W/Ru films with perpendicular magnetic anisotropy and strong Dzyaloshinskii–Moriya interaction. // Physical Chemistry Chemical Physics 24, 8225 (2022). DOI:10.1039/D1CP05456B (Q1, IF: 3.676)

6. Y. Madhwal, Y. Borbon-Galvez, N. Etemadi, Y. Yanovich and A. Creazza. Proof of Delivery Smart Contract for Performance Measurements. // IEEE Access, vol. 10, pp. 69147-69159, 2022. DOI: 10.1109/ACCESS.2022.3185634. (Q1, IF 3.476)

7. E. Bischof, A. Botezatu, S. Jakimov, I. Suharenko, A. Ostrovski, A. Verbitsky, Y. Yanovich, A. Zhavoronkov, G.Zmudze. Longevity Foundation: Perspective on Decentralized Autonomous Organization for Special-Purpose Financing. // IEEE Access, vol. 10, pp. 33048-33058, 2022. DOI: 10.1109/ACCESS.2022.3161392. (Q1, IF 3.476)

8. V. Amelin, E. Gatiyatullin, N. Romanov, R. Samarkhanov, R. Vasilyev and Y. Yanovich. Black-Box for Blockchain Parameters Adjustment. // IEEE Access, vol. 10, pp. 101795-101802, 2022. DOI: 10.1109/ACCESS.2022.3208702. (Q1, IF 3.476)

## Educating leaders

The Center continued delivery of MSc program "Internet of Things and Wireless Technologies", admitting 13 students based on review of more than 470 applications.
Students' research results were published in the top reputable sources, some highlights are presented below:

**CVPR2022, A*:** A. Kornilova, M. Faizullin, K. Pakulev, A. Sadkov, **D. Kukushkin**, A. Akhmetyanov, T.Akhtyamov, H. Taherinejad, G.Ferrer. SmartPortraits: Depth Powered Handheld Smartphone Dataset of Human Portraits for State Estimation, Reconstruction and Synthesis. // 2022 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), New Orleans, LA, USA, 2022, pp. 21286-21297, doi: 10.1109/CVPR52688.2022.02063)

**IROS2022, A:** A. Kornilova, D. Iarosh, **D. Kukushkin**, N. Goncharov, P. Mokeev, A. Saliou, G. Ferrer. EVOPS Benchmark: Evaluation of Plane Segmentation from RGBD and LiDAR Data. // 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Kyoto, Japan, 2022, pp. 13074-13080, doi: 10.1109/IROS47612.2022.9981470).

## Professional education

The portfolio of professional education programs was expanded. One notable result is the program "Development of hardware and software telecommunication solutions in the OpenRAN paradigm", the materials of which were a basis of lectures and labs for Astana IT University. 7 new programs were developed for NTI regional division at TUSUR on topics of error-correcting codes for wireless communication systems, WPAN simulation with discrete event simulators, mathematical modeling of radio access systems, development of embedded systems for IoT.
The Center also participated in programs and courses organized by other departments, including lectures about 5G and IoT for Sber, Evraz, Rosseti, MEPhI Engineering Center.

## International network

In the complicated context of 2022, several partnerships with companies were terminated, while Center's membership in technology consortia was suspended. Still, international lines were maintained via conferences and exhibitions, as well as new partnership opportunities.

The Center was presented at the Mobile World Congress 2022 (Barcelona), where negotiations were held with international companies, including AW2S (France), Radisys (USA), Arraycomm (China), Sunwave (China), Comba Telecom (China), Supermicro (China), Foxconn (Taiwan), Lanner Electronics (Taiwan), Silicom (Israel), Kontron (Canada), VVDN Technologies (India), Polaris Networks (India).

Collaborations were set with Kazakhstan (Energy Construction Engineering), India (Valles Marineris International Private Limited, Periyar Maniammai Institute of Science & Technology) and Vietnam (Vietnam Posts and Telecommunications Group).

## Professional and wider community engagement

The Center continued to support Skoltech wide outreach and wider community program.

Among top activities are 5G-lab tours of high-profile delegations, including governmental bodies, diplomatic missions. Multiple open lectures on next generation wireless technologies were delivered on a wide span of sites from Moscow to Tomsk.

The online content continued to attract wider audience: "Introduction to the Internet of Things" (4160 participants), "Internet of Things: from idea to product" (over 2900 views), "Development of smart devices based on Arduino" (537 participants).

In total, the Center participated in 27 events, including top industry conferences – Digital industry of Russia, Spectrum Forum 2022, Microelectronics 2022, Aeronet 2035 Exhibition. As a part of brand development, the team gave interviews on 5G topics for TASS, Vedomosti, ComNews, RSpectr, and other media.


Распределенный модуль базовой станции — OpenRAN 5G DU
Аппаратная платформа: Intel x86 (вкл. доп. FEC акселератор)
Интерфейсы: F1, O-RAN 7-2x, MGMT, Netconf, GPS
Производительность: до 4 RU/AAU с конфигурацией 100 МГц MIMO 4x4
Исполнение: 2U 19"
Электропитание: -48 В (постоянный ток)
Skoltech
NTI CoE
NTI Center of Excellence in Wireless Technologies and the Internet of Things
POWER
550W
550W

# Bio Center

The Center for Molecular and Cellular Biology was established in 2021 within the Institute's transformation of research and technology agenda, based on the Center for Life Sciences. The main strategic goal of the Center is to maintain the teaching and research excellence in molecular and cellular biology. The strategic program encompasses the following core areas: mass-spectrometry (Profs. Nikolaev and Kostyukevich), development of fluorescent probes (Prof. Lukyanov), antibiotic research (Prof. Sergiev), analysis of chromatin structure and epigenomics (Prof. Khrameeva), molecular biology of lncRNA and splicing (Profs. Dontsova and Pervouchine), protein structure and function (Profs. Ivankov, Popov, and Strushkevich), immunology (Prof. Chudakov), plant biology (Prof. Logacheva), comparative and functional genomics (Prof. Gelfand), molecular evolution (Prof. Bazykin). The Center is chaired by Prof. Gelfand, Vice President for Biomedicine.

**133**
faculty and researchers

**114**
MSc and PhD students supervised

**44**
MSc and PhD graduates

**153**
papers in Scopus, including 117 in Q1 journals, 20 in Nature Index journals

**484**
mln Rub sponsored research funding 2022-2024

**39**
projects supported with grants and industry funding

Life Sciences
& Health, Agro


protein
Thermo
UV

## R&D highlights

The Center continued the research and technology program, demonstrating a number of achievements.
Most important recent results are linked to various aspects of the SARS-CoV-2 epidemics. Prof. Bazykin with students characterized the different waves of the ongoing pandemic demonstrating, in particular, that much of the delta wave in Russia had been descendant to just a single introduction event.
Prof. Chudakov collected T-cell receptors specific for the virus.
Prof. Lukyanov developed sensors for detection of SARS-CoV-2 proteins that allow for cell screening and yield information about intracellular transport and interactions of viral proteins.
The mass-spectrometry team has developed a machine-learning procedure for prediction of the survival probability of patients with COVID-19 based on blood proteome analysis.

Another promising direction is that of mitochondrial research. The Mazunin group demonstrated that maternal age-independent association of increased mtDNA content and aneuploidy in human embryos may reflect a novel mechanism of purifying selection against potentially deleterious mtDNA variants arising from germline or early developmental events damaging mtDNA in human embryos prior to implantation.
Prof. Sergiev in collaboration with colleagues from Sweden characterized the dynamic ribosome assembly and maturation in mitochondria.
The group of Prof. Logacheva has developed a tool for the comparative analysis of transcriptomes, applicable in various experimental settings, including tissue differentiation, evo-devo studies etc.

The R&D agenda included projects supported with grants and contract funding:

- Pilot test systems based on quantitative blood proteomics for early diagnosis of Alzheimer's disease and for predicting complications associated with COVID-19 (Prof. Nikolaev).
- A project to develop and create a mock-up of an ultra-highresolution mass spectrometer with electron impact ionization for the identification of volatile compounds based on multielectrode harmonized Kingdon traps (Prof. Nikolaev).
- Web-service implementing a full cycle of HiC data analysis with a user-friendly interface suitable for medical doctors (Prof. Khrameeva).
- Study of alternative splicing as a drug target, joint project with China (Prof. Pervouchine).
- Development of genome editing tools for plants (Prof. Logacheva).
- A project aiming at identification of new antibiotics (Prof. Sergiev).
- A Moscow government project on analysis of drug metabolites in school wastewaters (Profs. Kostyukevich and Nikolaev).
- Series of projects about microbiome contribution to bioremediation of damaged soils (Prof. Gelfand).

- Sequencing the genome of the Sosnovsky hogweed and analysis of its metabolome, demonstrating considerable differences in the production of photosensitizing compounds (psoralen and its derivatives) among hogweed populations; with potential application to planning extermination of this invasive species (Prof. Logacheva).

## Top publications

1. Mechanism of mitoribosomal small subunit biogenesis and preinitiation (I. Laptev, P.Sergiev) Nature.

2. Complex fitness landscape shapes variation in a hyperpolymorphic species (A.V.Stolyarova, A.V.Fedotova, G.A.Bazykin) eLife.

3. Alternative RNA splicing modulates ribosomal composition and determines the spatial phenotype of glioblastoma cells (O.A.Dontsova) Nature Cell Biology.

4. VDJdb in the pandemic era: a compendium of T cell receptors specific for SARS-CoV-2 (M.Goncharov, D.Chudakov) Nature Methods.

5. Pinpointing the tumor-specific T cells via TCR clusters (M.M.Goncharov, N.I.Sharaev, V.Karnaukhov, D.M.Chudakov) eLife.

6. Genomic analysis reveals cryptic diversity in aphelids and sheds light on the emergence of Fungi (M.D.Logacheva) Current Biology.

7. The Parallel Reaction Monitoring-Parallel Accumulation–Serial Fragmentation (prm-PASEF) Approach for Multiplexed Absolute Quantitation of Proteins in Human Plasma (A.Brzhozovskiy, A.Kononikhin, A.E.Bugrova, G.I.Kovalev, E.N.Nikolaev, C.H.Borchers) Analytical Chemistry.

8. Aromaticity Index with Improved Estimation of Carboxyl Group Contribution for Biogeochemical Studies (A.Zherebker, G.D.Rukhovich, A.Sarycheva, E.N.Nikolaev) Environmental Science and Technology.

9. Inactive and active state structures template selective tools for the human 5-HT5A receptor (P.Popov) Nature Structural and Molecular Biology.

10. Memory persistence and differentiation into antibody-secreting cells accompanied by positive selection in longitudinal BCR repertoires (A.Mikelov, E.I.Alekseeva, D.M.Chudakov, G.A.Bazykin) eLife

## Educating leaders

The Center delivers one of the largest programs in Skoltech. Life Sciences students' success was evidenced in publications in top reputable journals, successful defenses and graduates' employment. Seven successful PhD defenses of graduates 2022 and 16 defenses of graduates of earlier classes were completed.

Selected (Q1, NI) first-author publications of students:

1. Complex fitness landscape shapes variation in a hyperpolymorphic species (A.V.Stolyarova) eLife (NI).
2. Interaction between transcribing RNA polymerase and topoisomerase I prevents R-loop formation in E. coli (D.Sutormin) Nature Communications (NI).
3. Pinpointing the tumor-specific T cells via TCR clusters (M.M.Goncharov) eLife (NI).
4. VDJdb in the pandemic era: a compendium of T cell receptors specific for SARS-CoV-2 (M.Goncharov) Nature Methods (NI).
5. Memory persistence and differentiation into antibody-secreting cells accompanied by positive selection in longitudinal BCR repertoires (A.Mikelov, E.I.Alekseeva) Elife (NI).
6. Persistence of plasmids targeted by CRISPR interference in bacterial populations (V.Mamontov) Proceedings of the National Academy of Sciences (NI).
7. Best templates outperform homology models in predicting the impact of mutations on protein stability (M.A.Pak) Bioinformatics.
8. Pairs of Mutually Compensatory Frameshifting Mutations Contribute to Protein Evolution (D.Biba) Molelcular Biology and Evolution.
9. Uncertainty-aware and interpretable evaluation of Cas9-gRNA and Cas12a-gRNA specificity for fully matched and partially mismatched targets with Deep Kernel Learning (B.Kirillov) Nucleic Acids Research.
10. Molecular epidemiology of HIV-1 in Oryol Oblast, Russia (K.Safina) Virus Evolution.
11. RtcB2-PrfH Operon Protects E. coli ATCC25992 Strain from Colicin E3 Toxin (T.Maviza) International Journal of Molecular Sciences.
12. Murine Falcor/LL35 lncRNA Contributes to Glucose and Lipid Metabolism In Vitro and In Vivo (E.Scherbinina) Biomedicines.
13. Recapitulation of the embryonic transcriptional program in holometabolous insect pupae (E.Ozerova) Scientific Reports.

14. Transcriptome analysis reveals high tumor heterogeneity with respect to re-activation of stemness and proliferation programs (A.Baranovsky) PLoS One.
15. Phenotypic Alteration of BMDM In Vitro Using Small Interfering RNA (N.Halimani) Cells.
16. Studying Chromatin Epigenetics with Fluorescence Microscopy (A.I.Stepanov) International Journal of Molecular Sciences.
17. A hierarchy in clusters of cephalopod mRNA editing sites (M.A.Moldovan) Scientific Reports.
18. S51 Family Peptidases Provide Resistance to Peptidyl-Nucleotide Antibiotic McC (E.Yagmurov†) mBio.

The graduates 2022 found career paths on junior research positions in Skoltech, Shemyakin-Ovchinnikov Institute of Bioorganic Chemistry, Dmitry Rogachev National Research Center, R&D companies (Boston Gene, MiLaboratories, "Alkor Bio"), or continued studies in universities abroad (Yale, Columbia, UCL and others).

## Professional education

The professional education track was presented with content on plant biology and molecular oncology:

- Prof. Logacheva: School for Young Scientists Plantings-2022 (24 attendees, offline, including wetlab workshop).
- Prof. Logacheva: "High-performance methods of genome analysis".
- Prof. Gelfand, Dr. Rybko: Online education initiative on molecular oncology for medical doctors in collaboration with MIMC (5 days, 400+ attendees).

The Center for Molecular and Cellular Biology aims to maintain teaching and research excellence in molecular, cellular and computational biology. 44 MSc and PhD students successfully graduated in 2022. Several new courses were developed, including professional education serving a wider community. Students and faculty published outstanding articles in top journals (Nature, PNAS, NAR), contributing, in particular, to understanding of the SARS-CoV-2 spread and evolution in Russia, reflected in policies towards containment of the epidemics.

**Prof. Mikhail Gelfand, Director of the Center, Vice President for Biomedical Research**

## Innovation activities

The startups founded by the Center's faculty were maintained: MiLaboratory (Prof. Chudakov), Target Medicals (Prof. Strushkevich), Crystera (Prof. Strushkevich), MRM Proteomics R (Prof. Nikolaev), MS Technologies (Prof. Nikolaev), Geonome (Prof. Gelfand).

The patent with priority from 05.09.2022 "Mass spectrometer with electron impact ionization based on a multielectrode harmonized Kingdon trap" W22050633 2022123612 issued (Prof. Nikolaev).

## Think-act tank role

The Center continued advising activities on a number of projects of the national level. Thus, Prof. Bazykin was involved in joint research of SARS-CoV-2 epidemiology in Russia with all core relevant governmental agencies: Ministry of Health, FMBA and Rospotrebnadzor. Prof. Kostyukevich participated in initiation, development and promotion of the Federal Program for the Development of Scientific Instrumentation.

## International collaborations

In the context of sanctions and raising isolation, several international collaborations were cancelled (Tartu University, Hamburg University). The RFBR-Germany grant submitted with European Molecular Biology Laboratory was not considered due to the program termination. Still, the Center maintained collaborations, most of which were on a faculty-to-faculty level. Prof. Sergiev collaborated with Stockholm University (mitochondrial ribosome biogenesis), University of Illinois at Chicago and University of Texas Medical Branch (ribosome-targeting antibiotics). Prof. Pervouchine collaborates with Zhejiang University (RNA-based regulation of alternative splicing), supported by the Russian Ministry of Science and Education.

## Outreach and wider community engagement

The Center is one of the core Skoltech contributors to the outreach and wider community engagement program. Center's faculty, researchers and students participated in multiple interviews, gave open public lectures at dozens of sites, including Zaryadie, Arhe, Skolkovo gymnasium, Letovo school, Sirius (Sochi), Yeltsin center (Ekaterinburg), Donor Forum (Peredelkino). Skoltech students and professor participated in a number of schools for high-school students, in particular, Summer School in Dubna, "Chimaera" (Kaluga region), Pushchino Winter School, School on Molecular and Theoretical Biology (online).

# Neuro Center

Vladimir Zelman Center for Neurobiology and Brain rehabilitation (Neuro Center) was established in 2018. The Center conducts interdisciplinary and translational research in neurobiology and neural technologies, addressing the areas of Brain-computer interfaces, Brain metabolism, Biomaterials, Computational neurobiology and neuroimaging, Neuromodulation, Small molecules.
The Center is led by Prof. Philipp Khaitovich.

**35**
faculty and researchers

**34**
MSc and PhD students supervised

**8**
MSc and PhD graduates

**30**
papers, including 20 in Q1 journals (3 papers in Nature Index)

**242**
mln Rub sponsored research funding 2022-2024

**13**
projects supported with grant and federal subsidies

Life Sciences
& Health, Agro


Skoltech
Skoltech
Skoltech
Skoltech

## Research and technology highlights

The Center's key achievements of the year include:

- Creation of novel technologies, including PLACE (printed layered adjustable cargo encapsulation) by biomaterial laboratory resulting in seven publications in Q1 journals with an average IF>7 and patent application.

- Breakthrough technology for chronic pain release development as a part of the study supported by the RSCF Grant No. 21-75-30024 and industrial partner "Motorica" LLC, bionic prosthesis producer. The Center successfully conducted a proof of concept study on the use of invasive peripheral nerve stimulation (PNS) of amputated limb with the goal of providing sensory feedback during the prosthetic hand control and reducing phantom pain. In addition to its therapeutic effects, PNS proved to be an effective tool for somatosensory feedback from the prosthesis. Further experimental study is required to confirm achieved 78% accuracy level using the prosthesis.

- Development of lipidome-based technology prototype for psychiatric diseases risk assessment resulting in publication in a highly reputable psychiatric Q1 journal with IF>25.9, patent application and two year R&D program funding by the Moscow Center for Innovative Technologies in Healthcare.

- Development of a new therapeutic platform prototype based on in vivo delivery of siRNA towards key regulators of innate inflammatory processes resulting in the publication in Q1 journal with IF>10.

- In collaboration with the consortium of NTI Center on Bionic technologies in medicine based on SamSMU, a new ambitious project on development of the technology for osseointegration of biomechanical exo-prostheses of upper and lower extremities with neurocontrol was started. A concept of technical solution on osseointegration with neurocontrol of biomechanical exo-prostheses of upper and lower extremities as a first step of a five years R&D project has been developed. The project is conducted under the program on development of NTI Center on Bionic technologies in medicine based on SumSMU by

the consortium of Universities and industrial companies. Within the first year a number of tasks were solved, including existing solutions study, patent search, analysis of the user-experience of amputees with removable prostheses, development of non-invasive myo-interfaces prototypes and algorithms for the control of exo-prostheses of the upper and lower extremities. The results of the first year R&D study may offer promising approaches for controlling exo-prostheses in patients with amputations, increasing their mobility, and improving their quality of life. The project is co-funded by NTI Center and producers of exo-prostheses Motorica, Salut-orto, Cybathletic Union.

- Commencement of a new project conducted in collaboration with the Russian Quantum Center and devoted to registration of ferro- and superparamagnetic nano- and sub-micro particles in living tissues. The registration is being done using high-sensitive yttrium-garnet iron film magnetometers, both in-vitro and in-vivo.

The publication 'Yttrium-iron garnet film magnetometer for magnetic microparticles in-vivo registration studies' was published at bioarxive. org and is currently under revision in IEEE Transactions on Medical Imaging journal (Q1). tic nano- and sub-micro particles in living tissues. Two research groups of the Neuro Center have been involved in the research – Biomaterials lab and Computational neurobiology and neuroimaging lab.

Two patent applications were submitted to secure research results:

1. RU № 2022129057 dd 09.11.2022, Abdurashitov, A.S., Proshin, P. I., Sukhorukov, G. B. Manufacturing and applications of free-standing drug-eluting films (PLACE).

2. RU № 2022123068 dd 29.08.2022, P.E. Khaitovich, E.A. Stekolshchikova, A.I. Tkachev, N.A. Anikanov, Method for diagnosing mental disorders by blood lipids.

## Top publications

Below are select papers to illustrate the scope and impact of research outputs in 2022:

1. Murat, F., Mbengue, N., Winge, S.B. et al. The molecular evolution of spermatogenesis across mammals. *Nature – Q1 – IF 41,5*.
2. Tkachev A, Stekolshchikova E, Vanyushkina A, et al. Lipid Alteration Signature in the Blood Plasma of Individuals With Schizophrenia, Depression, and Bipolar Disorder. *JAMA Psychiatry – Q1 – IF 25,9*.
3. Yavich N, Koshev N, Malovichko M, Razorenova A, Fedorov M. Conservative Finite Element Modeling of EEG and MEG on Unstructured Grids. *IEEE Trans Med Imaging*. 2022 Mar;41(3):647-656. – Q1 – IF 10.048
4. Sindeeva, O. A., Abdurashitov, A. S., Proshin, P. I., Kadrev, A. V., Kulikov, O. A., Shaparov, B. M., ... & Sukhorukov, G. B. (2022). Ultrasound-Triggerable Coatings for Foley Catheter Balloons for Local Release of Anti-Inflammatory Drugs during Bladder Neck Dilation. *Pharmaceutics*, 14(10), 2186. – Q1. – IF 6.5.
5. Syrov, N., Yakovlev, L., Nikolaeva, V., Kaplan, A., & Lebedev, M. (2022). Mental Strategies in a P300-BCI: Visuomotor Transformation Is an Option. *Diagnostics*, 12(11), 2607

## Educating leaders

The Center contributed to the Institute's educational domain by delivery of courses, students' research advising, as well as involving students in research projects.

Examples of students' papers in peer-reviewed scientific journals:

1. **Dmitry Senko**, Anna Gorovaya, Elena Stekolshchikova, Nickolay Anikanov, Artur Fedianin, Maxim Baltin, Olga Efimova, Daria Petrova, Tatyana Baltina, Mikhail A. Lebedev, Philipp Khaitovich, Anna Tkachev, "Time-dependent effect of sciatic nerve injury on rat plasma lipidome," International Journal of Molecular Sciences.

2. **Gurgen Soghoyan**, Artur Biktimirov, Yury Matvienko, Ilya Chekh, Mikhail Sintsov, Mikhail Lebedev. (2022). Peripheral nerve stimulation for both phantom limb pain suppression and somatosensory feedback in transradial amputees. Brain Stimulation (under review).

3. **Proshin, P. I.**, Abdurashitov, A. S., Sindeeva, O. A., Ivanova, A. A., & Sukhorukov, G. B. (2022). Additive

Manufacturing of Drug-Eluting Multilayer Biodegradable Films. Polymers, 14(20), 4318.

4. **Sapach, A. Y.**, Sindeeva, O. A., Nesterchuk, M. V., Tsitrina, A. A., Mayorova, O. A., Prikhozhdenko, E. S., ... & Sukhorukov, G. B. (2022). Macrophage In Vitro and In Vivo Tracking via Anchored Microcapsules. ACS Applied Materials & Interfaces, 14(46), 51579-51592.

5. **Halimani N**, Nesterchuk M, Andreichenko IN, Tsitrina AA, Elchaninov A, Lokhonina A, Fatkhudinov T, Dashenkova NO, Brezgina V, Zatsepin TS, Mikaelyan AS, Kotelevtsev YV. Phenotypic Alteration of BMDM In Vitro Using Small Interfering RNA. Cells.

Successful defenses:

- Abdurashitov Arkady (supervisor Prof. Gleb Sukhorukov), Dissertation defense "Methods of laser speckle visualization of dynamic processes in biological systems". Thesis for the degree of candidate of Physical and Mathematical Sciences in the specialty 1.5.2. – Biophysics.
- Tkachev Anna (Supervisor Prof. Philipp Khaitovich), Analytical pipeline for lc-ms-based global lipidomics data analysis and its application to the investigation of metabolic signatures of psychiatric disorders, PhD defense at HSE University, prepared at Skoltech? Thesis for the degree of candidate of Computer Science.

Center's students N. Pilyugin and G.Soghoyan founded the startup "Alter Sense", which is gamified stimulation system with virtual reality for rehabilitation of patients after a stroke, with spinal cord injury, limb amputation and other neurological diseases and injuries.

The Center also contributed to professional education: program for faculty of Advanced Engineering School in Medicine of Samara State Medical University, "Machine Learning", and in Neurotechnology workshop for EVRAZ young engineers were organized.

Advances in Neuroscience, one of the science fields with lots left to discover, will certainly affect our lives. The goal of our Center is to be and remain a number one place for Neuroscience in Russia. In 2022 we approached this goal by doubling our scientific grants and applied R&D contracts support and recruiting the best and the brightest young scientists and Skoltech students into our projects.

**Prof. Philipp Khaitovich, Director of the Center**

## Think-act tank role

The Center's core expertise was delivered for a number of federal level science and technology programs:

- project on "Technology development of osseointegration with neurocontrol for bionic hand and foot exoprosthesis" within a consortium of the National Technological Initiative Center on Bionic technologies in medicine based on Samara State Medical University.
- Project "Drugs microencapsulation and development of experimental therapy method using cellular technologies" (Priority 2030 program)
- Project "Development of methods for objective diagnosis of the risk of mental disorders based on lipid analysis of blood plasma" in collaboration with the Moscow center for innovative technologies in healthcare, Psychiatric Hospital no. 1 Named after N.A. Alexeev of the Department of Health of Moscow.

## International network

Despite the challenging year, when several collaborations were postponed, the Center continued joint research with groups from Max Planck Institute for Evolutionary Anthropology, Queen Mary University of London, UCL Queen Square Institute of Neurology, Harbin Institute of Technology, Institute of Computational Biology, Chinese Academy of Sciences. Also, the presence was ensured in the BRICS Working group on Biotech and Biomed including human health and neurosciences.

## Outreach and wider community engagement

The Center demonstrated dedication and support to advancement of Skoltech brand, delivering multiple science outreach activities. Among notable examples are participation in Filming in the Almanac of the Science Film Laboratory "16 Ways to Change the World", interviews to RIA Novosti, Kommersant, Russia-1, Russia-24, radio Mayak, lectures in Yeltsin Center, Arche. Below are some examples:

- Olga Sindeeva, Interviews on TV channel Russia-1, Russia-24 and radio Mayak, promoting science and innovative developments in

the field of high-tech medicine, created on the basis of the Neuro Centre
- Gleb Sukhorukov, Interviews to Kommersant Journal about Polymer biofilms
- Mikhail Lebedev, Lecture "The era of neurogadgets: can technology enhance consciousness?" (Yeltsin Center)
- Alexey Gorin, Interviews on radio Mayak. Why the brain learns faster when threatened
- Kirill Polovnikov, online seminar on bioinformatics and data science, «Non-backtracking walks reveal compartments in sparse chromatin interaction networks»
- Philipp Khaitovich, Lecture "My brain and me" at the Moskino Museon
- Philipp Khaitovich, Interviews to RIA Novosti
- Philipp Khaitovich, Lecture "Secrets of the brain: evolution, development and aging" at the Nauka 0+ Festival in Zaryadye
- Gurgen Soghoyan, Interviews on radio Mayak. The science. Sensation of bionic prosthetic hands and relief of phantom pains
- Lev Yakovlev, lectures at Nauka 0+, РОСИЗО, notes at "Scientific dzen"
- Nikolay Syrov, Lecture "Body illusions and phantom limbs"
- Natalya Podsosonnaya, panel discussion participant at Neurotechnology in Russia Forum.

# Agro Center

The Project Center in Agro Technologies was established in 2021 within the Institute's wide transformation of research and technology agenda based on the Center for Agro Technologies.
The Center's strategic program focuses on the following core areas: Plant Genetics, Animal Genetics, Envirotyping and Digitalization, Agro-processing and Food Tech. In pursuing the strategy, the Center focuses on problem-driven research in the Agro sector with particular dedication to impactful, innovative relationships with industrial partners. In addressing the second mission to 'educate leaders', the Center leads the Agro track (MSc and PhD programs) and professional education. The Center is chaired by Prof. Laurent Gentzbittel.

**16**
faculty and researchers

**8**
MSc and PhD students supervised

**4**
professional education programs

**8**
Papers in Q1 journals

**144**
mln Rub sponsored research funding 2022-2024

**>100**
participants in professional education

Life Sciences
& Health, Agro

## Research and technology highlights

During the year, the Center achieved a number of results, the most notable of which are presented further:

- Algorithm for crop yield prediction based on drought index with 75% accuracy was developed within the project "Prediction of crop yield using drought index analysis (with Seed Company "Rassvet")

- Design of SNP array suitable for the genotypes imputation, population analysis and study of economic traits of the Angus cattle (with Miratorg-Genetics): the bovine medium-density SNP genotyping array for economic traits of Angus beef cattle is optimized. Genotype information (50K SNP) of 300,000 Angus cows were imputed using whole genome sequences of 47 bulls belonging to the Miratorg herd and 128 bulls from the 1000 Bull Genomes Project as the reference population. In addition, phenotype information of 13261 animals for carcass and meat traits were used for genome wide association studies. Some novel genomic regions underlying carcass weight and meat quality traits in Angus beef cattle were identified which can be subject to patent

- Candidate genes of white lupine for editing in order to provide its immunity to anthracnose was defined within the project "Search for resistance genes to abiotic and biotic stressors and creation of stress-resistant barley and lupine lines using ionizing radiation and genome editing technologies (with All-Russian Research Institute of Radiology and Agro Ecology)

- A protocol for accelerated selection (accelerated reproduction) for white lupine developed

- For white lupine, CRISPR-Cas9 constructs were developed for the candidate gene encoding RING zinc-finger E3 ubiquitin ligase, potentially involved in plant immunity.

- Ten Isogenic lines of Black Soldier fly lines (3rd generation) developed

- A modification of the transformation technique with the help of gold microparticles was developed; an additional module for the "genetic gun" modeled and manufactured

- A new technique of storing the larvae of Black Soldier Fly developed

Patent applications were submitted for the invention "Set of Oligonucleotide Primers for Genotyping of Colletotrichum Acutatum", while startup applications for Skolkovo ecosystem were submitted for the project Black soldier fly – A golden bio-convertor for green waste management (result of the project supported by Skoltech translational research program), and the project EnvAgro (review for awarding status of resident is ongoing).

## Think-act tank role

The Center supported with expertise a number of national level events in science and technology. Thus, Prof. Laurent Gentzbittel and Prof. Hassan Baneh participated in the sessions of the Congress of Young Scientists as experts for Animal Breeding. Professor Gentzbittel also joined the Expert Council under the Ministry of Science and Higher Education on carbon balance control, taking part in the Open meeting.

## Top publications

1. Djouider, S. I., L. Gentzbittel, R. B. Jana, M. Rickauer, C. Ben, and M. Lazalli (2022), Contribution to improving chickpea (Cicer arietinum L.) efficiency in low-phosphorus farming systems: Assessment of the relationships between P and N nutrition, nodulation capacity and productivity performance in P-deficient field conditions, Agronomy, doi: 10.3390/agronomy12123150.

2. Petrovskaia, A., R. B. Jana, and I. V. Oseledets (2022), A single image deep learning approach to restoration of corrupted remote sensing products, Sensors, doi: 10.3390/s22239273.

3. Matvienko, I., M. Gasanov, A. Petrovskaia, M. Kuznetsov, R. B. Jana, M. Pukalchik, and I. V. Oseledets, (2022), Bayesian aggregation improves traditional single image crop classification approaches, Sensors, doi: 10.3390/s22228600.

4. Lytkin K, Nosulchak V, Agakhanov M, Matveikina E, Lushchay E, Karzhaev D, Raines E, Vasylyk I, Rybachenko N, Grigoreva E, Volkov V, Volynkin V, Gentzbittel L, Potokina E. Development of a High-Density Genetic Map for Muscadine Grape Using a Mapping Population from Selfing of the Perfect-Flowered Vine 'Dixie'. Plants. 2022; 11(23):3231. doi.org/10.3390/plants11233231.

5. Gubaev, R., Boldyrev, S., Martynova, E., Chernova, A., Kovalenko, T., Peretyagina, T., Goryunova, S., Goryunov, D., Mukhina, Z., Ben, C., Gentzbittel, L., Khaitovich, P., Demurin, Y. (2022) Genetic mapping of loci involved in oil tocopherol composition control in Russian sunflower (Helianthus annuus L.) lines. G3 Genes|Genomes|Genetics, Volume 12, Issue4 doi: 10.1093/g3journal/jkac036.

6. Mandal, A., Baneh, H., Rout, PK, Notter, DR, 2022. Genetic analysis of sexual dimorphism in growth of Jamunapari goats of India. Journal of Animal Breeding, Genetics 139, 1-14.

## Educating leaders

The Center continued to lead the Agro track, delivering courses, which included Plant Genetic Diversity & Adaptation to Stress, Modern Plant Breeding workshop, Computational Methods in Plant & Animal Quantitative Genetics, Experimental designs in Biology, and Advanced Topics in Bioinformatics.

## Professional education

On the basis of the Scientific Training Center established by Agro Center under the project with Bayer AG, a unique program on Modern technologies in Plant was developed. The programs of the partner institutions supervised by Skoltech covered Timiryazev Academy, Institute of Genetics and Cytology in Novosibirsk and Belgorod State Agrarian University.

4 schools with the program "Modern Technologies in Plant Breeding" were organized for Timiryazev Academy, RUDN, MSU, HSE and other institutions. The same course was delivered for RF Presidential Academy of National Economy and Public Administration (RANEPA) with attendees from business and industry.

1. 14-25, February 2022. Module 2 (Regular Level) "Organization of the Breeding Programs Using Statistical, Genetic and Molecular Approach", 20 attendees.
2. 14-25 March, 2022. Module 3 (Advanced Level) "Introduction to the Genomic Plant Selection", 20 attendees.
3. 10-21, October 2022. Module 2 (Regular Level) "Organization of the Breeding Programs Using Statistical, Genetic and Molecular Approach", 20 attendees.
4. 28-29 June Summer Schools or Bachelors "Modern technologies of plant breeding", 40 attendees.
5. December 2021 – April 2022. Joint Program with RANEPA "Technology for Agro Business:10 Main

"Going North, Keeping South, Securing Food". The Project Center for Agro Technologies continues to develop its strategy toward providing technological solutions to the agroindustry to overcome the current changes in local and global climates. The Center develops a new direction in agro-transformation (food and non-food) and maintains its attractiveness in hiring foreign specialists from various countries. Funding from industrial partners and grants confirm the excellence of the Center in both teaching/training activities and R&D.

**Prof. Laurent Gentzbittel, Director of the Center**

## Professional and wider community engagement

The Center continued to expand a partnership network, presenting results of collaborative activities in international conferences, held in Russia and abroad:

1. Jana, R. B. (2022), Envirotyping: A vital tool for better understanding of nature's dynamics, **4th Youth School on "Monitoring of Natural and Man-Made Systems"**, Perm Federal Research Center, Russian Academy of Sciences – Ural Branch, Perm, Russia, November 30 – December 01.

2. Gentzbittel, L.S., Ben C. (2022), "Whole genome-based breeding in crops: Genome Wide Association Studies and Genome Selection as powerful approach», Novosibirsk, **PlantaGen School 2022**, Institute of Genetics and Cytology, Russia, October 25-28.

3. Jana, R. B. (2022), Envirotyping: A critical tool for better productivity in agriculture, **International Forum Kazan Digital Week 2022**, Kazan, Russia, September 21 – 24.

4. Gentzbittel, L.S. (2022), Digitalization of the agro-industrial complex: opportunities along the value chain, **International Forum Kazan Digital Week 2022**, Kazan, Russia, September 21 – 24.

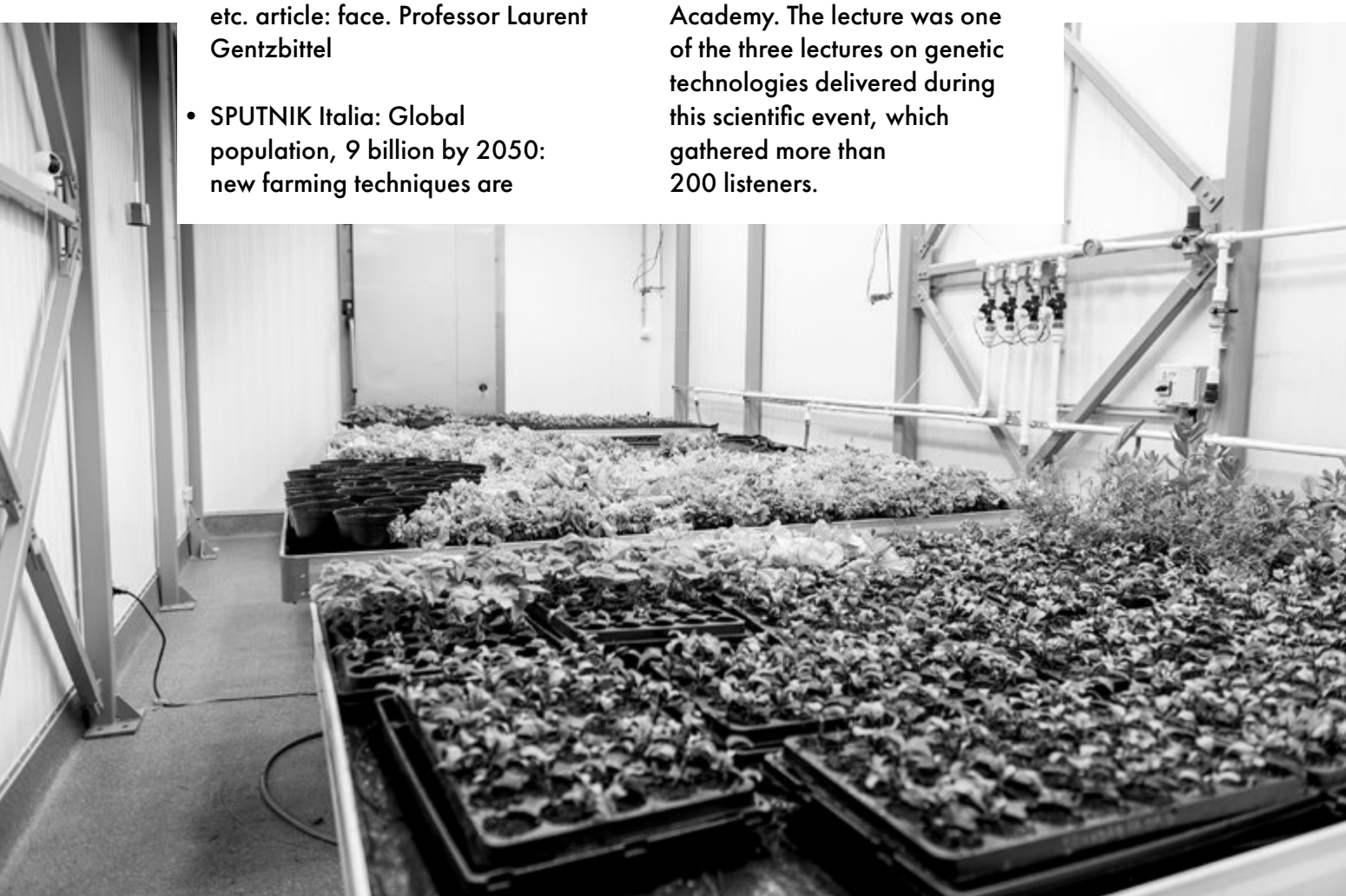
5. Jana, R. B. (2022), Envirotyping: Linking Environmental Data, AI/ ML, Genomics, and Food Security, keynote at **International Conference on Recent Trends in Science and Technology (IRCTC-2022)**, ATME College of Engineering, Mysuru, India, Jul. 14, 2022.

6. Fomenko, S. I.*, and R. B. Jana (2022), The Simulation of Elastic

Waves Propagation in Poroelastic Medium and Effective Module **Identification, International Conference on Mathematical Modeling in Natural Sciences (MMEN)**, Perm, Russia, Oct. 5 – 8, 2022.

Significant contribution was made to Skoltech visibility and brand advancement via highlighted articles in media (Kommersant, RIA Novosti, TASS etc.), radio (Mayak), as well as open lectures for the wider community:

- Kommersant: Chickpeas are the head of everything. Scientists around the world have teamed up to decipher the chickpea genome
- 02/09/2022, RIA Novosti, etc. article: face. Professor Laurent Gentzbittel
- SPUTNIK Italia: Global population, 9 billion by 2050: new farming techniques are needed. Professor Laurent Gentzbittel
- TV BRICS: Skoltech scientists develop new breeding technology. Professor Laurent Gentzbittel, research scientist Stepan Boldyrev, PhD student Alexey Zamalutdinov.
- TASS Interview with OilGene co-founder PhD student Rim Gubaev: we have invented a genetic test for seeds.
- Popular science lecture "Breeding: from past to modern days" given by PhD student Alexey Zamalutdinov during "Gutenberg's Smoking Room" in Obninsk in Rosatom Technical Academy. The lecture was one of the three lectures on genetic technologies delivered during this scientific event, which gathered more than 200 listeners.



# Engineering Center

The Digital Engineering Center was established in 2021 within the Institute's transformation of research and technology agenda, on the base of the Space Center. The main goal of the Center is to establish advanced engineering systems expertise for complex systems development to high Technology Readiness Levels (TRL) and provide world-class research, education and innovation in the area of Systems/Product Engineering, Systems Modelling, Robotics, Space Systems and scientific exploration. In 2022 the Center stayed within the strategy, targeting tasks to raise capacities in areas of specialization, update MSc program to increase its competitiveness, launch R&D projects, acquiring TRL5/6 technologies, conduct innovation activities. The Center is chaired by Prof. Tatiana Podladchikova.

**37**
faculty and researchers

**71**
MSc and PhD students supervised

**50**
MSc and PhD graduates

**59**
papers, including 29 in Q1 journals, and 6 in Nature Index

**143**
mln Rub sponsored research funding 2022-2023

**16**
projects supported with grants and industry funding

Cutting-edge Engineering and Advanced Materials

## Research and technology highlights

Most notable results in academic and technology excellence are presented below:

- Development and testing of the first CubeSat-type microsatellite has been completed. Two satellites, Skoltech B1 and Skoltech B2 were successfully launched from Baikonur on August 9, 2022 and reached the Earth's orbit.

- The first Skoltech satellite platform SkSCP-1 was designed, manufactured and tested. The SkSCP-1 satellite platform is now space qualified. The first ever software enabling communication and joint operation of satellites is developed and the CubeSats are taught to communicate with each other without human involvement.

- Development of a platform based on a know-how mobile robot, computer vision for greenhouses and model Based Systems Engineering documentation and acquiring technology transfer TRL-5 documents.

- Development of software and its implementation into Russian-manufactured electronic control unit for advanced driver assistance systems for a large industry partner (non-disclosure agreement).

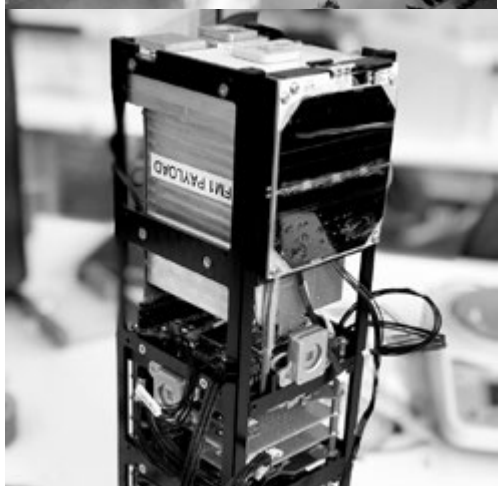
- Design, manufacture and testing of the chip-scale ion traps – the key component of new optical frequency standards for space applications. The single Yb+ ion was trapped.

- Development of experimental, theoretical and computational micromechanics of fiber-reinforced composites (carbon fiber, UHMWPE), and that of additively manufactured metallic alloys (also polymers, ceramics). Mg alloy bioresorbable bone implants. X-ray scattering and FIB-SEM methods of structure and deformation characterization. Approaches to residual stress analysis based on FIB-SEM ring-core drilling found application and use through collaborations with MISIS, MAI etc.

- New Space Weather Service on solar wind forecasting within European Space Agency Space Safety Program is delivered with the Skoltech logo.

- Technologies developed in the project with JSC Russian Space Systems in the field of optical frequency standards are implemented in Russian space industry related to GNSS, Deep space missions, telecommunications.

- Development of equipment for production of cellular panels: an adhesive application unit, an aggregate slice assembly unit, a decreasing unit. This technology has the following features: planned production capacity 12 thousand sq.m./year, panel dimensions 1.2x2.4 m.



- Development of a digital twin for the Lastochka electric train. As a part of industrial projects over 20 digital functional models developed and partially verified for airplanes and electric trains. In cooperation with the contractor, the software was developed, which allows to implement predictive maintenance technology in railway industry.
- Theoretical demonstration of the possibility of using superconducting quantum interference device for the direct high-precision measurement of acceleration, which may find application in, e.g., gravimetry on Earth and other celestial bodies. This work can pave the way to gravity effects on Cooper pairs in superconductors. The results are published in Nature Index Journal [Khomchenko et al., 2022].

- Parkinson' disease detection based on multimodal data analysis (wearable sensors and video). The results are published in Q1 journals [Kovalenko et al., 2022; Talitckii et al,. 2022] and were the base for getting a research grant by Russian Science Foundation (PI: Assistant professor Andrey Somov, 2023-2024, №23-21-00473) on the topic 'Investigation of common motor neurological diseases'.

- Study of the economic feasibility of a space advertising mission that would launch a formation of satellites into orbit to reflect sunlight and display commercials in the sky above cities [Biktimirov et al.,2022].

## Top publications

1. Khomchenko I., P. Navez, and H. Ouerdane (2022), *SQUID-based interferometric accelerometer*, **Applied Physics Letters** vol. 121, 152601, https://doi.org/10.1063/5.0126680, Q1, CiteScore = 6.6, Nature-indexed journal.

2. Podladchikova, T., J. Shantanu, A.M. Veronig, O. Sutyrina, M. Dumbovic, F. Clette, W. Poetzi (2022), *Maximal growth rate of the ascending phase of a sunspot cycle for predicting its amplitude*, **Astronomy & Astrophysics**, 2022, 663, A88, https://doi.org/10.1051/0004-6361/202243509, **Q1, Impact factor 6.240**.

3. Noda C.Q. and the EST team, *The European Solar Telescope*, **Astronomy & Astrophysics**, 666, A21, https://doi.org/10.1051/0004-6361/202243867, **Q1, Impact factor 6.240**.

4. Abramov S., A. Korotin, A. Somov, E. Burnaev, A. Stepanov, D. Nikolaev, M. Titova (2022), *Analysis of Video Game Players' Emotions and Team Performance: an eSports Tournament Case Study*, IEEE Journal of Biomedical and Health Informatics. 26: 3597-3606, https://doi.org/10.1109/JBHI.2021.3119202, **Q1, Impact factor 7.021**.

5. Kurenkov M., A. A. Potapov, A. Savinykh, E. Yudin, E. Kruzhkov, P. Karpyshev, D. Tsetserukou (2022), *NFOMP: Neural Field for Optimal Motion Planner of Differential-drive Robots with Nonholonomic Constraints*, **IEEE Robotics and Automation Letters**, Vol. 7, Issue 4, pp. 10991 – 10998, https://doi.org/10.1109/LRA.2022.3196886, **Q1, Impact factor 5.43**.

6. Talitckii A., E. Kovalenko, A. Shcherbak, A. Anikina, E. Bril, O. Zimniakova, M. Semenov, D. Dylov, A. Somov, Comparative Study of Wearable Sensors, Video, and Handwriting to Detect Parkinson's Disease. IEEE Transactions on Instrumentation and Measurement, 71: 1-10, https://doi.org/10.1109/TIM.2022.3176898, **Q1, Impact factor 5.332**.

7. Khomchenko I. , H. Ouerdane, and G. Benenti (2022), *Voltage amplified heat rectification in SIS junctions*, Physical Review B vol 106, 2454, https://doi.org/10.1103/PhysRevB.106.245413, **Q1, CiteScore 6.9**.

8. Petrovsky A., I. Kalinov, P. Karpyshev, D. Tsetserukou, A. Ivanov, A. Golkar, "The two-wheeled robotic swarm concept for Mars exploration (2022), **Acta Astronautica**, Vol. 194, pp. 1–8, https://doi.org/10.1016/j.actaastro.2022.01.025, **Q1 journal, CiteScore 5.7**.

9. Osinenko P (2022), *Towards a constructive framework for control theory*, **IEEE Control Systems Letters** (2022), vol. 6, pp. 379–384, https://doi.org/10.1109/LCSYS.2021.3076972, **Q1 journal, CiteScore 4.6**.

10. Denimal, E., Renson, L., Wong, C., & Salles, L. (2022), *Topology optimisation of friction under-platform dampers using moving morphable components and the efficient global optimization algorithm*, **Structural and Multidisciplinary Optimization**, 65(2), 1-19, http://doi.org/10.1007/s00158-021-03158-w, **Q1 journal, Impact factor 4.542**.

## Educating leaders

Efforts were made towards the educational offer competitiveness. The MSc curricula was updated and a redesigned program with 3 tracks was launched to attract talents from Russia and abroad. In addition to new courses, the Center launched the Digital Engineering research seminar featuring presentations of young researchers as well as invited speakers. Center's faculty also supported the Innovation workshop with sessions and short courses.

Multiple evidences of excellence were demonstrated by the students: top papers, internal and external grants, awards in contests and competitions and Skoltech programs, including Team Spirit Award, Best Paper Award, Entrepreneurial Spirit Award, Immersion Excellence Award. Select examples are highlighted below:

- Simona Nitti (supervised by Prof. Tatiana Podladchikova, best thesis research award) is a first author of a **Q1 paper, Impact factor 5.235** [Nitti et al., 2023].

- Ilia Khomchenko (supervised by Prof. Henni Ouerdane) is a first author of a **Q1 Nature-indexed paper, CiteScore = 6.6** [Khomchenko et al., 2022].

- Mikhail Kurenkov (supervised by Prof. Dzmitry Tsetserukou) is a first author of a **Q1 paper, Impact factor 5.43** [Kurenkov et al., 2022].

- Maxim Savinov (supervised by Prof. Andrey Somov) co-authored a **Q1 article, Impact factor 4.627** [Koshelev et al., 2023]

- Students supervised by Prof. Dzmitry Tsetserukou got best Paper Award at the International Conference Asia Haptics 2022, Beijing, China, November 14, 2022

- Ivan Apanasevich won with a team the National Technical Olympiad in Intelligence Robotics organized by Innopolis University.

- Alena Savinykh received the Bronze Prize in All-Russian Yandex Olympiad "I am professional", Computer Science (Robotics).

- The team headed by Prof. Dzmitry Tsetserukou is champions of Russia Eurobot, Competition on Autonomous Robots, reSET team Skoltech, 2022, Korolev, Russia.

- Erasmus student Giulia Maria Ronca supervised by Prof. Tatiana Podladchikova was awarded a prestigious award by Politecnico di Milano for international research at the partner institute.

The objective of the Center is to establish advanced engineering systems expertise at Skoltech for complex systems development at high TRL and to provide world-class research, education and innovations in Systems/ Product Engineering, Systems Modelling, Robotics, and Space. In 2022, we successfully completed restructuring of MSc program which attracted a significant increase of excellent candidates both in Russia and abroad. Notable achievements also include launching of two satellites Skoltech B1 and Skoltech B2 to the Earth's orbit using the first Skoltech satellite platform SkSCP-1, which enables communication and joint operation of satellites without human involvement. The relevance of the Center's scientific and industrial outcomes is supported by grant funding from both Russian and foreign foundations, high impactful publications in reputable journals and conferences, as well as significant financing from industrial partners. Despite the challenges of 2022, the Center could manage to keep international presence, including joint projects, academic mobility, conferences, and actively participated in outreach activities in Russia and worldwide contributing to the development of Skoltech brand. In 2023, the Center will advance the strategy in the selected areas to achieve KPIs with impact for the national economy, start-ups, high ranking journal publications, and graduates in the high-tech sector.

**Prof. Podladchikova, Director of the Center**

## Professional education

The Center delivered a number of programs, including "Restoring Technological Leadership in Aviation" for United Aircraft Corporation, lectures and session for Sber 'Digital Transformation of Business (Prof. Andrey Somov). Prof. Tsetserukou participated in EVRAZ Engineering Challenge. The project "Swarm of autonomous mining dump trucks for mine automation: modeling the behavior of a swarm of heterogeneous autonomous robots (dump trucks, loaders, bulldozers, excavators) for optimal mining" became the winner of the competition. Prof. Korskunsky delivered lectures on X-ray scattering for MISiS.

## Innovation activities

The IP portfolio of the Center was added with new patents and applications:

1. Patent (Russian): A.S. Somov, D.V.Dylov, E.A. Kovalenko, A.M. Talitsky, A.S. Anikina, A.S.Shcherbak, "A method for diagnosing Parkinson's disease based on video data analysis using machine learning". Patent for invention No. 2764568, 2022.

2. Patent (Russian): A.S. Somov, A.S. Stepanov, "Web-platform for visualization of multimodal data". Registration of the program on the computer No. 2022680745, 2022.

3. Patent: D. V. Lakontsev, M. A. Kurenkov, M. A. Ramzhaev, T. G. K. Fazli, D. O. Tsetserukou, A. V. Semenov, S. A. Novichkov. "Method for Building a Route and Controlling the Movement of a Mobile Service Robot in Retail Premises," Patent RU 2769710 C1, April 05, 2022.

4. Patent application by Prof. Henni Ouerdane: "Method for determining the metabolic parameters of a subject", under consideration at the US Patent and Trademark Office.

5. Patent application by Prof. Tatiana Podladchikova PCT/RU2019/000367, № R21100420, System and method of automated electrocardiogram analysis and interpretation. Under consideration at the Federal Institute of Industrial Property.

Two new startups were established: Game-R LLC (Sk resident, founded by Prof. Andrey Somov) and a company Game-R. New sub-division of the ISR Laboratory "Self-Driving Car Group" jointly with Integrant company was established.

## Think-act tank role

Following the Strategy initiative, Center's faculty contribute with advisory expertise to a number of national level concepts in science and technology. Strong contribution was made on preparation of the roadmap for development of a high-tech direction "Promising space systems and services" up to 2030, which passed the main stages of approvals. Support was also made on building of the roadmap of UAV development in Russia within the National Technology Initiative, the project on plastic waste detection and classification in the scope of smart city (funded by the National Technology Initiative). Skoltech presence was also ensured in working groups / committees involved in technology issues, including advising to JSC Russian Space Systems on commercial applications of new GNSS services, and participation in the Technical Committee 164 of Rosstandart, formely also in ISO/ EIC SC 42 "Artificial Intelligence".

## International network

Despite challenges of 2022, the Center supported diverse formats of international presence, including joint projects, academic mobility, conferences, membership in professional societies.

The EU HORIZON 2020 Solarnet project, where Skoltech representing Russia, brought Q1 publications, including the publication about the European Solar telescope. The grant project "Study on the Distributed Control of Heterogeneous Human-Robot Teams with Tactile Feedback for Collaborative Exploration and Patrolling" was ongoing with CNRS (Prof. Dzmitry Tsetserukou). Collaboration with University of Graz resulted in high-ranking publications and joint projects in Space Weather and Solar Physics. In particular, a New Space Weather Service within European Space Agency Space Safety Program on solar wind prediction was delivered with Skoltech logo.

The International Space Science Workshop was held in Switzerland with support of European Space Agency and Swiss Science Institute: Skoltech was represented by Prof. Tatiana Podladchikova and PhD student Galina Chikunova. Prof. Clement Fortin published and presented a common paper with researchers from Germany, France and Italy at the PLM conference in Grenoble. Prof. Pavel Osinenko chaired a session at the IEEE Conference on Decision and Control (CDC).

## Outreach and wider community engagement

The Center significantly supported Skoltech brand advancement and wider outreach programs. Multiple public lectures at sites in Moscow and far beyond, interviews to media sources (TASS, RIA news, Kommersant, Russia 1), invited talks at conferences. Some highlight examples are presented below:

- Prof. Tatiana Podladchikova and Prof. Dzmitry Tsetserukou participated in the movie "16 ways to change the world", a Russia's first Science Film Laboratory, built together by Skoltech and FANK.
- Open lectures on clock history and applications at Gorky Park (Dr. Ivan Sherstov).
- Programs for public education e.g. in dentistry; Christmas lectures and public lectures (Prof. Alexander Korsunsky).
- It Would Cost $65 Million To Display 60-Second Commercials In Twilight Above Cities, Forbes.
- Public lecture "How Sun creates Space Weather", Park Zaryadye, Prof. Tatiana Podladchikova.
- Interview to radio Mayak by Prof. Andrey Somov, served as an invited expert on detecting the Parkinson's disease using AI.
- Interview by Prof. Somov to Kommersant newspaper on hogweed detection.
- Invited talk of Prof. Andrey Somov, 'Data Collection and Data Analysis in eSports'. Sport of the Future Conference, Sirius Institute of Science and Technology, Russia, October 2022.
- Invited lecture of Prof. Dzmitry Tsetserukou. Autonomous Robots with AI Technologies. International Automobile Scientific Forum (MANF 2022), NAMI, Moscow, Russia.
- Invited lecture of Prof. Dzmitry Tsetserukou. Deep Learning for Mobile Robots and Self-Driving Cars. Keynote speech at the international Conference on Nonlinearity, Information and Robotics (NIR 2022), Innopolis, Russia.
- SQUID-based interferometric accelerometer. About the research under the guidance of Prof. Henni Ouerdane.

# Materials Center

The Center for Materials Technologies was established in 2021 within the transformation of Skoltech research and technology agenda, on the base of the Center for Design, Manufacturing and Technologies. The Center's development program covers three areas: (1) Polymer Composite Materials; (2) Functional Coatings; and (3) Additive Manufacturing. The specific goals are to develop research expertise, infrastructure, and commercialized solutions in the following areas: Large-scale composite structures for maritime applications and Arctic infrastructure, Import – substituting additive manufacturing, Certification of new materials and structures.
The Center is chaired by Prof. Ivan Sergeichev.

**53**
faculty and researchers

**34**
MSc and PhD students supervised

**11**
MSc and PhD graduates

**62**
papers, including 43 in Q1 journals, and 3 in Nature Index

**246**
mln Rub sponsored research funding 2022-2024

**20**
projects supported with grants and industry funding

Cutting-edge Engineering and Advanced Materials

## Research and technology highlights

In continuing the strategic program, the Center demonstrated a number of research and technology results, most important of which are outlined below:

1. NN XC functional was developed, which gives exchange potential and energy density without direct derivatives of exchange-correlation energy density. Proposed NN architecture consists of two parts NN-E and NN-V, which could be trained in separate ways, adding new flexibility to XC functional. We also show that the developed NN XC functional converges in the self-consistent cycle and gives reasonable energies when applied to atoms, molecules, and crystals.
   *Ryabov, A., Akhatov, I. & Zhilyaev, P. Application of two-component neural network for exchange-correlation functional interpolation. Sci Rep 12, 14133 (2022). https://doi.org/10.1038/s41598-022-18083-1 (Nature Index).*

2. Lunar regolith is the most critical material for the in-situ resource utilization (ISRU) in the crewed Moon exploration missions. This natural material can be utilized for the additive manufacturing of concrete or ceramic parts on the Moon's surface to support permanent human presence on the surface of Earth's natural satellite. The present study describes the characterization of the LHS-1 and LMS-1 simulants using XRF, XRD, SEM, EDX, DTA, TGA, UV/Vis/NIR spectroscopy, and laser diffractometry methods to provide data on their mineral, chemical, and fractional composition, as well as, on their morphology and optical properties. It was found that LHS-1 and LMS-1 simulants well mimic the primary properties of the original lunar regolith and can be potentially used for ISRU research tasks.
   *Isachenkov, et al. (2022). Characterization of novel lunar highland and mare simulants for ISRU research applications. // Icarus, 376, 114873. https://doi.org/10.1016/j.icarus.2021.114873 (IF=3.66; Q1).*

3. The technology of laser polishing was developed to simultaneously reduce factors that affected the fatigue properties, such as surface roughness and sub-surface porosity. Our findings show that significant porosity reduction in sub-surface area can be achieved with one scan pass without major deterioration of surface quality. The surface quality, sub-surface layer porosity and mechanical properties of the laser polished with pore removing pass and conventionally laser polished

samples are compared with as-built samples. *Panov, et al. (2022). Pore healing effect of laser polishing and its influence on fatigue properties of selective laser melted SS316L parts. // Optics and Laser Technology, 156, 108535. https://doi.org/10.1016/j.optlastec.2022.108535 (IF=4.94; Q1).*

4. The direct energy deposition approach implements a unique opportunity for controlling the fabrication of functionally graded (FG) and sandwich structures from different metal powders for artificial physical properties management. Our study revealed the promising FGS into Fe-Cu system based of SS316L with bronze and for the first time prediction of mechanical properties in those sandwich systems. *Makarenko et al. (2022). Mechanical characteristics of laser-deposited sandwich structures and quasi-homogeneous alloys of Fe-Cu system. // Materials and Design, 224, 111313. https://doi.org/10.1016/j.matdes.2022.111313. (IF=9.42; Q1).*

5. Developed a ceramic 3D-printer and AM technology for manufacturing of lead-free piezo-ceramics. *Smirnov et al. (2022) The Fabrication and Characterization of BaTiO3 Piezoceramics Using SLA 3D Printing at 465 nm Wavelength. Materials, 15, 960. https://doi.org/10.3390/ma15030960 (IF=4.94; Q1).*

6. The Center started cooperation with Russian Federal Nuclear Center – All-Russian Research Institute of Experimental Physics (RFNC-VNIIEF) in frames of works of the program *"Development of a software complex for modeling physical processes occurring in direct energy deposition /DED/ in order to predict the structure, material properties, as well as obtaining products with specified properties"*. Skoltech team has experimentally verified software modules, definition and data base filling of the process parameters as the project P.I. for subsection "Manufacturing".

7. RSF – OHK2020 project №-2020-19-00780 *"The novel manufacturing approach to the production of highly efficient lead-free textured piezo-ceramic materials using additive manufacturing technologies"* was successfully finished.

8. New technological approaches to the manufacturing of highly effective and textured piezoelectric materials using SLA-based 3D printing technology are developed. The use of ceramic additive SLA-

based 3D printing with various laser sources on several wavelengths, optimized in accordance with the optical characteristics of the lead-free piezoelectric materials – for a multiple increase of the 3D product's efficiency via additive manufacturing, compared with the existing world level used for the 3D printed piezo ceramics.

(Polymerization efficiency – from 10 microns to 100 or more μm). The use of additional subsystems of additive manufacturing installations that allow to be carried out the multi -material 3D -printing and to ensure the tasks of texturing piezoelectric ceramics items and creating a complex structure in the internal sample's topology.

## Top publications

1. S. Farisenkov, D. Kolomenskiy, P. Petrov, T. Engels, N. Lapina, F. Lehmann, R. Onishi, H. Liu, A. Polilov. Novel flight style and light wings boost flight performance of tiny beetles. Nature, 2022, 602:96-100. https://doi.org/10.1038/s41586-021-04303-7

2. A. Ryabov, I. Akhatov, P. Zhilyaev. Application of two-component neural network for exchange-correlation functional interpolation. Sci Rep 12, 2022, 14133. https://doi.org/10.1038/s41598-022-18083-1

3. I. Gerasimov, T. Losev, E. Epifanov, I. Rudenko, I. Bushmarinov, A. Ryabov, P. Zhilyaev, M. Medvedev. Comment on "Pushing the frontiers of density functionals by solving the fractional electron problem". Science, 2022, 377(6606), p.eabq3385. https://doi.org/10.1126/science.abq3385

4. K. Makarenko, O. Dubinin, S. Konev, I. Shishkovsky. Mechanical characteristics of laser-deposited sandwich structures and quasi-homogeneous alloys of Fe-Cu system. // Materials and Design, 224 (2022) 111313. Doi: 10.1016/j.matdes.2022.111313

5. M. Isachenkov, S. Chugunov, A. Smirnov, A. Kholodkova, I. Akhatov, I. Shishkovsky. The effect of particle size of highland and lunar regolith simulants on their printability in vat polymerisation additive manufacturing. Ceramics International, 2022, 43(23), 34713-19. doi: 10.1016/j.ceramint.2022.08.060

6. D. Panov, O. Oreshkin, B. Voloskov, V. Petrovskiy, I. Shishkovsky, I. Akhatov. Pore healing effect of laser polishing and its influence on fatigue properties

of selective laser melted SS316L parts. Optics and Laser Technology, Dec. 2022, v. 156, 108535. doi: 10.1016/j.optlastec.2022.108535

7. M. Isachenkov, S. Chugunov, Z. Landsman, I. Akhatov, A. Metke, A. Tikhonov, I. Shishkovsky. Characterization of novel lunar highland and mare simulants for ISRU research applications. Icarus, 2022, 376, 114873. Doi: 10.1016/j.icarus.2021.114873

8. N. Orekhov, J. Bondareva, D. Potapov, P. Dyakonov, O. Dubinin, M. Tarkhov, D. Diudbine, K. Maslakov, M. Logunova, D. Kvashnin, S. Evlashin. Mechanism of graphene oxide laser reduction at ambient conditions: Experimental and ReaxFF study. Carbon, 2022, 191, 546-554 https://doi.org/10.1016/j.carbon.2022.02.018

9. O. Dubinin, D. Chernodubov, Y. Kuzminova, D. Shaysultanov, I. Akhatov, N. Stepanov, S. Evlashin. Gradient soft magnetic materials produced by additive manufacturing from non-magnetic powders. Journal of Materials Processing Technology, 2022, 300, 117393. https://doi.org/10.1016/j.jmatprotec.2021.117393

10. S. Shalnova, Y. Kuzminova, S. Evlashin, O. Klimova-Korsmi, A. Vildanov, A. Shibalova, G. Turichin. Effect of recycled powder content on the structure and mechanical properties of Ti-6Al-4V alloy produced by direct energy deposition. Journal of Alloys and Compounds, 2022, 893, 162264. https://doi.org/10.1016/j.jallcom.2021.162264

11. K. Minchenkov, A.Vedernikov, Y. Kuzminova, S. Gusev, S. Sulimov, A. Gulyaev, A. Kreslavskaya, I. Prosyanoy, G. Xian, I. Akhatov, A. Safonov. Effects of the quality of pre-consolidated materials on the mechanical properties and morphology of thermoplastic pultruded flat laminates. Composites Communications 2022, 35, 101281, doi:10.1016/j.coco.2022.101281

12. A.Vedernikov, L. Gemi, E. Madenci, Y. Onuralp Özkılıç, S. Yazman, S. Gusev, A. Sulimov, J. Bondareva, S. Evlashin, S. Konev, I. Akhatov, A. Safonov. Effects of high pulling speeds on mechanical properties and morphology of pultruded GFRP composite flat laminates. Composite Structures 2022, 301, 116216, doi:10.1016/j.compstruct.2022.116216

13. P. Pathak, D. Dzhurinskiy, A. Elkin, P. Shornikov, S. Dautov, V. Ivanov. Enhanced High-Temperature YSZ-polyester Abradable Honeycomb Seal Structures. Journal of Thermal Spray Technology volume 31, 2022, pages307–314. http://dx.doi.org/10.1007/s11666-021-01298-5

## Educating leaders

New courses were developed to enrich the Materials Technology program, this included Fundamentals of Metallurgy, Advanced Additive Manufacturing – Ceramics, Computational Thermodynamics and Kinetics for Materials Design, Machine Learning for Engineering Applications, Functional Materials and Coatings.

Student success was evidenced in the papers published in impactful sources:

1. **Elkin, Aleksandr**, Viktor Gaibel, Dmitry Dzhurinskiy, Ivan Sergeichev. "A Multiaxial Fatigue Damage Model Based on Constant Life Diagrams for Polymer Fiber-Reinforced Laminates". Polymers 2022, 14(22), 4985; https://doi.org/10.3390/polym14224985

2. **Karamov, R.**, Akhatov, I., & Sergeichev, I. V. (2022). Prediction of fracture toughness of pultruded composites based on supervised machine learning. *Polymers*, 14(17), 3619. https://doi.org/10.3390/polym14173619

3. E. Syerko, T. Schmidt, D. May, C. Binetruy, S.G. Advani, S. Lomov, L. Silva, S. Abaimov, N. Aissa, I. Akhatov, M. Ali, N. Asiaban, G. Broggi, J. Bruchon, B. Caglar, H. Digonnet, J. Dittmann, S. Drapier, A. Endruweit, A. Guilloux, R. Kandinskii, A. Leygue, B. Mahato, P. Martínez-Lera, M. Matveev, V. Michaud, P. Middendorf, N. Moulin, L. Org´eas, C.H. Park, S. Rief , M. Rouhi, I. Sergeichev, M. Shakoor, O. Shishkina, Y. Swolfs, M. Tahani, R. Umer, K. Vanclooster, **R. Vorobyev**. "Benchmark exercise on image-based permeability determination of engineering textiles: Microscale predictions". Composites Part A: Applied Science and Manufacturing, Volume 167, April 2023, 107397

4. **A. Yu. Goldin** and A. R. Kasimov, "Synchronization of detonations: Arnold tongues and devil's staircases," Journal of Fluid Mechanics, vol. 946, R1, Sep. 2022, doi: 10.1017/jfm.2022.581.

5. Konstantin Leonov, Iskander Akhatov. The influence of dissolved gas on dynamics of a cavitation bubble in an elastic micro-confinement. *International Journal of Heat and Mass Transfer* 196, 123295 (2022) https://doi.org/10.1016/j.ijheatmasstransfer.2022.123295

6. **Konstantin I. Makarenko, Stepan D. Konev**, Oleg N. Dubinin, Igor V. Shishkovsky. Mechanical characteristics of laser-deposited sandwich structures and quasi-homogeneous alloys of Fe-Cu system. *Materials & Design, Volume 224, December 2022, 111313*

7. **Alexander Vedernikov, Kirill Minchenkov**, Sergey Gusev, Artem Sulimov, Ping Zhou, Chenggao Li, Guijun Xian, Iskander Akhatov and Alexander Safonov. Effects of the Pre-Consolidated Materials Manufacturing Method on the Mechanical Properties of Pultruded Thermoplastic Composites. *Polymers 2022, 14(11), 2246*; https://doi.org/10.3390/polym14112246

8. **Yulia O. Kuzminova**, Oleg N. Dubinin, Marina O. Gushchina, **Alexey P. Simonov, Stepan D. Konev**, Aigul A. Sarkeeva, Alexander P. Zhilyaev, Stanislav A. Evlashin, The mechanical behavior of the Ti6Al4V/Ti/Ti6Al4V composite produced by directed energy deposition under impact loading, Materialia, Volume 27,2023, 101684, https://doi.org/10.1016/j.mtla.2023.101684

**Daniil Panov** was awarded by DAAD by Funding Program Research Grants to visit RWTH (Aachen, Germany). **Igor Pchelintsev** was awarded by Skoltech-MIT long-term academic mobility program to conduct experimental research on dissertation. The thesis was successfully defended and the paper was submitted at Q1 journal «Ceramics International».

## Professional education

The Center also demonstrated success in ramping up professional education. The research and technology expertise was utilized in a number of programs for industry and academia:

- 3D Bioprinting: Processes, Materials, and Applications,
- Digital certification of composite materials and structures for civil engineering and infrastructure (delivered for the KuzSTU, RSC Energia, Mendeleev)
- Advanced additive manufacturing technologies (delivered for Mendeleev RCTU, Krastsvetmet)
- Manufacturing of polymer composite pultrusion products (delivered for Mendeleev RCTU).

## Think-act tank role

The contribution to the national scale technology projects was ensured via participation in the National Technology Initiative projects. In particular, in the project «Experimental and digital certification platform» project («TechNet» roadmap) the concept and infrastructure for accelerated certification of new materials and structures based on virtual testing was developed. The Center also involved in the NTI Center of Excellence «The new functional materials» based on Novosibirsk State University and a project «Design of structural materials with specified properties based on machine learning models».

In 2022, the Center for Materials Technologies successfully completed its reorganization and met all of KPIs, despite faculty layoffs and breaking international ties with a number of partners. We are actively developing cooperation with industrial companies in R&D and advanced training programs, which is extremely important for industry development in Russia and the creation of innovations.

**Prof. Ivan Sergeichev, Director of the Center**

## International network

The international ties were maintained on faculty-to-faculty level as well as in joint research projects, supported with grant funding.
The project "Topological design and selective laser melting of porous nitinol implants and scaffolds for medical applications" (Prof. Igor Shishkovsky) was implemented with support of Russian Foundation of Basic Research (RFBR-IRAN). Collaborations with Harbin Institute of Technology (China), University of Necmettin Erbakan (Turkey) and Federal Institute for Materials Research and Testing (Germany) on additive manufacturing were ongoing resulted in joint papers. Collaboration with SINTEF university (Norway) was maintained as a part of RFBR research project. Collaboration with the Institute of Transfusion Medicine and Immunology, Medical Faculty Mannheim, Heidelberg University was developed in terms of biomedical evaluation of prospective ceramic materials manufactured with AM technology at Skoltech.

## Innovation activities

**Patents and patent applications**

1. "Method for Improving Mechanical Properties of Ni-Based Alloys". Evlashin S., Bondareva Y., Akhatov I. S. (RU2021108682A)

2. Application for the invention «Method for Direct Laser Synthesis of Superelastic Endodontic Instruments from Titanium Nickel». Chernyshikhin S., Shishkovsky I. RU patent application № 2022117224

3. Application for the invention "Coating composition intended to protect steel structures against corrosion". Dzhurinskiy D. RU patent application №2022123666

**Startups:**
A startup WoonderTech LLC has been created to produce ceramic additive materials, equipment and software, as a part of Russian ceramic AM platform.

## Outreach and wider community engagement

Center's faculty, researchers and students supported Skoltech outreach and wider community with open lectures, interviews and summer schools. Some examples:

- summer schools for schoolchildren of Letovo School, Skolkovo Gymnasium, Pushkov Gymnasium (Troitsk)
- Prof. Iskander Akhatov gave a lecture on Mechanics and Physics in Materials Technologies
- Dr. Svyatoslav Chugunov gave a lecture on the Additive Ceramic Technologies – Problems and Solutions
- Daniil Panov (PhD3) presented interview about Laser polishes 3D-printed metal parts better than ever before
- Stanislav Chernyshikhin (PhD4) told Kommersant (RUS) about a 3D printing technology for manufacturing superelastic dental instruments
- Maxim Isachenkov (PhD4) gave a lecture on the Colonization of the Moon using 3D printing
- Prof. Ivan Sergeichev gave a lecture on Moscow Week of Design and Construction, https://mwdi.ru/education

Cutting-edge Engineering and Advanced Materials

# Petroleum Center

**The Center for Petroleum Science and Engineering was established in 2021 within the Institute's transformation of research and technology agenda, on the base of the Center for Hydrocarbon Recovery.**

The strategic program of the Center focuses on the following areas of specialization:

- Unconventional and hard-to-recover reservoir characterization (geophysics, petrophysics, geochemistry, digital core, geothermics and other)
- Geomechanics (experiment and mathematical modeling)
- Enhanced hydrocarbon recovery (gas, chemical, thermal methods)
- Geological, hydrodynamics, geome-chanics and coupled reservoir modeling
- Artificial Intelligence in oil and gas production
- Geocryology (permafrost and gas hydrate bearing reservoirs)
- Environmental science, geological risks, climate changes and energy transition

In 2022, the Center's goals included successful execution of the research plan, including specific results in all areas of activities, development of collaborations, execution of the grant for the "World level center on rational development of hydrocarbon resources", successful delivery of MSc, PhD programs and corporate education, development of commercial collaboration with industry, including companies from hydrocarbon production, oil and gas service, energy and other industries. The Center is chaired by Prof. Mikhail Spasennykh.

**112**
faculty and researchers

**69**
MSc and PhD students supervised

**33**
MSc and PhD graduates

**67**
papers, including 38 in Q1 journals. 2 special issues in Enhanced Recovery, Geocryology journals (Q1)

**622**
mln Rub sponsored research funding 2022-2024

**47**
projects supported with grants and industry funding

## Research and technology highlights

Despite of negative economic and political factors, the Center kept stability and continued execution of its strategy, demonstrating research and technology achievements.

The research excellence was evidenced with the following:

- Experimental study of fracture propagation in low permeable and fractured reservoirs for optimization of hydraulic fracturing technology, supported by the grant of Ministry of science and education 075-10-2022-011, applications in contracts with Gazprom Neft and Lukoil, results described in 3+ research reports and Q1 papers, including paper published in Nature Index Journal, Prof. S.Stanchits, Prof. D.Potapenko, Prof. A.Cheremisin.

- Development and application of XGBoost model for in- situ viscosity and water saturation determination in heavy oil using LF-NMR and density data. Published in 1 paper in Nature Indexed Journal publication, Prof. A.Cheremisin, Dr. A.Ivanova

- Experimental and theoretical study of thermal flow variations in sedimentary basins in West Siberia (North, Central and South), Volga-Ural basin, Pripyat basin, and Arctic shelf, research supported by the grant of Ministry of science and education 075-10-2022-011, applications in contracts with Gazprom Neft, Lukoil and Novatek, described in 3 research reports, published in 3 Q1 papers, monograph in preparation for publishing in 2023, Prof. Yu.Popov, Dr.E.Chekhonin

- Kinetics models of organic matter thermal destruction in geological and technological processes under reservoir conditions for RF source rock formations, supported by the grant of Ministry of Science and Education 075102022011, applications in contracts with Gazpromneft, Lukoil, Novatek, results described in 3 research reports, 3 papers in Q1 journals, 2 papers in preparation Prof. M.Spasennykh, Dr.E.Leushina.

- The experimental study of multiphase fluid filtration in collectors of hydrocarbons based on microfluidic technology for chemical EOR optimization, supported by the grant of Ministry of science and education 075-10-2022-011, applications (test of surfactants flooding agents) in contracts with Gazprom Neft and Zarubezhneft, results described in 3 research reports, 2 papers in Q1 Journals, Prof. A.Cheremisin.

- Study of carbonate rock wettability and sorption of HC gases on the surface of source rocks using molecular dynamics methods, supported by the grant of Ministry of science and education 075-10-

2022-011, results described in 1 research report, published in 3 Q1 papers, Prof. A.Vishniakov

- Study of geological risks for hydrocarbon production, relating to permafrost, methane emission and has hydrate saturating sediments, research under grant of RSF, published in 3 Q1 papers. Dr.Chuvilin

- Technology for improving mechanical properties of asphalt concrete by hyperbranched polymers (S.Abaimov, grant RSF 22-23-20170).

The portfolio of R&D contracts was extended, main directions included enhanced recovery, geomechanics, geochemistry and petrophysics of unconventional reservoirs, digital rock, artificial intelligence, nuclear waste disposal. The key clients were Gazprom Neft, Lukoil, Rosneft, Zarubezneft, Novatek, Rosatom.

Select technology results:

- Software solution for processing of microstructural multiscale core images developed for a major oil company, Skoltech – Digital Petroleum (Prof. D.Koroteev)

- Development of microfluidic technology for enhanced oil recovery optimization (surfactants flooding) in collaboration with oil and gas industry (Prof.A.Cheremisin)

- Optimization for hydraulic fracturing technology for low permeable reservoir (composition of hydraulic fracturing fluid, rate of injection, rheological properties) in collaboration with oil and gas industry (Prof. S.Stanchits, Prof. D.Potapenko)

- "Methodological recommendations for determination of thermal flow variations in the Earth crust for petroleum exploration, geothermal resource assessment and nuclear waste disposal" is developed in collaboration with oil and gas industry (Prof.Yu.Popov)

- Development of technological conception of supercritical water injection technology for production of hydrocarbons from unconventional reservoirs, in collaboration with oil and gas industry (Prof. A.Cheremisin, Prof. M.Spasennykh)

- A model of liquid carbon dioxide dissolution in a turbulent water flow for optimum designing $CO_2$ sequestration systems (Prof. D.Eskin).

The Center also organized 4 expeditions to geological objects in West Siberia and Belorussia and participated in Arctic marine expedition (study of methane greenhouse gas emission and environmental effect of Norilsk diesel oil spill in the Laptev sea, the Kara sea, the Eastern Siberia sea.)

## Top publications

Below are examples of the most influential papers to demonstrate the scope and impact of the Center's research:

1. Ebadi, M; Orlov, D; Alekseev, V; Burukhin, A; Krutko, V; Koroteev, D; Lift the veil of secrecy in sub-resolved pores by Xe-enhanced computed tomography, Fuel, 328, 125274, 2022 (Q1)

2. Ebadi, M; Armstrong, R; Mostaghimi, P; Wang, Y; Alqahtani, N; Amirian, T; James, L A; Parmar, A; Zahra, D; Hamze, H; Predictive Soft Computing Methods for Building Digital Rock Models Verified by Positron Emission Tomography Experiments, Water Resources Research, 58, 11, e2021WR031814, 2022 (Q1)

3. S. Markovich, A. Cheremisin, D. Koroteev and others, Application of XGBoost model for in-situ water saturation determination in Canadian oil-sands by LF-NMR and density data, Scientific Reports, DOI: 10.1038/s41598-022-17886-6, (Q1, Nature publishing group)

4. Ivanova, A; Orekhov, A; Markovic, S; Iglauer, S; Grishin, P; Cheremisin, A; Live imaging of micro and macro wettability variations of carbonate oil reservoirs for enhanced oil recovery and CO2 trapping/storage, Scientific Reports, DOI:10.1038/s41598-021-04661-2 (Q1, Nature publishing group)

5. Oye, V., Stanchits, S., Babarinde, O. et al. Cubic-meter scale laboratory fault re-activation experiments to improve the understanding of induced seismicity risks. Sci Rep 12, 8015 (2022). https://doi.org/10.1038/s41598-022-11715-6 (Q1, Nature publishing group)

6. Chuvilin E., Bukhanov B., Yurchenko A., Davletshina D., Shakhova N., Spivak E., Rusakov V., Dudarev O., Khaustova N., Tikhonova A., Gustafsson O., Tesi T., Martens J., Jakobsson M., Spasennykh M., Semiletov I. In–situ temperatures and thermal properties of the East Siberian Arctic shelf sediments: Key input for understanding the dynamics of subsea permafrost. Marine and Petroleum Geology, 138, 105550, 2022. DOI: 10.1016/j.marpetgeo.2022.105550 (Q1)

7. Eskin D., An Engineering Model of Heat Transfer through a Turbulent Falling Liquid Film for a Condensing Vapor Flow, Chem. Eng. Res. & Design 187, 2022, pp. 1-8 (Q1).

8. T. Karamov, E. Leushina, E. Kozlova and M. Spasennykh; Broad Ion Beam–Scanning Electron Microscopy Characterization of Organic Porosity Evolution During Thermal Treatment of Bazhenov Shale Sample SPE Res Eval & Eng 1–11. https://doi.org/10.2118/210599-PA (Q1)

9. Bruna F. Faria and Aleksey M. Vishnyakov Simulation of surfactant adsorption at liquid–liquid interface: What we may expect from soft-core models? J. Chem. Phys. 157, 094706 (2022); https://doi.org/10.1063/5.0087363 (Q1)

10. Pichugin Z., Chekhonin E., Popov Y., Kalinina M., Bayuk I., Popov E., Spasennykh M., Savelev E., Romushkevich R., Rudakovskaya S. Weighted geometric mean model for determining thermal conductivity of reservoir rocks: Current problems with applicability and the model modification. Geothermics 2022, 104, 102456. https://doi.org/10.1016/j.geothermics. 2022.102456 (Q1)

11. M. Owais, A. Shiverskii, A. Sulimov, D. Ostrizhiniy, Y. Popov, B. Mahato, S.G. Abaimov, Scalable fabrication of thermally conductive layered nacre-like self-assembled 3D BN-based PVA aerogel framework nanocomposites, Polymers, 14(16), 3316, 2022, DOI 10.3390/polym14163316. (Q1)

## Educating leaders

The Center continued to deliver the Petroleum Engineering (MSc and PhD) program, which was for the second year in a row recognized in QS subject ranking (position 101-105). Students' achievements were observed in successful defenses, top publications, awards and recognition. Select examples:

- Strahinja Markovic successfully passed a joint PhD defense with Curtin University, Australia. The joint defense took place at Skoltech and was held in a blended format. Strahinja became the second Skoltech PhD student defending a doctoral thesis within a joint procedure with Curtin University.
- The Journal of Petroleum Technology, the Society of Petroleum Engineers' flagship magazine, featured a recent research by Evgeny Baraboshkin and his colleagues, who trained a neural network to recognize roc samples in core box images efficiently.
- The paper with co-authorship of MSc student Z.Pichugin and PhD student M.Kalinina "Weighted geometric mean model for determining thermal conductivity of reservoir rocks: Current problems with applicability and the model modification" has been published

in Q1 journal Geothermics 2022, 104, 102456.
- Vitalii Kazaku became the winner of the Russian national award Student of the Year in the nomination "Intelligence." The contest is organized by the Ministry of Science and Higher Education, the Ministry of Education, the Federal Agency for Youth Affairs (Rosmolodezh), the Russia — Land of Opportunity nonprofit, and the Russian Union of Youth.

As for graduation class 2022, the majority of students were employed in R&D sector in Russia (Aramco, Gazprom, Rosneft) or continued in the Center on junior research and engineering positions.

The professional education track was expanded with new programs and workshops for the industry partners. Thus, more than 30 workshops and technological seminars were delivered for Gazprom Neft, LUKOIL Engineering Company, Belorusneft, Zarubezhneft, Rosatom and other companies of the oil and gas sector. The new program composed of 20 courses was delivered by Prof. A. Tchistiakov, and lectures on AI for industrial applications in exploration and development of natural recourses were presented for SBER's top management by Prof. Koroteev.

## Innovation activities

The Center contributed to Skoltech IP with a number of patents:

- RF patent 2786927 by P.Afanasiev, A.Cheremisin, E.Popov The method for enhanced recovery of heavy oil and bitumen with production of light oil and hydrogen containing gas;
- RF patent 2022110266 by B.Bukhanov, E.Chuvilin, A.Mukhametdinova, V.Istopmin, The method for determination of water in gas hydrate saturated reservoirs (granted);

The key task of the Center for today is to keep stability, ability to provide world class science, education and innovation, keep research potential, people, academic and industrial partners in spite of unstable environment.

**Prof. Spasennykh, Director of the Center**

- Russian patent application 2022116006: Mahato B., Abaimov S.G., Lomov S.V., The method to determine or monitor the degree of cure of thermosets.

The patent 2764734 was licensed to LabAdvance company (researcher E.Shilov and Prof. A.Cheremisin). Five startups founded by the Center's faculty, students continued their activities.

A new company "Hydrogen Power" was created by PhD student P.Afanasiev and Prof. A.Cheremisin. The first international startup in UAE was created by "Digital Petroleum" (Prof. D.Koroteev).

## Think-and-act tank role

The Center's expertise is in demand in various national level technology initiatives, and top oil and gas companies. Prof. Spasennykh chairs the Expert Group of the Commission on Technological Development of Russia's Economy under President of RF, responsible for development and control of innovation activity in oil and gas industry, while Prof. A.Cheremisin is a member of the Group. Professors M. Spasennykh, A.Cheremisin, D.Koroteev, S.Stanchits, Y.Popov, A.Tchistiakov are the members of joint Skoltech-Lukoil, Skoltech-Gazprom neft, Skoltech-Zarubezhneft Councils on research and development. Prof. Y.Popov and colleagues are participants in development of the program "Geothermal Energy" in "Arctic Energy" program to ensure sustainable development and development of the northern and Arctic territories of the RF.

## International collaborations

Despite the challenging international context, the Center opened new avenues of collaboration with universities and research centers in the Middle East (Khalifa University (UAE), KAUST (Saudi Arabia), Asia (Nanjing University (China), Vietnam Petroleum Institute, Research Center of Oil and Natural gas company (India), Belorussia (BelNIPIneft). Joint projects were continued with peers in France, Canada, Germany, Norway, India and other countries. Examples include renewal of the agreement with IFP School (France), ongoing projects with KU Leuven (Belgium), collaboration with SINTEF (Norway) on ice accretion modeling, collaboration with University of Alberta on emulsion modeling within co-supervision of PhD student, continuation of the research agreement with Indian State Oil and Gas Corporation (ONGC).

## Outreach and wider community engagement

The Center's research and technology expertise was widely featured in news, interviews, open lectures and other formats for brand development. Select highlights included:

- Prof. Chuvilin: "The Russian Arctic and the enigmatic permafrost". Popular science lecture at the RGS 2022.
- Prof. Chuvilin, Natalia Sokolova. What do the hillocks on the surface of the tundra hide in themselves? Popular science article on the site goarctic.ru.
- Interview of Prof. Chuvilin to the Vice: The Arctic Seafloor Is Degrading and Could Be a Climate Time Bomb.
- Interview of Prof. Chuvilin to Turkish television: Methane blowout craters in Siberia are 'canary in a coal mine for global climate'
- Interview of Prof. Chuvilin to Newsweek
- Participation in a short scientific film in the almanac Almanac "16 Ways to Change the World"
- News on 3D nanocomposites boost heat dissipation in electronics (PhysOrg, TASS, Habr)
- Nanostructure strengthens, de-ices, and monitors aircraft wings, wind turbine blades, and bridges (PhysOrg, NakenScience, Habr)


Skoltech

# Energy Center

The Center for Energy Science and Technology was established in 2018 on the base of Skoltech Center for Energy Systems and Skoltech Center Electrochemical Energy Storage. The strategic program of the Center aims at high impactful research and education in the area of energy efficiency and energy storage to facilitate transition of Russia to low- and zero-carbon economy, development of technological solutions and preparing high quality specialists for modern energy industry. The program is organized in five thrusts (1) Electrochemical Energy Storage, (2) Electrochemical Energy Conversion, (3 Smart Energy Grids: Systems and Devices, (4) Sustainable Low-Carbon Energy Systems, (5) Artificial Intelligence in Energy. The Center is chaired by Prof. Artem Abakumov.

**81**
faculty and researchers

**69**
MSc and PhD students supervised

**29**
MSc and PhD graduates

**109**
papers, including 88 in Q1 journals (14 papers in Nature Index)

**263**
mln Rub sponsored research funding 2022-2024

**27**
projects supported with grant and federal subsidies

Energy Efficiency & Energy Transition


СОЛЬ
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## Research and technology highlights

In implementing the program, the Center demonstrated a number of achievements:

- A new artificial intelligence approach is developed to find and understand (possibly alternative) pathways towards optimizing functional properties of materials *Mazheika, A., Wang, Y.G., Valero, R., Viñes, F., Illas, F., Ghiringhelli, L.M., Levchenko, S.V. and Scheffler, M., 2022. Artificial-intelligence-driven discovery of catalyst genes with application to $CO_2$ activation on semiconductor oxides. Nature Communications, 13(1), pp.1-13.*

- New record-breaking eleactrode materials NaVPO4F for Na-ion batteries have been discovered. *S.D. Shraer, N.D. Luchinin, I.A. Trussov, D.A. Aksyonov, A.V. Morozov, S.V. Ryazantsev, A.R. Iarchuk, P.A. Morozova, V.A. Nikitina, K.J. Stevenson, E.V. Antipov, A.M. Abakumov, S.S. Fedotov, Development of vanadium-based polyanion positive electrode active materials for high-voltage sodium-based batteries, Nat. Commun., 13, 4097 (2022).*

- Methods for degradation-aware optimal cycling of electro-chemical storage units have been developed. *Sayfutdinov, T., & Vorobev, P. (2022). Optimal utilization strategy of the LiFePO4 battery storage. Applied Energy, 316, 119080.*

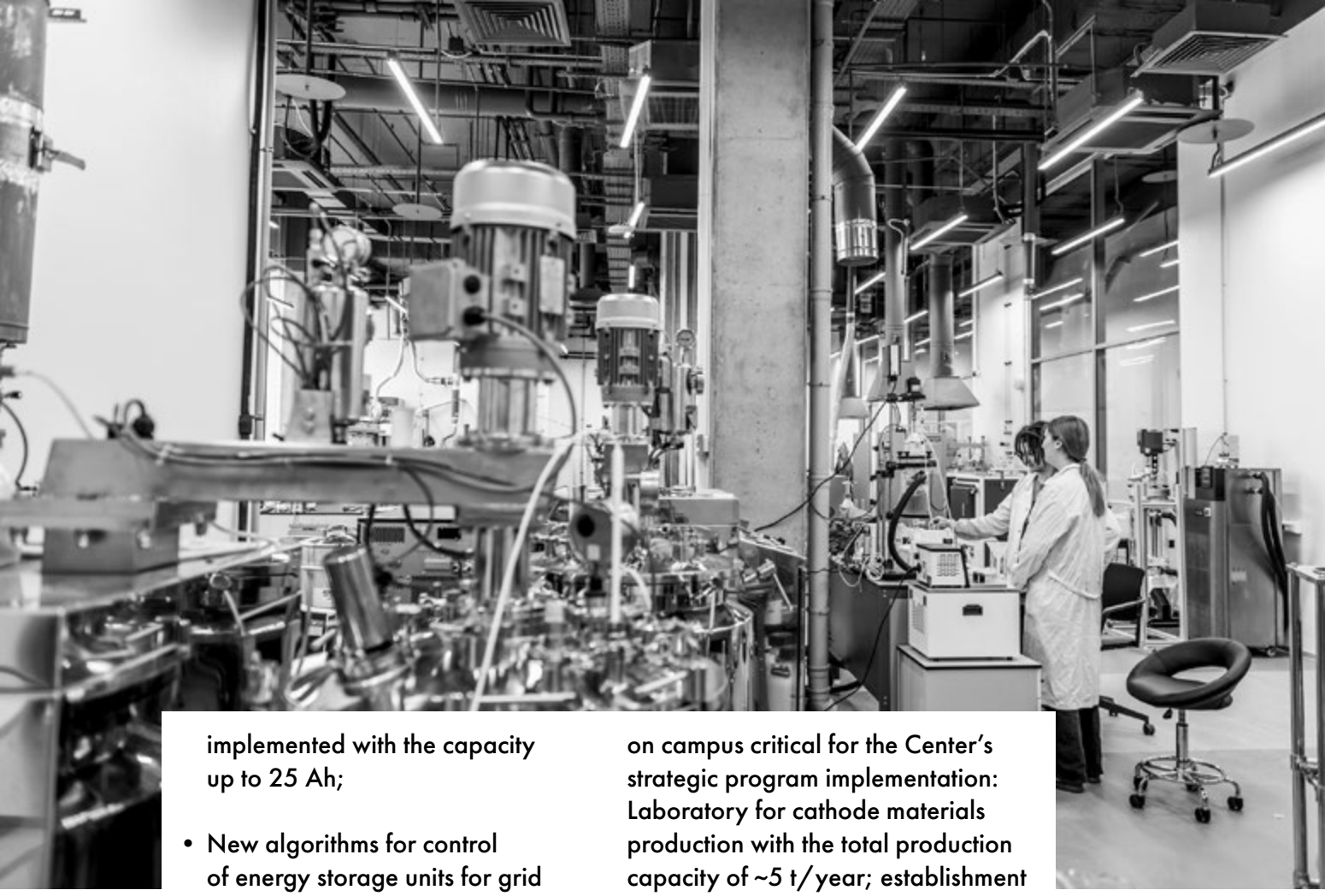
- Novel methods for microgrid stability assessment were developed, with computation complexity not sensitive to microgrid size (thus, breaking the curse of dimensionality): *Gorbunov, J. C. -H. Peng, J. W. Bialek and P. Vorobev, "Identification of Stability Regions in Inverter-Based Microgrids," in IEEE Transactions on Power Systems, vol. 37, no. 4, pp. 2613-2623, July 2022.*

- Dynamic models for vanadium redox flow batteries were proposed. *Dynamic modeling of vanadium redox flow batteries: Practical approaches, their applications and limitations, Bogdanov, S., Pugach, M., Parsegov, S., …Stevenson, K.J., Vorobev, P. Journal of Energy Storage, 2023, 57, 106191.*

- A new technology of high-Ni high-density single crystal cathode materials has been patented; *Abakumov, A.M., Savina A.A., Moiseev I.A, Pavlova A.D. High bulk energy density cathode material for lithium ion batteries, RU 2 776 156, 14.07.2022.*

- A set of new fluorinated organic solvents were predicted with ab initio computational methods,

- New formfactor for the LIB pouch cells has been



implemented with the capacity up to 25 Ah;

- New algorithms for control of energy storage units for grid services are developed.

The core infrastructural developments included a launch of research facilities on campus critical for the Center's strategic program implementation: Laboratory for cathode materials production with the total production capacity of ~5 t/year; establishment of the Electrocatalysis lab and modernization of facilities of the Real Time Digital Simulator laboratory (supported with Megagrant project).

In 2022 CEST has made a great step towards establishing the world-class R&D labs in the energy domain by launching the Laboratory for Cathode Materials Production with the total production capacity of ~5 t/year and Electrocatalysis Lab, as well as by modernization of facilities of the Megagrant Real Time Digital Simulator Laboratory. CEST confirmed its positioning as a leading research unit in this field by demonstrating outstanding publication activity resulting in 14 Nature Index papers. As a partner, CEST has started a new NTI Center of Competence on Mobile Energy Storage Technologies. Industrially-oriented research at CEST has resulted to protected IP in a form of a patent, know-how and registered software. CEST delivers the competences to the industrial partners through dedicated professional education programs, such as "Chemical background for obtaining battery electrode materials" (Nornickel) and "PJSC Rosseti Energy Leaders.

**Prof. Artem Abakumov, Director of the Center**

## Top publications

1. Mazheika, A., Wang, Y.G., Valero, R., Viñes, F., Illas, F., Ghiringhelli, L.M., Levchenko, S.V. and Scheffler, M., 2022. Artificial-intelligence-driven discovery of catalyst genes with application to CO2 activation on semiconductor oxides. Nature Communications, 13(1), pp.1-13.

2. S.D. Shraer, N.D. Luchinin, I.A. Trussov, D.A. Aksyonov, A.V. Morozov, S.V. Ryazantsev, A.R. Iarchuk, P.A. Morozova, V.A. Nikitina, K.J. Stevenson, E.V. Antipov, A.M. Abakumov, S.S. Fedotov, Development of vanadium-based polyanion positive electrode active materials for high-voltage sodium-based batteries, Nat. Commun., 13, 4097 (2022).

3. B. Li, K. Kumar, I. Roy, A.V. Morozov, O.V. Emelyanova, L. Zhang, T. Koç, S. Belin, J. Cabana, R. Dedryvère, A.M. Abakumov, J.-M. Tarascon, Capturing dynamic ligand-to-metal charge transfer with a long-lived cationic intermediate for anionic redox, Nature Mater., 21, 1165–1174 (2022).

4. Y. Watanabe, K. Hyeon-Deuk, T. Yamamoto, M. Yabuuchi, O.M. Karakulina, Y. Noda, T. Kurihara, I.-Y. Chang, M. Higashi, O. Tomita, C. Tassel, D. Kato, J. Xia, T..Goto, C.M. Brown, Y. Shimoyama, N. Ogiwara, J. Hadermann, A.M. Abakumov, S. Uchida, R. Abe, H. Kageyama, Polyoxocationic antimony oxide cluster with acidic protons, Sci. Adv., 8, eabm5379 (2022).

5. Liu, Y., Han, Z., Gewinner, S., Schöllkopf, W., Levchenko, S.V., Kuhlenbeck, H. and Roldan Cuenya, B., 2022. Adatom Bonding Sites in a Nickel-Fe3O4 (001) Single-Atom Model Catalyst and O2 Reactivity Unveiled by Surface Action Spectroscopy with Infrared Free-Electron Laser Light. Angewandte Chemie International Edition, 61(28), e202202561.

6. A. A. Buchachenko, G. Visentin, and L. A. Viehland, Gaseous transport properties of the ground and excited Cr, Co and Ni cations in He: Ab initio study of electronic state chromatography, J. Chem. Phys., 2022, 157, 104303.

7. Komayko, A. I.; Arkharova, N. A.; Presnov, D. E.; Levin, E. E.; Nikitina, V. A. Resolving the Seeming Contradiction between the Superior Rate Capability of Prussian Blue Analogues and the Extremely Slow Ionic Diffusion. J. Phys. Chem. Lett. 2022, 13 (14), 3165-3172.

8. Liu, Y., Ćetenović, D., Li, H., Gryazina, E., & Terzija, V. (2022). An optimized multi-objective reactive power dispatch strategy based on improved genetic algorithm for wind power integrated systems. International Journal of Electrical Power & Energy Systems, 136, 107764.

9. Network Topology Invariant Stability Certificates for DC Microgrids With Arbitrary Load Dynamics, Chevalier, S., Ibanez, F.M., Cavanagh, K., ...Daniel, L., Vorobev, P. IEEE Transactions on Power Systems, 2022, 37(3), pp. 1782–1797.

10. Dynamic modeling of vanadium redox flow batteries: Practical approaches, their applications and limitations, Bogdanov, S., Pugach, M., Parsegov, S., ...Stevenson, K.J., Vorobev, P. Journal of Energy Storage, 2023, 57, 106191.

## Educating leaders

The Center continued to deliver the Energy program. New courses were developed: Monitoring, protection, and control for future power systems, Density Functional Theory (Joint undergrad program with Mendeleev University of Chemical Technology), Materials Chemistry, Materials Characterization Techniques, Digital Technologies in Electrical Grids. Considering the new federal regulations, the curriculum for Doctoral Program in Materials Science & Engineering was designed and updated. Nine graduates successfully defended in 2022.

Students' success was evidenced in publications, highlight examples include:

1. **Ivan A. Moiseev,** Aleksandra A. Savina, **Alina D. Pavlova,** Tatiana A. Abakumova, Vladislav S. Gorshkov, Egor M. Pazhetnov, Artem M. Abakumov, Single crystal Ni-rich NMC cathode materials for lithium-ion batteries with ultra-high volumetric energy density, Energy Adv., 1, 677–681 (2022).

2. **Anatolii V. Morozov**, Haemin Paik, Anton O. Boev, Dmitry A. Aksyonov, Svetlana A. Lipovskikh, Keith J. Stevenson, Jennifer L. M. Rupp, Artem M. Abakumov, Thermodynamics as a Driving Factor of LiCoO2 Grain Growth on Nanocrystalline Ta-LLZO Thin Films for All-Solid-State Batteries, ACS Appl. Mater. Interfaces, 14, 39907–39916 (2022).

3. **Anatolii V. Morozov, Ivan A. Moiseev**, Aleksandra A. Savina, Anton O. Boev, Dmitry A. Aksyonov, Leiting Zhang, **Polina A. Morozova**, Victoria A. Nikitina, Egor M. Pazhetnov, Erik J. Berg, Stanislav S. Fedotov, Jean-Marie Tarascon, Evgeny V. Antipov, Artem M. Abakumov, Retardation of Structure Densification by Increasing Covalency in Li-Rich Layered Oxide Positive Electrodes for Li-Ion Batteries, Chem. Mater., 34, 6779–6791 (2022).

4. **Semyon D. Shraer, Nikita D. Luchinin**, Ivan A. Trussov, Dmitry A. Aksyonov, **Anatoly V. Morozov**, Sergey V. Ryazantsev, Anna R. Larchuk, **Polina A. Morozova**, Victoria A. Nikitina, Keith J. Stevenson, Evgeny V. Antipov, Artem M. Abakumov, Stanislav S. Fedotov, Development of vanadium-based polyanion positive electrode active materials for high-voltage

sodium-based batteries, Nat. Commun., 13, 4097 (2022).

5. **Artem D. Dembitskiy**, Dmitry A. Aksyonov, Artem M. Abakumov, Stanislav S. Fedotov, NH4+-based frameworks as a platform for designing electrodes and solid electrolytes for Na-ion batteries: A screening approach, Solid State Ionics, 374, 115810 (2022).

6. **Irina Skvortsova**, A.A. Savina, E.D. Orlova, V.S. Gorshkov **A.M. Abakumov**, Microwave-Assisted Hydrothermal Synthesis of Space Fillers to Enhance Volumetric Energy Density of NMC811 Cathode Material for Li-ion Batteries, Batteries, 8, 67 (2022).

7. **D. Slaifstein**, F. M. Ibanez and K. Siwek, "Supercapacitor Modeling: A System Identification Approach," in IEEE Transactions on Energy Conversion, 2022.

8. Ali, M.H., **Slaifstein, D.**, Ibanez, F.M., Zugschwert, C., Pugach, M., Power Management Strategies for Vanadium Redox Flow Battery and Supercapacitors in Hybrid Energy Storage Systems, IEEE PES Innovative Smart Grid Technologies Conference Europe, 2022.

9. **Shubnaya, A.**, Ibanez, F.M., Rodriguez Cortes, P. Compensating measurement delays in decoupling blocks of dq control technique for multiple active bridge converter, IECON Proceedings (Industrial Electronics Conference), 2022.

Considering the graduates' employment, the majority stayed in the Center on junior research positions to continue R&D projects. Those decided to continue for PhD, were admitted to Skoltech, or European universities (Technical University of Denmark, Groningen).

## Professional education

The results were also achieved in development of professional education. The "Chemical background for obtaining battery electrode materials" was delivered for Nornickel, while the program "PJSC Rosseti Energy Leaders" was designed and delivered for 100 engineers holding senior positions. The program composed of 5 modules with foreign speakers involved, and became the biggest professional education program in Skoltech so far.

## Innovation activities

Select research results were secured with IP:

- Abakumov, A. Savina, I. Moiseev, A. Pavlova, Cathode material with high energy density for lithium-ion batteries, patent RU 2 776 156, 14.07.2022;
- The know-how protection of the technical solution "Evaluation

of the intensity of icing at an arbitrary point on the wire of an overhead line by measuring the mass of deposits on the wire at two other points" was implemented (Order № 1425 22.12. 2022; authors: Titov D. Volkhov K.).

## Think-act role

The Center is strongly involved in advising on national level science and technology concepts and initiatives related to energy storage direction. Thus, the Center became a partner in a new NTI Center of Competence on Mobile Energy Storage Technologies, took part in development of the RF roadmap for the high-tech area "Electricity storage systems" up to 2030, analytical report "Demand factors for electric vehicles among the population of Russia". Center's faculty also serve on a number of scientific councils: scientific council of the RENERA company (division of Rosatom) (Prof. Antipov), Council for the priority direction of scientific and technological development of the RF "Transition to environmentally friendly and resource-saving energy" (Prof. Antipov), Russian Science Foundation and Komissarov Foundation.

## International collaborations

The international agenda was influenced with geopolitical tensions, resulted in stand-by in some projects or cancellation in participation of international partners. Below are select examples of research supported with grants:

- BRICS-STI (Russian Ministry of Education, China and India) grant "Active Machine Learning Guided Discovery and Optimization of Effective MOF-based Catalysts for Electrolysis of Water",
- RFBR 21-53-12039 Complex approach towards design of potassium-ion batteries, 2021-2023. In March German partners left the project, but it is still supported by RFBR.
- RSF-FWO project 20-43-01012 Towards improved high capacity layered electrode materials for Li-ion batteries through atomic-level understanding of the redox reactions. The Belgian partner left the project, but the project was completed.
- RSF-DST project 22-49-02065 UNIFY (solutions for clean energy iNtegration in power grids with Improved Flexibility). In collaboration with IIT Kanpur, India.

The Center was involved in organizing international research symposia or seminars: "Agile Design of Electronic Materials: Aligned Computational and Experimental Approaches and Materials Informatics" within the conference Electronic Materials and Applications jointly with Oak Ridge National Laboratory, Los Alamos National Laboratory, TUM and Juelich Research Center; and Seminar Series on Smart Technologies and Solutions for Future Energy Systems, involving international speakers (Prof. Terzija).


**Professional and wider community engagement**

A range of activities were held to highlight the Center's research and advance Skoltech in a wider community by delivery of open lectures, interviews to media. Two conferences were organized on campus: XVII International conference «Actual problems of energy transition in lithium electrochemical systems, and VII International School-Conference of Young Scientists in Topical Issues of Modern Electrochemistry and Electrochemical Materials Science. The wider outreach included the following lectures and interviews:

- "Computational materials design" course (Prof. Levchenko at Vysshaya Tekhnicheskaya Shkola),
- FUNK laboratory project movie (Prof. Fedotov in starring on Na-ion batteries),
- lectures to Rotary Clubs in Moscow (Prof. Terzija),
- lecture in ArChe on digital transformation in electric power industry (Prof. Titov),
- lectures on renewable energy in ESG professional program (Prof. Vorobev),
- Prof. Abakumov gave interviews for TASS, Stimul journal,
- Prof. Antipov gave interviews to Vedomosti, Ren.TV, Tvc.


7-11 НОЯБРЯ 2022, E-R2-2019
«Технологический менеджмент» для победителей первого всероссийского конкурса «Лидеры энергетики»
Skoltech


SMART GRID
КВЕСТ

# Energy Transition Center

The Project Center for Energy Transition was established in 2021 under the chair of Prof. Andrey Osiptsov within the process of transformation of Skoltech research and technology agenda. The Center supports Skoltech strategic goal to become a leading think tank and technology provider, conducting a program in the field of decarbonization of heavy industry in Russia.
The Center's capacities are formed in the following core lines: (i) continued professional education, public analytics and business development, (ii) technology consulting, and (iii) R&D projects within national science and technology programs or in collaboration with industry. Since the Center is newly established, main goals for 2022 were to operationalize the team and make the first progress.

**8**
faculty and researchers

**6**
MSc and PhD students supervised

**4**
professional education programs for > 100 participants

**31**
Mln Rub sponsored research funding per faculty (62 mln Rub total)

**15**
papers in Q1 journals, incl. 3 in Nature index journals

**5**
analytical reviews on technology trends

Energy Efficiency & Energy Transition

## R&D highlights

In 2022, the Center advanced collaboration with a key partner, Gazprom Neft on several directions. Collaboration on CCUS (carbon capture, utilization and storage) and green oilfield services technologies was set in the program that will cover fluid mechanics and geomechanics modeling of $CO_2$ storage reservoirs to evaluate capacity, injectivity and containment and will be implemented in support of development of Russian technology of carbon capture and storage. Within this strategic level collaboration, Skoltech becomes the key scientific partner and a lead of consortium for Gazprom Neft on CCUS. R&D program on flowback technology for well startup after a multistage hydraulic fracturing was continued. The Center also started to perform the program on self-trained reservoir model co-funded jointly with the Applied AI Center. The highlights of research of the Center's teams are presented below:

### Prof. Kvashnin's team:

- Computational prediction of stable stoichiometries in ternary refractory system Hf-Ta-C with their synthesis by plasma dynamics method with subsequent investigation of thermal stability and mechanical properties *(Adv. Func. Mat., 2206289 (2022))*.
- Optimization of synthesis process of WB5-x by using vacuumless arc plasma method allowing the synthesis of nanopowders perspective in various applications including catalysis *(Inorg. Chem. 61, 18, 6773-6784 (2022))*.

### Dr. Sergei Boronin's team:

- Development and implementation of a mathematical model for evaluation of geomechanical risks during $CO_2$ injection into underground formations *(E. Kanin I. Garagash, S. Boronin, S. Zhigulskiy, A. Penigin, A. Afanasyev, D. Garagash and A. Osiptsov, $CO_2$ storage in deep saline aquifers: evaluation of geomechanical risks using integrated modeling workflow. Manuscript under review in Journal of Natural gas Science and Engineering*);
- Development and numerical implementation of algorithm for building of reservoir permeability map using combined mechanistic and machine learning approach *(E.A. Kanin, A.A. Garipova, S.A. Boronin, V.V. Vanovsky, A.L. Vainshtein, A.A. Afanasyev, A.A. Osiptsov and E.V. Burnaev, Combined mechanistic and machine learning method for construction of oil reservoir permeability map consistent with well test measurements. Manuscript under*

*review in Computers & Geosciences journal);*

- Development of mathematical model for fracture flowback to mitigate loss of long-term production (*S.A. Boronin, K.I. Tolmacheva, I.A. Garagash, I.R. Abdrakhmanov, G. Yu Fisher, A.L. Vainshtein, P.K. Kabanova, E.V. Shel, G.V. Paderin, A.A. Osiptsov (2022) Integrated modeling of fracturing-flowback-production dynamics and calibration on field data: Optimum well startup scenarios, Petroleum Science, https:// doi. org/ 10.1016/ j.petsci.2022.12.009).*

## Think-act tank role

The Center co-founded the Climate Business Club, together with Gazprombank's Center for International Comparative Law Research. The club united representatives of business, government and educational communities to address the avenues of development of climate business strategies and climate regulation in Russia. Over 20 meetings were held, also involving academic staff of other Skoltech Centers with targeted expertise. The Club was endorsed by Ruslan Edelgeriev, Advisor to the RF President on climate issues, as a think tank for preparation of COP28 and various strategies and initiatives in the field.

The Center also released several reviews on the subjects for Energy Transition: A review on the status and prospects of CCUS technology for decarbonization of Russian industry, a series of 3 monthly reports on Technology & Market Watch in the field of Energy Transition, with the annual review for 2022 and a review on the key outcome of 2022 for the energy industry in Russia and in the world.

Energy Transition Center has extended collaboration with the key partner, Gazprom Neft, on several directions. Collaboration on CCUS (carbon capture, utilization and storage) and green oilfield services technologies continues. Fluid mechanics and geomechanics modeling is underway to evaluate capacity, injectivity and containment of $CO_2$ storage reservoirs in support of development of Russian CCUS technology for the benefit of two ultimate clients, large emitters from heavy industry. Within this strategic level collaboration, Skoltech becomes the key scientific partner and a lead of consortium for Gazprom Neft on CCUS. We now also take part in the work group on developing CCUS standards at the state level.

**Prof. Andrey Osiptsov, Director of the Center**

## Top publications

The following publications are examples to illustrate the scope and impact of Center's research outputs in 2022:

1. A.Ya. Pak, D.V. Rybkovskiy, Yu.Z. Vassilyeva, E.N. Kolobova, A.V. Filimonenko, A.G. Kvashnin*, Efficient Synthesis of WB5-x-WB2 Powders with Selectivity for WB5-x Content, Inorg. Chem. 61, 18, 6773-6784 (2022) (DOI: 10.1021/acs.inorgchem.1c03880), Q1, **Nature Index**, Journal Cover.

2. D.V. Semenok, W. Chen, X. Huang*, D. Zhou, I.A. Kruglov, A.B. Mazitov, M. Galasso, C. Tantardini, X. Gonze, A.G. Kvashnin*, A.R. Oganov, T. Cui*, Sr-Doped Molecular Hydrogen: Synthesis and Properties of SrH22, Adv. Mat. 2200924 (2022) (DOI: 10.1002/adma.202200924), Q1, Nature Index.

3. A.G. Kvashnin*, D.S. Nikitin*, I.I. Shanenkov, I.V. Chepkasov, Yu.A. Kvashnina, A. Nassyrbayev, A.A. Sivkov, Z. Bolatova, A.Ya. Pak, Large-Scale Synthesis and Applications of Hafnium–Tantalum Carbides, Adv. Func. Mat., 2206289 (2022) (DOI: 10.1002/adfm.202206289), Q1.

4. Duplyakov V. M., Morozov A. D., Popkov D.O, E.V.Shel, A.L.Vainshtein, E.V.Burnaev, A.A.Osiptsov, G.V.Paderin, Data-driven model for hydraulic fracturing design optimization. Part II: Inverse problem. Q1J. Petrol. Sci. Eng., 208, Part A, 1093036 (2022), https://doi.org/10.1016/j.petrol.2021.109303, Q1.

5. S.A. Boronin, K.I. Tolmacheva, I.A. Garagash, I.R. Abdrakhmanov, G. Yu Fisher, A.L. Vainshtein, P.K. Kabanova, E.V. Shel, G.V. Paderin, A.A. Osiptsov, Integrated modeling of fracturing-flowback-production dynamics and calibration on field data: Optimum well startup scenarios, Petroleum Science (2022) (DOI: https://doi.org/10.1016/j.petsci.2022.12.009), Q1

6. Khmelenko, P., Shel, E., Boronin, S., Paderin, G., & Osiptsov, A. (2022). Proppant Packing Near the Fracture Tip during Tip Screenout: Asymptotic Models for Pressure Buildup Calibrated on Field Data and Verified with Two-Continua Simulations. SPE Journal, 27(04), 2126-2144. Scopus.

7. Kanin, E. A., Garagash, D. I., & Osiptsov, A. A. (2022). Turbulent Flow Effects on Propagation of Radial Hydraulic Fracture in Permeable Rock. Chapter in "Mechanics of Hydraulic Fracturing: Experiment, Model, and Monitoring."

## Educating leaders

The major activities were held in advancing the Center's expertise through professional education programs. Jointly with Ufa REC the Center conducted «ESG in new reality» program for over 40 representatives from regional business, academia and governmental authorities. Also, the Center delivered a part of the program for Rosneft and Gazprombank on topics related to energy transition. Based on the results, the fill scale program will be delivered for Gazprombank while Rosneft initiated a follow up training on technology management: both activities are planned for 2023.
Two programs on application of AI in ESG projects were delivered for over 40 participants, representing business, Moscow Government, startups and research communities.
With regards to MSc programs, the Center designed a concept for a new MSc program on Applied Computational Mechanics, which was reviewed and supported by key industry players, including Gazprom Neft, Novatek, Rosatom. The program will be started in AY2023.

## Intellectual property

Select research results were secured with IP: patent RU 2786303: E. Shel, A. Valov, A. Baykin, V. Neverov, S. Golovin, S. Boronin, D. Derbyshev, A. Osiptsov, Method to determine hydraulic fracture dimensions considering splitting and interaction of hydraulic fracturing fluid fluxes in between fractures [in Russian], issued on December 19, 2022.
"Method for selecting the optimal hydraulic fracturing design based on intellectual analysis of field data to increase hydrocarbon production" patent has been approved RU277503413C1.
The patent on Flowback «A method for maintaining a safe operating envelope of fracture conductivity while bringing a well into operation after hydraulic fracturing» won the 1st prize «Successful Patent 2020-2021» in the FIPS contest 2022 in the category "Business".

## Professional and wider community engagement

The Center's team participated in a number of professional and wider outreach activities. Prof. Alexander Kvashnin gave a lecture "Digital design of new materials" (XXII International Conference on Science and Technology Russia-Korea-CIS), and a lecture "Data for Machine Learning in Materials Science" for MSc students in ITMO University.
Irina Gayda conducted a few pro-bono lectures on ESG for "Women in Energy" association, "Union of women of Russia", TMK University students, Association of European Business.
Alexander Vainshtein participated in Start-Up Village 2022, INNOPROM 2022, Congress Sputnik YAMAL 2022.


Ирина Гайда
Образование:
Опыт работы:
BCG
Skoltech


SKOLTECH
Skoltech
Skolkovo Institute of Science and Technology

# Photonics Center

Established in 2021 following the restructuring of the Skoltech research and technology agenda as the successor of the Center for Photonics and Quantum Materials, the Photonics Center focuses on the R&D of advanced photonics technologies with wide-ranging applications. Since its inception, the Center demonstrated excellence through the publication of high-impact articles in prestigious journals (Nature, Science, etc.), by increasing its portfolio of industry-oriented projects, by participating in national technology program, by creating valuable intellectual property and by launching photonics startups. The Center is headed by Prof. Pavlos Lagoudakis, Vice President for Photonics.

**67**
faculty and researchers

**60**
MSc and PhD students supervised

**27**
MSc and PhD graduates

**67**
papers in Q1 journals, including 16 Nature Indexed

**222**
Mln Rub sponsored research funding (2022 -2024)

**24**
projects supported by grants and industry funding

Photonics and Quantum Technologies

## Research and technology highlights

The academic excellence of the Center was demonstrated by its publication output, dominated by papers in Q1 and Nature Indexed journals that have contributed a large fractional count to Skoltech's Nature Index. Among the most impactful publications were articles in Nature Physics Review (IF 36), Science Advances (IF 17) and Nature Communications (IF 17) and 5 Physical Review Letters among other high impact journal publications (see further highlighted publications).

Researchers from the Biophotonics Laboratory developed a prototype of a device for hemangioma assessment and prediction. By providing doctors with a mean to differentiate skin malformations and rapidly assess the development of hemangiomas, such device allows to prescribe treatment in a timely manner and only as needed. The device uses hyperspectral imaging techniques to study malformations, with custom software processing the resulting images. It is currently the focus of an ongoing pilot clinical study in Saratov, where it was used on more than 60 patients.

The Biophotonics Laboratory also developed microbubbles-based contrast agents for multimodal fluorescence, optoacoustic, and ultrasound imaging. Based on bovine serum albumin (BSA) and polyarginine (PA), the microbubbles were simultaneously doped with various functional agents in their shell structure, which resulted in strong multimodal imaging properties. Iron oxide nanoparticles acted for instance as an optoacoustic and MRI contrast agent and dyes provided fluorescence properties, while the gaseous core supported ultrasound techniques.

The Hybrid Photonics Laboratories furthered its pioneering work in optical computing by pushing its technology to the single photon limit. The single photon and room temperature optical logical switch thus developed is believed to be key to unlock the advantages of optical computing, such as ultra-fast operation and ultra-low power consumption. A patent on this technology granted in 2022 furthers the wide IP portfolio of the Center in key disruptive photonic technologies.

The Nanomaterials Labs developed a compact low-cost femtosecond fiber lasers operating at submicron wavelengths. A winner of the competitive translation research program, the technology is currently being spun-off as a Skolkovo startup. The primary client base of the laser is expected to be the emerging quantum technology market, with MSU's quantum computing initiatives identified as a first customer.

In parallel, the Center continued efforts to push advanced integrated photonics technologies

towards the marketplace, most notably by developing unique photonic integrated circuits (PIC) platforms (Prof. Arkady Shipulin) for industrial applications in collaboration with Russian industry, including PICs for Quantum Key Distribution with RZD (developed and design sent for production), PICs for various types of transceivers (developed and design sent for production) and PICs for structural health monitoring for distillation towers (developed).

## Top publications

1. Kavokin, A., Liew, T. C., Schneider, C., Lagoudakis, P. G., Klembt, S., and Hoefling, S. (2022). Polariton condensates for classical and quantum computing. *Nature Physics Reviews*, 4, 435-451. DOI: 10.1038/s42254-022-00479-7 **(IF = 36.273, Q1)**

2. Ilatovskii, D. A., Gilshtein, E. P., Glukhova, O. E. and Nasibulin, A. G. (2022). Transparent Conducting Films Based on Carbon Nanotubes: Rational Design toward the Theoretical Limit. *Advanced Science* 9(24), 2201673. DOI: 10.1002/advs.202201673 **(IF = 17.521, Q1)**

3. Grebenko, A. K., Krasnikov, D. V., Bubis, A. V., Stolyarov, V. S., Vyalikh, D. V., Makarova, A. A., Fedorov, A., Aitkulova, A., Alekseeva, A. A., Gilshtein, E., Bedran, Z., Shmakov, A. N., Alyabyeva, L., Mozhchil, R. N., Ionov, A. M., Gorshunov, B. P., Laasonen, K., Podzorov, V., Nasibulin, A. G. (2022). High-Quality Graphene Using Boudouard Reaction. *Advanced Science* 9(12), 2200217. DOI: 10.1002/advs.202200217 **(IF = 17.521, Q1)**

4. Król, M., Septembre, I., Oliwa, P., Kędziora, M., Łempicka-Mirek, K., Muszyński, M., Mazur, R., Morawiak, P., Piecek, W., Kula, P., Bardyszewski, W., Lagoudakis, P. G., Solnyshkov, D. D., Malpuech, G., Piętka B. and Szczytko, J. (2022). Annihilation of exceptional points from different Dirac valleys in a 2D photonic system. *Nature Communications*, 13, 5340. DOI: 10.1038/s41467-022-33001-9 **(IF = 17.694, Q1, Nature Indexed Journal)**

5. Sitnik, K.A., Alyatkin, S., Töpfer, J. D., Gnusov, I., Cookson, T., Sigurdsson, H., and Lagoudakis, P.G. (2022). Spontaneous Formation of Time-Periodic Vortex Cluster in Nonlinear Fluids of Light. *Physical Review Letters*, 128(23): p. 237402. DOI: 10.1103/PhysRevLett.128.237402. **(IF = 9.185, Q1, Nature Indexed Journal)**

6. Baryshev, S., Zasedatelev, A., Sigurdsson, H., Gnusov, I., Töpfer, J. D.,

Askitopoulos, A., and Lagoudakis, P. G. (2022). Engineering photon statistics in a spinor polariton condensate. *Physical Review Letters*, 128(8), 087402. DOI: 10.1103/PhysRevLett.128.087402 **(IF = 9.185, Q1, Nature Indexed Journal)**

7. Shishkov, V. Y., Andrianov, E. S., Zasedatelev, A. V., Lagoudakis, P. G., and Lozovik, Y. E. (2022). Exact Analytical Solution for the Density Matrix of a Nonequilibrium Polariton Bose-Einstein Condensate. *Physical Review Letters*, 128(6), 065301. DOI: 10.1103/PhysRevLett.128.065301 **(IF = 9.185, Q1, Nature Indexed Journal)**

8. Kuzin, A., Chernyshev, V., Kovalyuk, V., An, P., Golikov, A., Goltsman, G., Gorin, D. (2022). In Situ Monitoring of Layer-by-Layer Assembly Surface Modification of Nanophotonic-Microfluidic Sensor. *Analytical Chemistry* 94(42), 14517–14521.DOI: 10.1021/acs.analchem.2c03909 **(IF = 8.008, Q1, Nature Indexed Journal)**

9. Zaytsev, V., Ermatov, T. I., Fedorov, F. S., Balabin, N., Kapralov, P. O., Bondareva, J. V., Ignatyeva, D. O., Khlebtsov, B. N., Kosolobov, S. S., Belotelov, V. I., Nasibulin, A. G., Gorin, D. A. (2022). Design of an Artificial Opal/Photonic Crystal Interface for Alcohol Intoxication Assessment: Capillary Condensation in Pores and Photonic Materials Work Together, *Analytical Chemistry*, 94(36), 12305–12313, DOI: 10.1021/acs.analchem.2c00573 **(IF=8.008, Q1, Nature Indexed Journal)**

10. Chetyrkina, M. R., Cvjetinovic, J., Fedorov, F. S., Perevoschikov, S. V., Mikladal, B., Gladush, Yu. G., Nasibulin, A. G. and Gorin, D. A. (2022). Carbon Nanotube Microscale Fiber Grid as an Advanced Calibration System for Multispectral Optoacoustic Mesoscopy, *ACS Photonics*, 9(10), 3429–3439. DOI: 10.1021/acsphotonics.2c01074 **(IF = 7.077, Q1)**

## Educating leaders

The Center continued to lead the Photonics program. Two new courses were launched: Photonics Research Seminar (Prof. Pavlos Lagoudakis) and Nanomaterials E&I (Prof. Albert Nasibulin).

The students of the Center contributed to most of its research output, of which a few publications can be highlighted:

1. **Grebenko, A. K.**, Krasnikov, D. V., Bubis, A. V., Stolyarov, V. S., Vyalikh, D. V., Makarova, A. A., Fedorov, A., Aitkulova, A., Alekseeva, A. A., Gilshtein, E., Bedran, Z., Shmakov, A. N., Alyabyeva, L., Mozhchil, R. N., Ionov, A. M., Gorshunov, B. P., Laasonen, K., Podzorov, V., Nasibulin, A. G. (2022). High-Quality Graphene Using Boudouard Reaction. *Advanced Science* 9(12), 2200217.DOI: 10.1002/advs.202200217 **(IF = 17.521, Q1)**

2. **Sitnik, K.A.**, Alyatkin, S., Töpfer, J. D., **Gnusov, I.**, Cookson, T., Sigurdsson, H., and Lagoudakis, P.G. (2022). Spontaneous Formation of Time-Periodic Vortex Cluster in Nonlinear Fluids of Light. *Physical Review Letters*, 128(23): p. 237402. DOI: 10.1103/PhysRevLett.128.237402. **(IF = 9.185, Q1, Nature Index Journal)**

3. **Baryshev, S.**, Zasedatelev, A., Sigurdsson, H., **Gnusov, I.**, Töpfer, J. D., Askitopoulos, A., and Lagoudakis, P. G. (2022). Engineering photon statistics in a spinor polariton condensate. *Physical Review Letters*, 128(8), 087402. DOI: 10.1103/PhysRevLett.128.087402 **(IF = 9.185, Q1, Nature Index Journal)**

4. **Zaytsev, V.**, Ermatov, T. I., Fedorov, F. S., Balabin, N., Kapralov, P. O., Bondareva, J. V., Ignatyeva, D. O., Khlebtsov, B. N., Kosolobov, S. S., Belotelov, V. I., Nasibulin, A. G., Gorin, D. A. (2022). Design of an Artificial Opal/Photonic Crystal Interface for Alcohol Intoxication Assessment: Capillary Condensation in Pores and Photonic Materials Work Together, *Analytical Chemistry*, 94(36), 12305–12313, DOI: 10.1021/acs.analchem.2c00573 **(IF=8.008, Q1, Nature Indexed Journal)**

5. **Kuzin, A.**, Chernyshev, V., Kovalyuk, V., An, P., Golikov, A., Goltsman, G., Gorin, D. (2022). In Situ Monitoring of Layer-by-Layer Assembly Surface Modification of Nanophotonic-Microfluidic Sensor. *Analytical Chemistry* 94(42), 14517–14521.DOI: 10.1021/acs.analchem.2c03909 **(IF = 8.008, Q1, Nature Indexed Journal)**

6. **Mkrtchyan, A. A., Mishevsky, M. S.**, Gladush, Y. G., Melkumov, M. A., Khegai, A. M., Lagoudakis, P. G., & Nasibulin, A. G. (2022). Dispersion Managed Mode-locking in all-fiber Polarization-maintaining Nd-doped Laser at 920 Nm. *Journal of Lightwave Technology* (early access). DOI: 10.1109/JLT.2022.3229826 **(IF = 4.439, Q1)**

7. **Ramírez-Morales, M. A.**, Goldt, A. E., Kalachikova, P. M., Ramirez B, J. A., Suzuki, M., Zhigach, A. N., ...Krasnikov, D.V,. & Nasibulin, A. G. (2022). Albumin Stabilized Fe@ C Core–Shell Nanoparticles as Candidates for Magnetic Hyperthermia Therapy. *Nanomaterials*, 12(16), 2869. DOI: 10.3390/nano12162869 **(IF = 5.719, Q1)**

MSc students Olga Griaznova and Nikita Grishaev received the Best Project Excellence Award for the industrial immersion project "Development of immunomagnetic particles based on nano- and submicron particles for specific isolation of biomarkers", conducted in TetraQuant. Three PhD students received the RF President's Scholarship to Study Abroad in 2022. Sergei Perkov, Maxim Mokrousov, and Alexey Kuzin will study at the Bar Ilan University, Tel Aviv University and Fudan University, respectively.

## Innovation activities

Significant efforts to commercialize the technology developed at the Center were undertaken, as demonstrated by the on-going pre-clinical study of hemangioma assessment at the University of Saratov, the submission of an application for Skolkovo residency for a start-up developing electronic noses and the filing/granting of 7 Russian and WIPO patents.

"I am immensely proud and at the same time humbled by the prodigious efforts of our faculty, researchers, and students. Their successes in broadening and consolidating our international leadership, in innovation and the founding of new startups, and in educating the next generation of scientists and engineers in the field of photonics, have astonished even our harshest critics."

**Prof. Pavlos Lagoudakis, Director of the Center, Vice President for Photonics**

**Patents filed:**

1. E. Khabushev, D. Krasnikov, A. Goldt, S. Fedotov, A. Nasibulin "Метод высокотемпературного допирования углеродных материалов" ("A method for high-temperature doping of carbon materials") Russian patent application #2022123434 filed on 01.09.2022

2. Y. Gladush, A. Mcrtchyan, M. Mishevskii, A. Nasibulin "Neodymium fiber laser emitting femtosecond pulses at a wavelength of 920 nm" Russian patent application filed on in December 2022.

**Patents granted:**

1. B. Gartseev, F.S. Fedorov, Y. Ainul, A.G. Nasibulin, M.V. Pikhletsky, C. Qiu, H. Li. Gas sensing structure and method of fabrication thereof, WO 2022/019794 A1, date issued 27.01.2022.

2. Yakin, F. S. Fedorov, V. A. Kondrashov, G. V. Ovchinnikov, A. G. Nasibulin. "Способ определения состояния готовности и качества продуктов питания" ("Method of determining state of readiness and quality of food"). RU 2767711 C1, date issued 18.03.2022.

3. P. Lagoudakis, A. Zasedatelev, "Способ переключения макроскопического состояния поляритонов при помощи одного фотона" ("A method for switching the macroscopic state of polaritons using a single photon"). RU 2782686 C2, date issued 31.10.2022.

4. D. V. Krasnikov, B. X. A. Ramirez, V. A. Kondrashov, Yu. G. Gladush, A.G. Nasibulin, "Способ регенерации аэрозольных фильтров и защитных мембран". RU 2786874 C1, date issued 26.12.2022.

5. P. Lagoudakis, I. Gnusov, S. Baryshev "Способ оптического управления линейной поляризацией излучения" ("Optical control method for linear polarization of radiation") Russian patent application #2022118433 filed on 06.07.2022 (accepted on 09.03.2023)

The spin-off company "TETRAQUANT" of the Biophotonics Labs prepared the supporting documents for a certification application for its CR-1 B bioreactor. 125k kRUB of external investment was obtained. The spin-off company "PICTechs" from the Photonics Circuits and Systems Labs raised about 90 mln rubles and submitted 3 patent applications. Business networking with industrial companies resulted in 4 project proposals at advanced stages. Researchers of the Laboratory of Nanomaterials submitted an application for Skolkovo residency for the project "ELNOPRO: hardware and software complex

for detecting plastic off-odors based on a multisensor "electronic nose" based on metal oxides and AI signal processing." Additionally, the STRIP project "Multifunctional membranes for air disinfection and quality control" initiated the process of Skolkovo residency application and plans to establish a startup in 2023.

## Think-act tank role

Center faculty continued efforts to contribute to the Russian science and technological landscape by being involved in various national level initiatives and working groups. Prof. Albert Nasibulin became a member of the steering committee in the initiative "Carbon" headed by NII Graphite. In 2022, members of the Laboratory for Nanomaterials also applied for and were included in the working groups of the research initiative "Highly Pure Compounds" led by Giredmet (https://giredmet.ru/ru/). A plan for the establishment of a 2B Rub National Center for Photonics Integrated Circuits to be situated in the Moscow region is currently being developed, with strong input from Center faculty. Prof. Arkady Shipulin and Dr. Sergey Alyatkin discussed with the Ministry of Industry and Trade how the advanced optical technologies developed in Skoltech can be brought to the national industry. They presented their development strategy of Photonics in Russia, with a focus on local design and manufacturing of Photonic Integrated Circuits (PICs). The proposal includes a 500M Rub test lab to be located in Skoltech.

## International collaborations

Center faculty retain strong international collaborations with various partners around the globe. Formal externally-funded international projects are on-going through RFBR programs: "Bioactive ultrasound-driven microbubbles for theranostics" in collaboration with Fudan University (China) and the Indian Institute of Technology (Prof. Dmitry Gorin) and "Physics of strong coupling in hybrid organic-inorganic semiconductor microcavities" in collaboration with Wurzburg University (Prof. Pavlos Lagoudakis). A proposal for a joint laboratory with the University of Sharjah was presented to the University of Sharjah leadership. Receiving positive feedback, planning will continue in 2023. The Center also launched the new Clover Photonics Initiative, in collaboration with MIPT and ITMO, supported by the Academic Council. A joint funding scheme for projects is to be announced shortly.

## Outreach and wider community engagement

Numerous outreach and wider community activities were conducted by the Center: this included open lectures, interviews and talks, participation in workshops and seminars. Several notable examples are outlined below:

- Prof. Dmitry Gorin, "Nanostructural materials with controlled properties", IV School of Young Scientists (Moscow, Gubkin University)
- Prof. Dmitry Gorin, "Biosystems: organization, behavior, control", 75th All-Russian School-Conference for Young Scientists with international participation (Nizhny Novgorod)
- Prof. Albert Nasibulin, Congress of Young Scientists, Sirius, Sochi
- Prof. Albert Nasibulin, Panasonic DTIC 3. Panasonic Deep Tech Innovation Challenge 3, Panasonic R&D Center, Singapore
- Employees of the Center (Prof. Dmitry Gorin, Julijana Cvjetinovic, Dr. Sergei German, Dr. Sergey Alyatkin) took part in the FANK Science Film Laboratory "16 Ways to Change the World", presenting highlights of Center's research.

Among other national media outlets, interviews were given to Radio Mayak (Rudakovskaya P.G), Smotrim online radio (Dmitry Krasnikov) and Rossiskaya Gazeta (Prof. Lagoudakis). Rudakovskaya P.G. also participated in the "Decade of Science and Technology" and "Institute for the Development of the Internet" workshop with representatives of the Russian Science Foundation.

# Physics Center

The Center for Engineering Physics was established in 2021 within the transformation of Skoltech research and technology agenda, on the base of the Center for Photonics and Quantum Materials. The Center's strategic goal is to develop new capabilities starting from the development of fundamentals in physics to technologies aimed at clearly defined industrial demands. In pursuing the strategic goal, the Center focuses on the following core areas: Plasmonics and Nanophotonics, including integrated silicon photonics, Superconducting Materials and Quantum Technologies. The specific goals include: (1) completion of development and demonstration of a prototype of the quantum current standard for the first time in the world in the next three years, (2) development of a micro-spectrometer for optical fiber sensors based on integrated Si-photonics technology, (3) development of components of next generation of wireless communications based on available integrated Si technology.
The Center of chaired by Prof. Vladimir Drachev.

**34**
faculty and researchers

**19**
MSc and PhD students supervised

**13**
MSc and PhD graduates

**19**
papers in Q1 journals, including 6 in Nature Index

**74**
Mln Rub sponsored research funding 2022-2024

**9**
projects supported by grants and industry funding

Photonics and Quantum Technologies

## Research and technology highights

Highlights in the Center's research program in 2022 included:

- The first experimental demonstration of the AC Coherent Quantum Phase Slip effect (AC CQPS). The effect is among the most fundamental phenomena of superconductivity and Physics and was a goal of research of many scientific groups worldwide over 30 years. The work has been done in collaboration with researchers of other universities and institutes, however the leading role and intellectual support belong to Oleg Astafiev – professor of Skoltech. Another Skoltech professor, Vladimir Antonov led technological and experimental works by supervising and guiding a team of young students and postdocs. The work will have a strong impact on metrology as it provides a basis for building quantum current standards. So far, the current standard is the only one missing element among electrical quantum metrology standards. The work is published in Nature: Rais S. Shaikhaidarov, Kyung Ho Kim, Jacob W. Dunstan, Ilya V. Antonov, Sven Linzen, Mario Ziegler, Dmitry S. Golubev, Vladimir N. Antonov, Evgeni V. Il'ichev, Oleg V. Astafiev. Quantized current steps due to the a.c. coherent quantum phase-slip effect. Nature 608, 45–49 (2022).

- Demonstration of solving of classification problems with machine learning algorithms on a quantum processor with 8 superconducting qubits. The work is an experimental confirmation of the feasibility of solving practical problems with quantum processors already at the present level state-of-the-art. The work is on the forefront of physics and technology.

- As part of the work on the topic "Development of technologies and components of integrated ultrahigh frequency radiophotonics based on silicon MOS structures with an embedded ITO layer" high-performance diffraction gratings of input-output radiation for planar silicon waveguides on a silicon-on-insulator substrate were manufactured and studied. The results are published in the journal Optics Letters (Q1, IF: 3.776) with only Skoltech affiliation: D. S. Zemtsov, D. M. Zhigunov, S. S. Kosolobov, A. K. Zemtsova, M. Puplauskis, I. A. Pshenichnyuk, V. P. Drachev, "Broadband silicon grating couplers with high efficiency and a robust design", Optics Letters, 2022, 47 (13), 3339-3342; doi: 10.1364/OL.457284.

- Micro-spectrometer based on photonics integrated circuits have been designed, fabricated and demonstrated for industry application.

- Theoretical and experimental studies of a Purcell effect in the photonic crystal slabs with Ge

quantum dots. A plasmonic grating for circularly polarized outcoupling of waveguide-enhanced spontaneous emission has been developed and demosnstrated. Fradkin, I. M., Demenev, A. A., Kulakovskii, V. D., Antonov, V. N., & Gippius, N. A. (2022). Plasmonic grating for circularly polarized outcoupling of waveguide-enhanced spontaneous emission. Applied Physics Letters, 120(17), 171702.

Some results were secured with patents, including:

- Planar electro-optical light modulator based on the field effect of excitation of angular plasmons in a hybrid waveguide. RF patent 2775997, issued on 12.07.2022.

## Top publications

1. **Oleg V. Astafiev**. Quantized current steps due to the a.c. coherent quantum phase-slip effect. *Nature* 608, 45–49 (2022).

2. Il'ichev, E. V., V. V. Ryazanov, and **O. V. Astafiev**. "Comment on "Coulomb Blockade and Bloch Oscillations in Superconducting Ti Nanowires"." *Physical Review Letters* 128, no. 15 (2022): 159701.

3. Vasenin, A. V., A. Yu Dmitriev, S. V. Kadyrmetov, A. N. Bolgar, and **O. V. Astafiev**. "Dynamics of multiphoton scattering in a two-level mixer." *Physical Review* A 106, no. 4 (2022): L041701 (Letter).

4. **Fradkin, I. M.**, Demenev, A. A., Kulakovskii, V. D., **Antonov, V. N., & Gippius, N. A.** (2022). Plasmonic grating for circularly polarized outcoupling of waveguide-enhanced spontaneous emission. *Applied Physics Letters*, 120(17), 171702

5. **Gromyko, D. A., Dyakov, S. A., Gippius, N. A.**, Weiss, T., Tikhodeev, S. G., Astrakhantseva, A. S., ... & Kukushkin, I. V. (2022). Strong Local Field Enhancement of Raman Scattering Observed in Metal-Dielectric Gratings due to Vertical Fabry-Perot Modes of Surface Plasmon Polaritons. *Physical Review Applied*, 17(2), 024015.

6. **D. S. Zemtsov, D. M. Zhigunov, S. S. Kosolobov, A. K. Zemtsova, M. Puplauskis, I. A. Pshenichnyuk, V. P. Drachev**, "Broadband silicon grating couplers with high efficiency and a robust design", *Optics Letters*, 2022, 47 (13), 3339-3342; doi: 10.1364/OL.457284.

7. S. Modak, L. Chernyak, A. Schulte, C. Sartel, V. Sallet, Y. Dumont, E. Chikoidze, X. Xia, F. Ren, S.J. Pearton, A. Ruzin, **D.M. Zhigunov, S.S. Kosolobov, V.P. Drachev**, "Variable temperature probing of minority carrier transport and optical properties in p Ga2O3", *APL Materials*, 2022, 10, 031106; doi: 10.1063/5.0086449.

8. Shornikova, E. V., Yakovlev, D. R., **Gippius, N. A.**, Qiang, G., Dubertret, B., Khan, A. H., Di Giacomo, A., Moreels, I. and Bayer, M. (2021). Exciton Binding Energy in CdSe Nanoplatelets Measured by One-and Two-Photon Absorption. *Nano letters*, 21(24), 10525-10531.

## Educating leaders

The Center continued to expand the Photonics program with a number of courses: Engineering Physics (V.P. Drachev and D.M. Zhigunov), Introduction to Solid State Physics (S.S. Kosolobov and D.M. Zhigunov), Nanooptics (I.A. Pshenichnyuk), series of lectures on Fundamentals of Photonics (N.A. Gippius), Quantum mechanics (S.D. Dyakov). A course of lectures on Computational Electrodynamics for Master students at Moscow State University was delivered by Prof. Sergei Tikhodeev (invited lectures).
The majority of graduates 2022 decided to continue for PhD at Skoltech or other top universities in Russia or abroad, including MIPT, Weizmann, Aalto.

## Think-act tank role

The Center's faculty were involved in providing expertise for national level projects in science and technology.

Prof. Vladimir Antonov is a member of Rosatom expert committee of quantum technology, also leading the Regional

The Center for Engineering Physics focuses on Plasmonics and Nanophotonics, Superconducting Materials and Quantum Technologies. Breakthrough results published in Nature by Profs. Astafiev and Antonov with co-authors demonstrate, for the first time, the AC Coherent Quantum Phase Slip effect. Machine learning algorithms on a quantum processor with 8 superconducting qubits has been realized. Silicon photonics integrated circuits have been designed, fabricated, and demonstrated for industry application.

**Prof. Vladimir Drachev, Director of the Center**

Megagrant "Multimodal diagnostics of high accuracy in medicine and biology based on advanced methods of intelligent signal processing and their generation by means of integrated photonics". Prof. Vladimir Drachev is a member of Bashkortostan Megagrant Committee.

## International network

In addition to faculty-to-faculty ties, international collaborations were maintained through grant projects. Prof. Oleg Astafiev led the international (Russia-China) project between Russian Science Foundation and National Science Foundation of China, where Russian side is represented by Skoltech Laboratory of Superconducting Quantum Technologies and Chinese side includes several leading universities: University of Science and Technology of China, Tsinghua University, Hunan Normal University. The project aims to address and study physical principles of new prospective approaches for quantum systems based on superconducting technologies.

## Professional and wider community engagement

The Center participated in a number of professional events, as well as supported the Institute's wide brand advancement and programs for the wider community: summer and winter schools. Some examples are outlined below:

- Article on the topic of the AC CQPS effect (https://www.skoltech.ru/2022/08/fiziki-reshili-odnu-iz-poslednih-fundamentalnyh-problem-sverhprovodimosti/)
- Article about 8-qubit quantum processor in Kommersant (https://www.kommersant.ru/doc/5734154?ysclid=l-cw6h6ops3550381360)
- Invited lecture at scientific school (Prof. Astafiev). "Physics of superconducting quantum systems". 7-11 November, 2022. Nonlinear waves-2022. Nizhny Novgorod, Russia.
- Drachev V.P., Plasmonic optical metamaterials, The Russia-China Workshop on Metamaterials and Nanophotonics (RCWMN 2022) June 8-9, 2022
- Organizer for Nanophotonics section at International seminar on fiber lasers 2022 (Prof. Drachev).
- Invited lecture at Winter school for three University (Skoltech, MIPT, ITMO) December 2022. (Prof. Drachev).

# Krichever Center

The Center for Advanced Studies was established in 2016 with the mission to develop the tradition of worldwide excellence of Soviet and Russian mathematics and theoretical physics schools, and foster new generation of scientists by integrating education and research, creating an innovative model of education, which will allow to include Russian and international leading scientists into educational process. Center's research is focused mainly on the areas of geometric representation theory, string theory, conformal and gauge field theory, integrable models, combinatorics and singularity theory, symplectic geometry, topology, statistical physics, dynamical systems, hyperbolic geometry. In 2022, in memory of Prof. Igor Krichever, Center's founder and academic leader, the Center was renamed into the Igor Krichever Center for Advanced Studies.
The Center is chaired by Prof. Andrey Marshakov.

**42**
faculty and researchers

**27**
MSc and PhD students supervised

**9**
MSc and PhD graduates

**69**
publications in high impact factor journals, including 53 in Scopus

**6**
papers in Nature index journals

**30**
preprints published in arXiv

Advanced Studies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## Research highlights

The Center demonstrated highest academic results, recognized at the international level. At the International Congress of Mathematicians 2022, Prof. Igor Krichever presented a talk as a plenary speaker, while Prof. Evgeny Feigin presented a talk as invited speaker.

Prof. Igor Krichever and Prof. Anton Zabrodin found integrals of motion for the recently introduced deformed Ruijsenaars-Schneider many-body system which is the dynamical system for poles of elliptic solutions to the constrained Toda lattice. Algebraic-geometrical solutions of the constrained Toda lattice in terms of Riemann and Prym theta-functions were constructed. This is the most recent development of the approach, described by Igor Krichever in his talk at ICM2022.

**Krichever, A. Zabrodin**, "Constrained Toda hierarchy and turning points of the Ruijsenaars-Schneider model", Lett Math Phys 112, 23 (2022). doi.org/10.1007/s11005-022-01519-0

Prof. Finkelberg (with R. Travkin and A. Braverman) developed the "hyperbolic calculus" of perverse sheaves on a complex affine space, smooth along a real hyperplane arrangemement. They proved a famous conjecture of Lusztig about equivalence of various constructions of S-cells in the affine Weyl groups. **A. Braverman, M. Finkelberg, R. Travkin**, "Orthosymplectic Satake equivalence", Comm. in Number Theory and Physics, 16(2022) #4 695–732, doi.org/10.4310/CNTP.2022.v16.n4.a2

**A. Braverman, M. Finkelberg**, H. Nakajima, "Kazhdan-Lusztig conjecture via Zastava spaces", Journal fur die Reine und Angewandte Mathematik 2022, v.787, 45-78 doi.org/10.1515/crelle-2022-0013

Prof. A. Gaifullin constructed first examples of 27-vertex triangulations of 16-dimensional manifolds like the octonionic projective plane have been constructed. The question on the existence of such triangulation was open for more than 30 years.

**A. Gaifullin**, 634 vertex-transitive and more than 10^{103} non-vertex-transitive 27-vertex triangulations of manifolds like the octonionic projective plane, 2022, 37 pp., arXiv: 2207.08507.

Prof. Mikhail Bershtein and Prof. Andrey Marshakov (with P. Gavrylenko and M. Semenyakin) almost completed the study of cluster reduction of the Goncharov-Kenyon integrable systems. They now constructed all examples of q-difference Painleve equations by deautonomization of cluster integrable systems, filling the gap in earlier paper of M. Bershtein, P. Gavrylenko and A. Marshakov.

Prof. Maxim Kazarian (with P. Dunin-Barkrowski) studied the topological recursion and its

application to enumerative problems in combinatorics and mathematical physics. They proved the topological recursion for the extended generalized Hurwitz numbers and symplectic duality for this topological recursion.

B. Bychkov, **P. Dunin-Barkowski, M. Kazarian**, S. Shadrin, Symplectic duality for topological recursion, preprint (2022), https://arxiv.org/abs/2206.14792

## Top publications

1. **A. Artemev**, "Note on large-p limit of (2,2p+1) minimal Liouville gravity and moduli space volumes" Nuclear Phys. B, v.981, 2022, 115876 doi.org/10.1016/j.nuclphysb.2022.115876

2. A. Alexandrov, **A. Basalaev, A. Buryak**, "A construction of open descendant potentials in all genera", International Mathematics Research Notices, 2022;, rnac240, doi.org/10.1093/imrn/rnac240

3. **M. Bershtein, P. Gavrylenko**, A. Grassi, "Quantum spectral problems and isomonodromic deformations", Commun. Math. Phys. 393, 347–418 (2022) doi.org/10.1007/s00220-022-04369-y

4. **A. Braverman, M. Finkelberg, R. Travkin**, "Orthosymplectic Satake equivalence", Comm. in Number Theory and Physics, 16(2022) #4 695–732, doi.org/10.4310/CNTP.2022.v16.n4.a2

5. **A. Braverman, M. Finkelberg**, H. Nakajima, "Kazhdan-Lusztig conjecture via Zastava spaces", Journal fur die Reine und Angewandte Mathematik 2022, v.787, 45-78 DOI 10.1515/crelle-2022-0013

6. **E. Feigin, I. Makhlin**, A. Popkovich, "Beyond the Sottile-Sturmfels degeneration of a semi-infinite Grassmannian" International Mathematics Research Notices, 2022; rnac116, doi.org/10.1093/imrn/rnac116

7. **I. Krichever, A. Zabrodin**, "Constrained Toda hierarchy and turning points of the Ruijsenaars-Schneider model", Lett Math Phys 112, 23 (2022). doi.org/10.1007/s11005-022-01519-0

8. **I. Krichever, N. Nekrasov**, "Novikov-Veselov symmetries of the two dimensional O(N) sigma model", SIGMA 18 (2022), 006, doi.org/10.3842/SIGMA.2022.006

9. M. Alfimov, **A. Litvinov**, "On loop corrections to integrable 2D sigma model backgrounds", J. High Energ. Phys. 2022, 43 (2022). https://doi.org/10.1007/JHEP01(2022)043

10. A. Bufetov, **G. Olshanski**, "A hierarchy of Palm measures for determinantal point processes with gamma kernels", Studia Mathematica 267 (2) (2022), 121-160, doi: 10.4064/sm210823-10-3

11. O. Ogievetsky, **S. Shlosman**, "Art of Unlocking ", Math Intelligencer 44, 320–325 (2022). https://doi.org/10.1007/s00283-022-10210-0

12. S. Zakany, **S. Smirnov**, M. Milinkovitch, "Lizard Skin Patterns and the Ising Model" Phys. Rev. Lett. (2022) 128, 048102 doi:10.1103/PhysRevLett.128.048102

## Educating leaders

Faculty designed a number of new courses for the program "Mathematical and Theoretical Physics", including Universal enveloping algebras and Yangians (Prof. G. Olshanski), Critical points of functions / Prof. Maksim Kazarian, Hitchin systems and complex geometry / Prof. Alexey Rosly, Cohomology of groups and classifying spaces / Prof. Aleksandr Gaifullin, Introduction to cluster algebras and varieties / Prof. Mikhail Bershtein.

Center's students demonstrated excellence in papers as outlined in highlighted examples:

1. A. Artemev, "Note on large-p limit of (2,2p+1) minimal Liouville gravity and moduli space volumes" Nuclear Phys. B, v.981, 2022, 115876 doi.org/10.1016/j.nuclphysb.2022.115876

2. A. Artemev, A. Belavin, "Five-point correlation numbers in minimal Liouville gravity and matrix models" Nucl.Physics B, V.985, 2022, 116019, doi.org/10.1016/j.nuclphysb.2022.116019

3. Belavin, B. Eremin, "Multiple mirrors and the JKLMR conjecture", Theor Math Phys 213, 1441–1452 (2022). doi.org/10.1134/S0040577922100105

4. I. Kochergin, "On Calabi-Yau manifolds in weighted projective spaces and their mirror GLSMs", Phys. Rev. D 105, 066008, doi.org/10.1103/PhysRevD.105.066008

5. A. Gorsky, M. Vasilyev, A. Zotov, "Dualities in quantum integrable many-body systems and integrable probabilities. Part I. J. High Energ. Phys. 2022, 159 (2022). doi.org/10.1007/JHEP04(2022)159

6. M. Bershtein, A. Grigorev, A. Shchechkin, "Hamiltonian reductions in Matrix Painlevé systems" arXiv: 2208.04824

7. P. Nikitin, N. Safonkin, "Semifinite harmonic functions on the direct product of graded graphs", arXiv: 2209.05901

8. G. Shuklin, "A Voevodsky motive associated to a log scheme" arXiv: 2209.03720

9. I. Spiridonov, "The top homology group of the genus 3 Torelli group", arXiv: 2208.10326

All MSc graduates continued their scientific career as PhD students at the Center or top universities abroad, such as Princeton and MIT. Two PhD students joined the Center as postdocs.

## International visibility

Research results were presented in numerous top conferences in the field:

1. ICM2022 – I.Krichever – plenar talk Algebraic-geometrical methods in the theory of integrable systems and Riemann-Schottky type problems

2. ICM2022 / Section Lie theory and generalizations – E.Feigin – invited talk PBW degenerations, quiver Grassmannians, and toric varieties

3. A. Marshakov – Cluster integrable systems and supersymmetric gauge theories, zoom talk: seminar of Center for Geometry and Physics, Institute of Basic Science, Korea, March 2022

4. A. Marshakov – invited talk: Cluster reductions and Painlev´e equations, Quantum Integrability and Geometry, Steklov Mathematics Institute, June 2022

5. A. Marshakov – invited talk: Mutations, cluster reductions and Painlev´e equations, XII – Workshop on Geometric Correspondences of Gauge Theories – 22, SISSA, Trieste, June 2022

6. A. Marshakov – invited talk: Supersymmetric gauge theories, quivers and Painlev´e equations, New Mathematical Methods in Solvable Models and Gauge/String Dualities, Varna, August 2022

7. S. Lando – invited talk: Symmetric groups and enumeration of meromorphic functions, International Conference Algebraic groups, their friends and relations, September 18-23, 2022 St. Petersburg Department of Steklov Mathematical Institute of Russian Academy of Sciences, St. Petersburg

8. S. Lando – invited talk: Weight systems related to Lie algebras, International Conference Uncertainty and Random Structures: Signal Analysis, Representation Theory and Applications Saint-Petersburg December 12-16, 2022

9. S. Lando – invited talk: Weight systems related to Lie algebras, International Conference 2nd Russia-China Conference on Topology and Combinatorics,Yanqi Lake Beijing Institute of Mathematical Sciences and Applications (BIMSA), Zoom, December 22-25, 2022

10. M. Bershnein – Workshop on Geometric Correspondence of Gauge Theories, Trieste 4–7 July 2022 talk " Local systems, reductions and quivers"

11. M. Bershnein – Workshop on Supermoduli and superstrings, Trieste 27–30 June 2022 talk "Folding transformations of the Painlev´e equations"

12. M. Bershnein – Vertex Algebras and Poisson Geometry, Zoom / Geneve 20–25 February 2022 talk " Twisted Fock module of toroidal algebra via DAHA and vertex operators

13. M. Bershnein – Talk on GTM seminar in Kavli IPMU, Kashiwa 08 November 2022 Highest weight vectors in Coset Construction

14. M. Bershnein – Talk on algebra seminar in Tohoku University, Sendai/Zoom 11 November 2022 Cluster algebras, q-Painleve equations and quantization

15. M. Kazarian – Seventh Winter School-Conference "String Theory, Integrable Models and Representation Theory" January 17-22, 2022, a minicourse «Hurwitz numbers and integrability»

16. M.Kazarian – invited talk: Symplectic duality for topological recursion, International Conference "Quantum integrability and geometry", Moscow, Steklov Institute, June 01-04, 2022

17. M. Kazarian – Plenary talk Int. Conference "Ergodic theory and related topics", Steklov Institute. November 21, 2022. "Infinite invariant measures for infinite-dimensional groups over finite fields"

18. S. Shlosman – invited talk at the conference Inhomogeneous Random Systems, January 25-26, 2022, IHP, Paris (Non-)Gaussian fluctuations with exponent N^{≠(1/2)}

19. S. Shlosman – Invited talk at the conference "Randomness, Integrability and Universality", Galileo Galilei Institute for Theoretical Physics: How to see the KPZ fluctuations (and Tracy-Widom?) in the Ising model

20. S. Shlosman – Invited talk at "Spring Day in Probability and Statistical Mechanics", Friday May 5, Math Department., Florence: Random surfaces in statistical mechanics

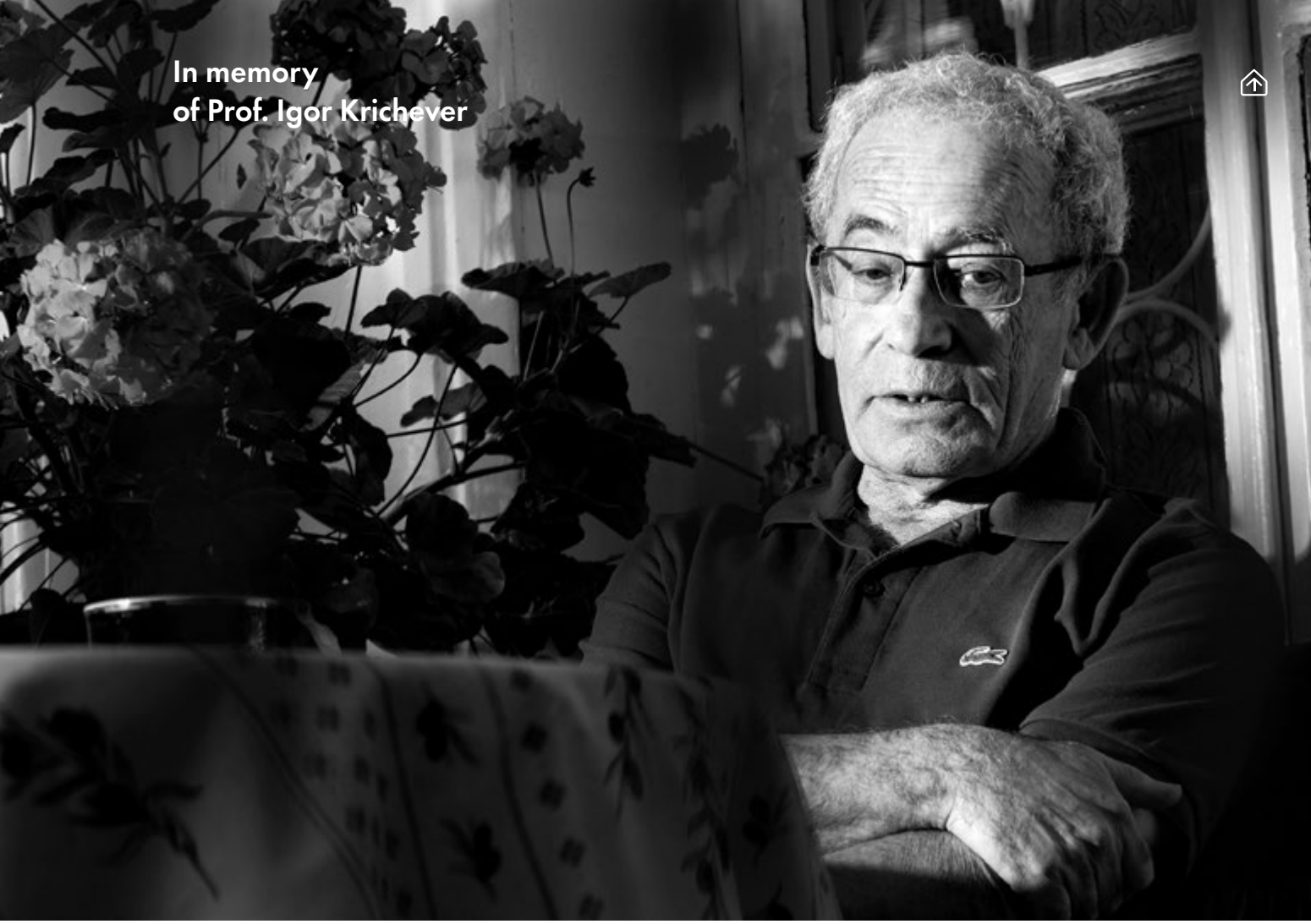
21. S. Shlosman – Invited talk at the conference Stochastic Models in Mathematical Physics, 5/9/2022 – 8/9/2022, Technion, Haifa: The Tracy-Widom distribution and where to look for it in the Ising model

22. S. Shlosman – Invited talk at the BIMSA Workshop on String Theory at Tsinghua Sanya International Mathematics Forum (TSIMF), November 2022: Tracy-Widom distribution and the 3D Ising model

23. A. Skripchenko – Combinatorics, Dynamics and Geometry of moduli spaces (Sept. 2022, CIRM, Marseille)

**Professional and wider community engagement**

The professional and wider community engagement included summer schools and lectures for gifted kids: XXI Summer School «Contemporary Mathematics», Dubna 19–30 July 2022 (Prof. Aleksandra Skripchenko, Prof. Aleksandr Gaifullin, Prof. Mikhail Bershtein), courses for kids of Lyceum #2, Summer Working Seminar on Mathematics and Physics, 7th Winter school-conference "String Theory, Integrable Models and Representation Theory" 7STIMaRT, AnAnnLecture course: Modern Trends in Mathematical Physics (for pedestrians … cyclists and drivers).



# “I would like the Center for Advanced Studies to have a great team of world-class mathematicians and physicists. This is the only way to attract young talents and grow future stellar scholars.”

On December 1, 2022, our friend and colleague, founder and Director of the Center for Advanced Studies, Professor Igor Krichever passed away. On December 26, the Center was awarded with Prof. Krichever name. In memory of Igor Moiseevich, we publish select quotes from his interview for “Mathematical Walks” project*.

"Very few people have ability to compose music, but almost all can enjoy it. I read in a book once, that we should bring mathematics to the people as it is beautiful. It really is beautiful and you can enjoy it. When schoolkids start to solve Olympiad level problems, and not routine ones, very soon they discover a "beautiful solution". What does a "beautiful solution" mean? It is a kind of finesse that comes out of nowhere."

"Mathematics teaches you to think. It teaches you to apply critical thinking to any statement, analyze its content, origin, and implications. I believe that, in this sense, mathematics is a science that everyone should learn."

"Mathematics teaches you not to take anything for granted: reasoning should be based on evidences. It is like a pair of good glasses: if you want to get a clearer picture of the world, study mathematics."

"I think that success of any scientific field development is based on how it can interrelate with its environment and other sciences. It was always a mystery to me how, on the one hand, mathematics progresses following its own laws. However, at another point it helps to solve problems arising in Physics. I saw it many times. This confirms my thought that the entire world around is already programmed inside our mind, and we just try to understand it with various methods."

"Somewhere inside me, I have faith in inner beauty and harmony of the world. I always tried to prove something with an energy worthy of a better cause. It seemed that in whatever problem I solved, some piece was missing, like a piece of a puzzle or a painting. Since this is right and beautiful. I am not sure whether this is intuition or logic. This could be due to my belief that, as I already said, the whole world is somehow recorded in our brain."

"Some five, ten or fifteen years from now, Skoltech will launch its own baccalaureate. Could it happen that Skoltech will attract talented schoolkids and a number of applicants to MIPT, MSU and other top universities will decrease? Competition is always good, and competing for students is natural. Boston has MIT and Harvard alongside one another, New York has Columbia University and NYU with its famous Courant Institute, and Princeton close by. All of them are the world's top universities that coexist quite nicely and never lack students. It's more a responsibility of society to have more schoolkids."

"I would like the Center for Advanced Studies to have a great team of world-class mathematicians and physicists. This is the only way to attract young talents and grow future stellar scholars."

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* Skoltech's "Mathematical Walks+" (December 2022) would not have seen the light of day without the inspiring support of Igor Krichever, the longtime scientific supervisor of this media project.

# Education Offer: MSc, PhD, Professional Education

## MSc and PhD programs

Skoltech offers high quality education through MSc and PhD programs, organized around Centers' core areas of expertise. The programs are designed in a way to effectively meet the needs of industry and society, preparing students with deep disciplinary knowledge, skills and abilities to translate knowledge from science to innovation.

## Artificial Intelligence and Telecommunications

- Data Science (MSc)
- Internet of Things and Wireless Technologies (MSc)
- Advanced Computational Science (MSc)
- Information Science and Technology (MSc)
- Computational and Data Science and Engineering (PhD)

## Energy Efficiency and Energy Transition

- Energy Systems (MSc)

## Life Sciences, Agro

- Life Sciences (MSc)
- Life Sciences (PhD)

## Photonics

- Photonics and Quantum Materials (MSc)
- Physics (PhD)

## Engineering and Advanced Materials

- Engineering Systems (MSc)
- Petroleum Engineering (MSc)
- Materials Science (MSc)
- Space and Engineering Systems (MSc)
- Materials Technologies (MSc)
- Advanced Manufacturing Technologies (MSc)
- Engineering Systems (PhD)
- Petroleum Engineering (PhD)
- Materials Science and Engineering (PhD)

## Advanced Studies

- Mathematical and Theoretical Physics (MSc)
- Mathematics and Mechanics (PhD)

*Basic distribution of programs per Target Domains*

The rich course catalogue of more than 200 courses was added with 27 new courses, delivered offline and in a hybrid mode.

PhD curriculum was updated to comply with new Federal state requirements focusing more on research. Respective updates were introduced to the Policy on PhD programs and PhD student handbook, which navigates students on essentials of studies.

The milestone legislative decision was made with the adoption of the Law that allows Skoltech to award degrees of Candidate of Sciences and Doctor of Sciences recognized at the national level. Graduates with such degrees will have the rights of persons holding degrees awarded within the state academic degree system. What is also important, graduates awarded Skoltech PhD prior the adoption of the Law, will have the same rights.

### Innovation Workshop

The Innovation Workshop (IW) is a four-week full-time dive into Skoltech ecosystem designed to foster innovators, focus on teamwork, group projects, sparking entrepreneurial instincts from the very first days of studies. The workshop was successfully delivered to 340 students and 16 visitors by Skoltech faculty and 20 mentors coming from Russia, Israel, Switzerland, Turkey, Canada, and Armenia. The workshop resulted in students' startups applications to Skolkovo residency, some projects started preparation for company registration.

### Industrial Immersion

Skoltech rich partnerships with industry provide excellent opportunities for valuable experiences during the studies. The Industry Immersion program, embedded into MSc curriculum, is a way to familiarize students with companies through applied research projects.
In 2022, almost 200 projects were completed in 105 companies spreading from St. Petersburg, Perm, Tomsk, and Novosibirsk to Krasnodar, Samara, Grozny and Yuzhno-Sakhalinsk. The pool of the companies included top market players, small enterprises as well as technology startups, mainly Skolkovo residents.
For the second year in a row, students demonstrated a strong interest for internships in Skolkovo: 42% of industry immersion companies are Skolkovo startups, including Skoltech affiliated companies (16%).
On top of valuable first-hand experiences in companies, Industry Immersion brings joint theses research

and further graduates' employment in such companies. Among examples are companies Samsung AI, Sberbank, Sber AI Institute, BostonGene, KAMAZ, Nanosematic Lab, Piklema, Huawei, Gazprom, Hait.AI.

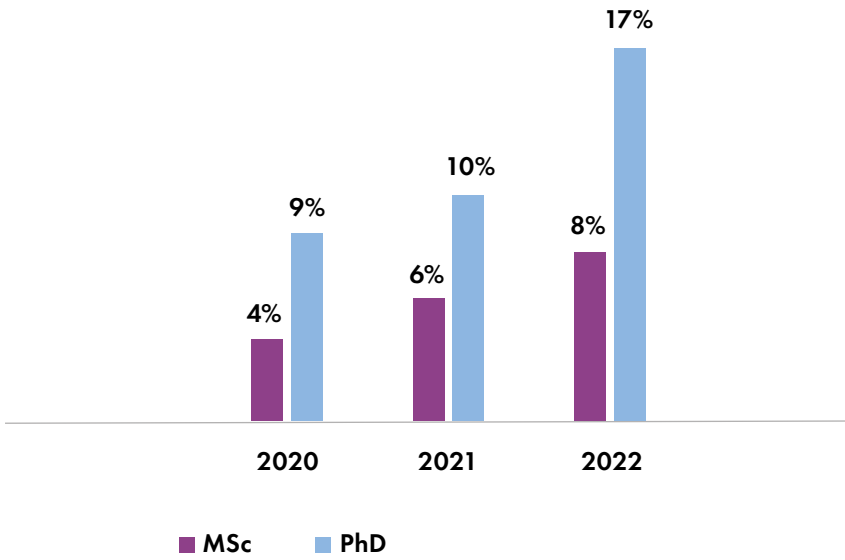
## Academic Mobility

The mobility program gives students opportunities to gain experience in the international community that, first of all, broadens professional networks. After two years of pandemic, the mobility program became fully operational. The geography of long-term trips covered Humboldt University Berlin, MIT, ETH Zurich, KU Leuven, Sharjah University, RWTH Aachen University, Ben Gurion. Short-term trips were mainly conducted to support students' participation in top conferences organized in Russia.

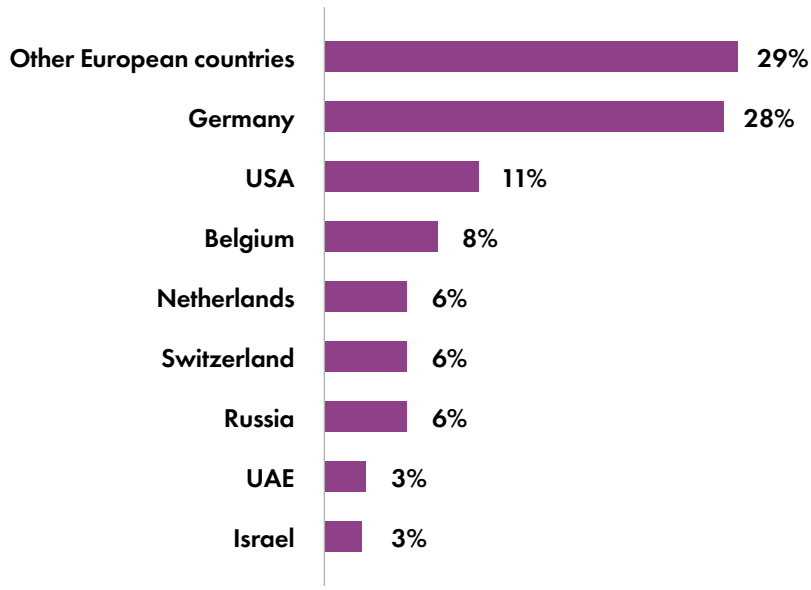
The adoption of the Law became a real test for the Legal Department to respond to a fast-changing context. Skoltech applied for a formal status of one of the leading universities within a general procedure. The extensive lawmaking track turned into an intensive one, once the Parliament initiated support measures for sanctioned persons. It was essential to present materials substantiating the position of the Institute – we had it fully ready, presenting instantly.

**Natalia Shepeleva, Head of the Legal Department**
**Dmitry Golovanov, Head of Legal Support of the Educational Activities**

## Students participated in academic mobility




## Long-term mobility trips



## Independent Study Period

The Independent Study Period (ISP) provides students with wide flexibility and freedom to discover areas not bound with curriculum. The "Best ISP Student Course Competition" was initiated to reward students who sophisticatedly developed and outstandingly delivered own courses. To support such students in content design, the course "Teaching Essentials" was organized. Traditionally, the ISP was rich with activities proposed by faculty, researchers, invited speakers and students. Just some examples: "Literature of the 20th Century: Modernism and Realism (Prof. Maksim Zhuk, Far Eastern Federal University), "Critical Thinking and Design of Experiment" (Irina Muhina, Founder and President of iECARUS), "Introduction to Model UN: Diplomacy and International Relations (Elena Kiseleva, Student Affairs, and Aayush Jha, MSc student), "Chess Strategies" (Konstantin Zamansky, PhD student).

## MSc Defenses

In 2022, 256 students defended theses in front of 22 Defense Committees, comprised of 118 members. Industry representatives typically constitute nearly 20 percent of Committee members.

| MSc Program | Graduates 2022 |
|---|---|
| Advanced Manufacturing Technologies | 13 |
| Life Sciences | 34 |
| Information Science and Technology | 30 |
| Data Science | 75 |
| Energy Systems | 13 |
| Materials Science | 19 |
| Mathematical and Theoretical Physics | 9 |
| Petroleum Engineering | 21 |
| Photonics and Quantum Materials | 19 |
| Space and Engineering Systems | 23 |
| **TOTAL** | **256** |

The best thesis research projects are outlined below.

| Student | Thesis Title | Research Advisor |
|---|---|---|
| Elizaveta Gladchenko | Application of CR-Type Models for Well Layout Optimization and Decreasing Well-Drilling Risks | Prof. Dmitry Koroteev |
| Valentina Kravtcova | Wasserstein Gradient Flows: Modeling and Applications | Prof. Alexander Safonov |
| Nargiza Toboeva | Design Guidelines for Active EMI Filter for Three-Phase Inverters | Prof. Federico Martin Ibanez |
| Irina Skvortsova | Advanced Ni-Rich Layered Cathode Materials for Lithium-Ion Batteries: Soft-Chemistry Synthesis and Modification | Prof. Artem Abakumov |
| Assel Yermekova | Machine Learning Methods in the Physics of Laser Plasma Accelerators | Prof. Sergey Rykovanov |
| Timotei Ardelean | Towards Improving 3D Computer Vision Solutions Using Depth Data | Prof. Evgeny Burnaev |
| Petr Mokrov | Wasserstein Gradient Flows: Modeling and Applications | Prof. Evgeny Burnaev |
| Gaith Mqawass | Receptor-Ligand Binding Affinity Prediction Using Graph Neural Networks | Prof. Christoph Borchers |
| Simona Nitti | Geomagnetic Storms Forecasting from Solar Coronal Holes | Prof. Tatiana Podladchikova |
| Aleksandr Artemov | Five-Point Correlation Numbers in Two-Dimensional Quantum Gravity | Prof. Pavlo Gavrylenko |
| Nikolay Kishmar | Influence of the Resonant Scattering Processes on the Josephson Current Through an Anderson Insulator | Prof. Konstantin Tikhonov |
| Dmitrii Kalashnikov | Resonance Spectroscopy of the Superconducting Current Vortex Dynamics in Planar Josephson Junctions | Prof. Anton Andreev |
| Mikhail Skutel | Antirestriction Mechanisms of the Phage P1 Dar System | Prof. Konstantin Severinov |
| Dmitry Fedorov | Genome Biology and Adaptations in in Midge Dasyhelea Calycata (Diptera: Ceratopogonidae) | Prof. Georgii Bazykin |

The Post-Defense Committee and student surveys were conducted to collect feedback on procedures for theses preparation and defenses to compare students' and advisors' views and define actions for improvement.

Several steps were taken to increase quality of the whole process. This included new MSc Thesis Manuscript Regulations, thesis manuscript and defense templates, specification of assessment criteria, introduced to all parties involved – students, faculty advisors, reviewers, Defense Committees.

Academic integrity and writing support resources were collected and became available for students. Extra English language classes were offered for those willing to improve quality of texts. Digital MSc thesis and defense evaluation forms were revised to reflect MSc Thesis Manuscript Guidelines, including two assessment domains: criteria for thesis contents and criteria for assessment of text.

## PhD Defenses

For the first time, the annual PhD graduation class exceeded 100 students. Despite the limited international ties, the highest standards for defenses were maintained, and top-notch international faculty participated in PhD defense juries.

All 39 PhD defenses were organized in a hybrid mode with online presence of jury external members, while keeping the requirement of onsite attendance of 1/3 of the jury.

Joint doctoral programs with leading international universities were ongoing: two double degree PhD defenses were organized with Curtin University and University Grenoble Alps.

Summarizing the outcomes of all PhD defenses (2017 – onwards), from total of 183 PhD students defended degrees, 148 successfully defended Skoltech PhD degree including 11 double degree defenses. 35 students defended at external committees of the top national universities or research institutions.

| PhD Program | Total Defenses | Skoltech PhD | External Defenses | Place | Double degree defenses | Partner |
|---|---|---|---|---|---|---|
| Life Sciences | 46 | 38 | 8 | MSU, HSE, RAS | 2 | Sorbonne, Uni de Paris |
| Computational and Data Science and Engineering | 28 | 22 | 6 | RAS, MIPT | 1 | - |
| Engineering Systems | 26 | 25 | 1 | HSE | 3 | University Grenoble Alps |
| Materials Science and Engineering | 26 | 21 | 5 | RAS, MIPT, ITMO | 2 | |
| Physics | 23 | 16 | 7 | RAS, HSE, MIPT | 3 | Aalto University |
| Petroleum Engineering | 18 | 17 | 1 | MSU | | Curtin University |
| Mathematics and Mechanics (Mathematics) | 12 | 5 | 7 | HSE, RAS | | HSE |
| Mathematics and Mechanics (Mechanics) | 4 | 4 | | | | |
| **Total** | **183** | **148** | **35** | | | |

## Teaching and Learning Community

One of priorities in the education domain is to shape a joint team of faculty, students, and administration to share teaching and learning experiences and develop innovative approaches. The effort is led by the Center for Teaching and Learning Excellence.

The Faculty Development Program was continued to support new faculty

in teaching and pedagogical skills. The course "Facilitating and Accessing Learning" (Prof. Magnus Gustafsson), Round Table "Excellence in Research Supervision", a training course "Towards Excellence in Teaching Assistantship", as well as day-by-day consultations were provided.

The "Innovations in Education" internal grant award was introduced to support development of new approaches enhancing studies. The "Computational Biology of Aging" course (Prof. Ekaterina Khrameeva) and "Nanomaterials E&I" course (Prof. Albert Nasibulin and Prof. Dmitry Kulish) received awards.

The recipients of the Teaching Excellence Award were announced at the July commencement ceremony to recognize faculty contributed to teaching and learning.

Prof. Albert Nasibulin

Teaching Excellence

Prof. Alexey Nikolaev

Best Instructor of the Year

Prof. Maxim Panov

Best Research Supervisor

Prof. Dzmitry Tsetserukou

Best Career Trainer

Prof. David Pozo

Best Mentor

Prof. Ivan Oseledets

Best Professor

Prof. Elizaveta Tikhomirova

Best New Course Development While Adapting to Hybrid Mode

This is the first course focusing on computational methods in the biology of aging, which have had a significant impact on the field in recent years. We immerse students in the context of this problem, considering it from different angles, and using different statistical models, machine learning and dynamic models. This course bridges the gap between molecular biology, bioinformatics, and machine learning, complementing the molecular part of aging biology with the latest computational methods. Therefore, the course is suitable, on one side, for biologists with basic coding skills, and, on the other side, for data scientists with a very basic background in biology. Developing such new courses that present cutting-edge research and methodology to students is essential for keeping Skoltech educational programs up-to-date within the fast progressing framework of modern science and technology.

**Prof. Ekaterina Khrameeva, Bio Center**

## Library

Skoltech library is a key component to support teaching and learning, actively engaging with all Skoltech community.
The year was challenging due to the closed access to many sources. To ensure a seamless access to resources, several measures were taken, including migration of the library system to the local servers. Skoltech and a Skoltech Founder, Skolkovo School of Management, merged print books collections to provide access to more than 3500 business related books.
The online course "Digital Literacy" was piloted for students. In 2023, the course will be updated considering available access to scientific digital resources.

| Databases | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|
| **Print books collection** | 930 | 1 100 | 1 248 | 2700 | 5967 |
| **Skoltech e-books** | 370 | 420 | 435 | 469 | 497 |
| **Full-texts downloads from e-library databases** | 110 000 | 214 000 | 206 000 | 191 000 | 204 000 |

The main principle of my teaching is "Learning by doing". An old Chinese Proverb says "I read – I forget, I see – I remember, I do – I understand". One can forget facts, but one cannot forget understanding! We all have learnt as a child how to talk, to walk, to ride a bicycle and many other things. Many arts and special skills like dancing, singing, swimming, and martial arts are all learnt by doing to an expert or a teacher, who makes us to learn by doing rather than by listening to lectures or reading books. "Learning by doing" is very important, since while we are doing we are prone to fail and failures (and mistakes) are important in the learning process. Once we fail we start analysing the situation. Thus, at the point of failure a profound learning takes place. That is why people say: "Failures are the stepping stones to success!".

**Prof. Albert Nasibulin, Photonics Center**

## Professional Education

The professional education function was successfully ramped up with the strategy for a quick growth in the market, thanks to distinctiveness of Skoltech offer. In total, 26 programs for more than 600 participants were delivered, more than 520 participants receive state diplomas, while the income raised from the contracts reached the highest ever amount of 130 mln Rub.

Skoltech offer was composed of programs for senior engineering staff, young specialists of high-tech companies, as well as faculty of top Russian universities. The programs of different scope and duration were offered in the fields of Advanced Materials, Agro, Additive Manufacturing, 5G and IoT, Oil and Gas, Neuro Technologies, Technology Management. Several notable examples include the following:

- **Technology Management program** for the winners of the 1st National Contest "Leaders in Energy". Jointly with Skoltech staff, 100 participants representing senior engineering staff of energy companies designed 13 applied projects, presenting the outcomes to the Chief Engineer of Rosseti.
- **Engineering Quest** for young engineers, winners of the EVRAZ internal contest. During the program, the participants and Skoltech researchers generated technology driven ideas, which were further presented to EVRAZ VP for Technology Development. Several examples of such ideas:

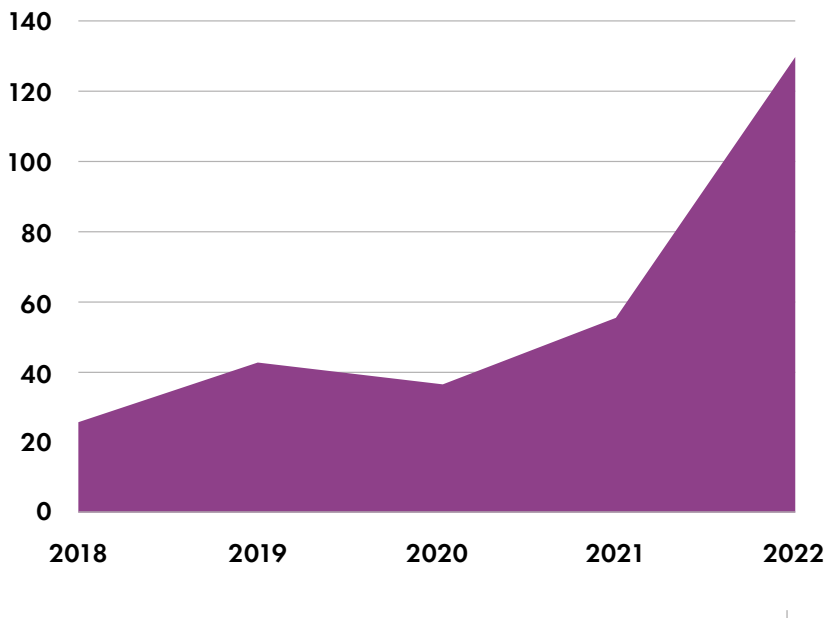
› predictive analytics and optimization of operating modes of rolling mill equipment,
› design and implementation of a digital twin of a mechanized support to train employees and monitor conditions in real time,
› evaluation of prospects for creating a product line of metal powders for 3D printing,
› evaluation of creation of a fleet of metal 3D printers for the purpose of equipment repairing at metallurgical companies,
› LPWAN networks for connecting devices while implementing industrial Internet of Things systems,
› improving energy efficiency by creating energy consumption model, modeling the inclusion of renewable energy in the consumption cycle to reduce carbon footprint.

- **Fundamentals of Electrode Materials Production Technology program** for senior engineering staff of Nornickel delivered by Laboratory of Cathode Materials Synthesis,
- **Digital Modeling of New Thermoelectric Materials** program for Thermointech company to train specialists in modeling structures of thermoelectrics, searching for optimal values of compositions of thermoelectric materials.

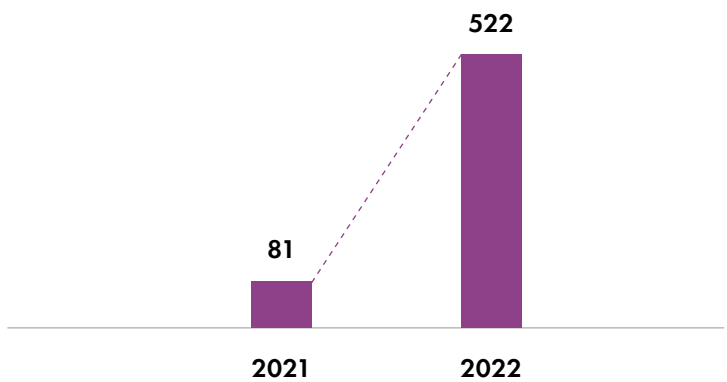
Skoltech network with international

universities, research institutions and companies is the absolute competitive advantage, appraised by many clients. Invited speakers from top universities and technology centers share expertise required for understanding global technology context. In responding to the fragmented international cooperation, Skoltech shifted a focus to Asia: more than 10 faculty and industrial experts from top universities in China and India became invited speakers by Skoltech invitation.

**Income from professional education (mln Rub)**




**Professional education diplomas issued**




Предиктивная аналитика и
оптимизация режимов работ
оборудования прокатны
Команда № 2


ЕВРАЗ
Skoltech
23–25 марта 2022

Skoltech has become a permanent partner for technology companies within developing the competencies necessary for the development of knowledge-intensive business areas and introducing new competitive technologies into the activities of companies We create special educational products in professional education that provide a transfer to the world-class knowledge industry, the formation of unique human capital and the experience of effective collaboration between the university and leading technology companies.

**Alena Norko, Head of Professional Training Programs**

# Entrepreneurial Readiness and Spirit

The Center for Entrepreneurship and Innovation (CEI) continued to deliver a comprehensive program to support students and academic staff in implementing ideas to create impact, accelerate Skoltech research outcomes towards commercialization.

## Education in Innovation

The Startup Funnel is the core of Skoltech E&I curriculum. In 2022, more than 350 students experienced a seamless journey "From Idea to Startup", participating in various team-based and project-based activities. The Funnel brought more than 60 projects and more than 15 project applications for Skolkovo residency.

| Innovation Workshop (IW) | Startup Workshop | Startup Founders Workshop | Technological Entrepreneurship Workshop |
|---|---|---|---|
| One-month course for MSc intake that unites students, faculty and mentors to create foundational experience in Entrepreneurship and Innovation | The course to accelerate teams born in IW and similar project-based courses and programs | A learning-by-doing course to provide experience of translating technologies into innovative products and startups | A practical workshop to "level up" startup projects for capacities required for receiving external support /funding |

The new courses in the CEI portfolio included "Startup Launchpad: Deep Tech and Digital", "Startup Lab", "Technology Entrepreneurship Seminar", "Technological Innovations: from Research Results to Commercial Product". The courses "Business Communication" and "Leadership for Innovators" received high appraisals of students.

## Startups

The number of Skoltech associated startups in Skolkovo and far beyond reached almost 150 companies, many of which received business development support of the CEI.

Among the new companies established and received Skolkovo residency are ANRIA RESEARCH (augmented reality glasses for robotization of labor-intensive assembly processes), UMNYASH (software based on AI to assess readiness of children for primary schools), NEUTRONAI LABS (early diagnosis of plant diseases in greenhouses using a software and hardware complex based on AI technology), Eco Energy (a smart waste management system for home and industrial use).

To stimulate entrepreneurial spirit among students, the Triple Point Program opened the Energy+ track supported by Gazprom Neft and Energotechnohub Petersburg. The Jury of industry experts reviewed pitches from 10 finalists to select the winners. The event held on campus, gathered students from Skoltech, MIPT, ITMO, Pirogov Medical University, Polytechnic University of Milan.

## Translational Research Program

The Translational Research program was further continued bringing new IP and startups. The new call for proposals resulted in 34 applications, 10 projects were considered for approval to start in 2023. The select examples of ongoing projects are presented below:

| Project PI | Project | Project scope |
|---|---|---|
| Prof. Evgeny Nikolaev | Portable mass spectrometer for identification bacterias and virus | Development of a reproducible universal mass spectrometer based on a new type of mass analyzer – a multi-electrode Kingdon trap and an ion source based on electron impact ionization |
| Prof. Evgeny Burnaev | EpiDetect | EpiDetect is a prototype recommender system that can be used at all stages of an MRI study of epilepsy |
| Prof. Philipp Khaitovich | Olfactory Rehabilitation System | Incorporating a brain-computer interface into an olfactory diagnostic and learning system designed for clinical and home use |
| Prof. Dmitry Yudin | Neuromorphic event camera for vibrodiagnostics and surveillance | Development of a system and method for non-contact measurement of object surface vibration parameters based on a neuromorphic camera. This technical solution relates to the field of non-contact measuring instruments and can be used in machine vision systems to assess the technical condition of equipment, machines, mechanisms, building structures and production facilities as well as to solve tasks related to vibration diagnostics optical way |
| Prof. Igor Shishkovskiy | 3D printing of superelastic intermetallic nitinol parts for endodontic instruments | Development of technology for 3D printing of self-adapting files used in endodontics to clean tooth canals |

## Business Development

The commercialization of Skoltech research is made through business development programs which include preparation of business cases, consulting, partnerships development. In the context of sanctions and decrease of overall investment activities in Russia, the business development track was refocused towards working more intensely with state and state-owned companies and corporations, as well as individual investors.

Skoltech associated startups were included into Moscow Innovation Cluster, Technopolis Moscow, Moscow City Government Cluster, to expand opportunities for finding new partners and investors. Activities were launched with Armenia (Ministry of High-Tech Industry): the working group for joint interaction of scientists and startups to develop new technologies in various fields was established. Communication lines were opened with North Ossetia (North Ossetian State University), and Kyrgyzstan (Bilimkana Foundation) to attract investors and strategic partners.

Negotiations were held with a number of companies: Nornickel, PIK and Samolet (on use of anti-virus paint), Rostelecom and Electronic Mushrooms (development and promotion of a platform for evaluating behaviour of players in computer games).

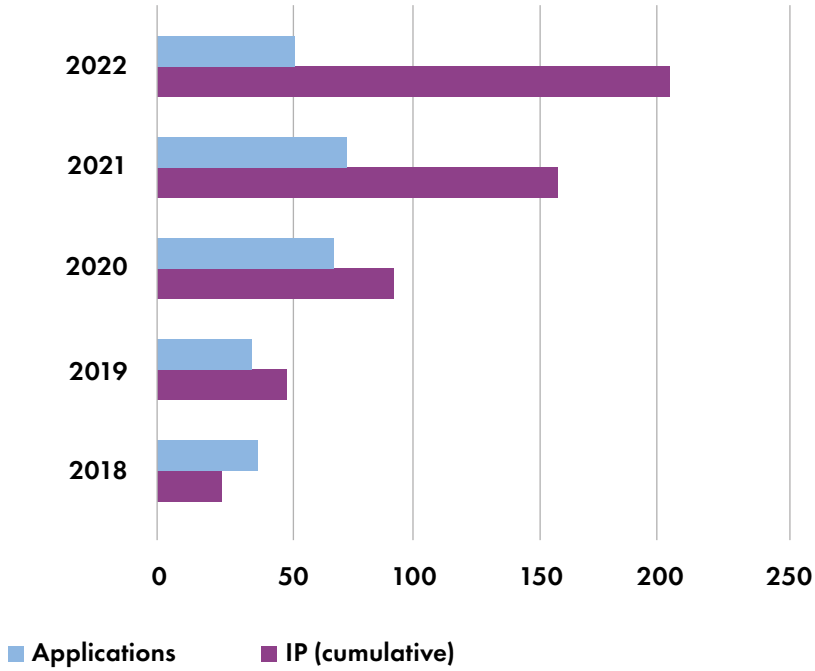
Collaborations were established with a number of national universities (MGIMO, Financial Academy) to pursue different opportunities of experience exchange, conferences, business development programs.

By the end of 2022, Skoltech associated startups and projects raised more than 260 mln. Rub, both of public and private investments, including Bortnik Fund, New Industry Fund, Skolkovo Foundation, and the Moscow Government.

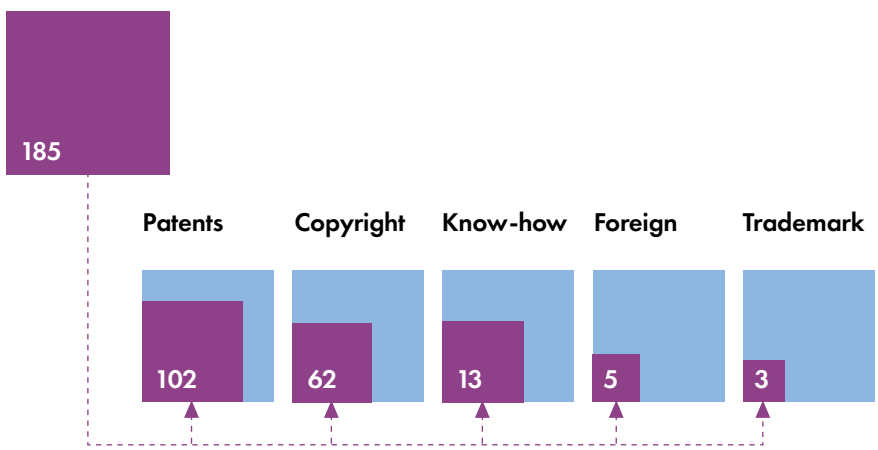
## IP Management

The Technology Transfer Office continued to work with IP portfolio, stimulating patent activities and technology licensing. The sanctions influenced the plans for international patenting and licensing: restrictions on patent applications and termination of several contracts with US and EU contractors were in place. Still, 9 licensing agreements were signed in total of 21.6 mln Rub subject to a company's annual income. The majority of the agreements cover areas of application of AI technologies in Oil and Gas, Medicine and Telecommunications. Half of the signed agreements are with Skoltech associated startups.

## Patents




## IP Portfolio




The IP Policy was revised predominantly to reduce risks of IP loss. In particular, provisions were fixed to ensure obligation of authors to disclose a conflict of interest, definition of previous and third-party IP and the obligation of authors to disclose such IP. The concept of priority right was introduced to encourage authors to create and disclose IP. The electronic IP Disclosure Portal was finalized and will be opened in 2023.

# Community Engagement

## Science Outreach

Science outreach was significantly expanded, both as for the programs and audience coverage. Numerous lectures involving faculty, researchers and students were conducted in Arhe, Gorky Park, Zaryadye, Consortium of universities and organizations of the Eurasian World-class Science and Education Center (Ufa), Yeltsin Center (Yekaterinburg), Tochka Kipeniya (Moscow, St. Petersburg, Perm, Kazan, Yekaterinburg, Samara), Yandex, Noôdome, Medio Modo, Atomic energy information centers and other sites.

The Lecture Hub successfully delivered more than 90 lectures, while the "Hi, Tech" program was conducted from Moscow to Novosibirsk. Skoltech also participated in the large national science fests, such as Festival of Russian Geographical Society, and NAUKA 0+.

Summer schools, workshops and excursions were organized for schoolchildren of Skolkovo Gymnasium, Letovo school, Pushkov Gymnasium, Dubna, Sirius Educational Center and Sirius Presidential Lyceum, as well as different STEM schools in Moscow and beyond.

On top of that, the Open Learning team delivered targeted programs for teachers: "Training of mentors of research projects" in cooperation with NSU, Innopraktika and Foundation for Support of Projects in the Field of Education, a workshop for mentors from the flagship Artek, and video content for the Academy of the Ministry of Education.

**>90**
open lectures

**>300**
activities for schoolchildren

**13**
cities in Russia

**>1.9**
mln offline and online listeners

In 2022, more than 3200 gifted kids from 12 regions of Russia joined lectures, classes and excursions at Skoltech. One of the highlights is Skoltech participation in the program “Training of mentors for research projects”, implemented by the Foundation “Education” and “Innopraktika”, which allowed school teams to prepare high quality projects. We are glad that the Skolkovo Gymnasium became the winner at the Interregional Conference of Network Research Projects in one of nominations. The other highlight to be noted is a large project of Skoltech Laboratory for Metagenome Analysis for students in the field of “civil science”, organized jointly with the Ministry for Science and Higher Education. Thanks to the efforts of the Laboratory team, over 1,680 schoolkids and students gained knowledge and skills in Bioinformatics and Molecular Biology, contributing to the lab research projects.

**Natalia Matsneva, Projects Coordinator**

## Media Projects

Several media projects dedicated to excellence in science were delivered in Life Sciences and Mathematics.

### Life and Other Stories

The interviews with top scholars in biological research. Among the invited guests are famous physicians, biologists, mathematicians that work in bioinformatics, spectroscopy, zoology and ecology.

39 publications released in 7 media, total audience coverage exceeded 2 million people.

General partner: RSF

Partners: Kommersant – Nauka and Schrödinger's Cat magazines,

Naked Science, Biomolecula, PCR-News and Stimul internet-media

### Kolmogorov 120

The project dedicated to the 120th anniversary of the great 20th century mathematician, initiated in frame of the Decade of Science and Technology in Russia. The project main consultant was Andrey Kolmogorov's successor, academician of the RAS Albert Shiryaev.

Partners: Steklov Institute of Mathematics, Yaroslavl State University

### Mathematical Walks+

Interviews with top world mathematicians: Yakov Sinai (Abel Laureate of 2015), Maxim Kontsevich, (Fields Medalist of 1996), Andrei Okounkov (Fields Medalist of 2006).

The updated and expanded edition of "Mathematical Walks+. A Collection of Interviews" released in Russian. The new edition contains 32 interviews.

Partner: Kommersant – Nauka

## Media and PR

To highlight Skoltech research, 119 press releases were issued. More than 50 long-form features were published in the federal media. Some research was listed by the media among the breakthroughs of 2022. The following stories caught media attention and got viral.

- Large-scale forecasting model of Sosnowsky's hogweed habitat suitability under climate change using publicly available data
- A feasibility study of satellite formation-flying missions for space advertising
- Design of a high-capacity and high-voltage positive electrode active material for sodium-ion batteries
- Modeling of salt migration and its effect on the speed of permafrost meltdown

Selected stories in English:

- Ad-block this: Space advertisers ready to display commercials in the sky
- New material pushes sodium-ion batteries to phase out costly lithium
- Study probes Earth's turbulent past to explain where oceans came from
- Improved cathode material for electric vehicle batteries packs up to 25% more energy for longer drives
- Scientists use toxic hogweed to make anode material for cheap sodium-ion batteries for wind farms

In 2022, Skoltech was in the spotlight of the largest national and foreign media, including Izvestia, TASS, Rossiyskaya Gazeta, Habr, CNN, The Independent, La Nacion, El Pais, El Universal, Newsweek, Daily Mail, Fortune, and CNBC.

Faculty and researchers gave interviews and comments to news agencies (TASS, RIA Novosti), federal media (Kommersant, Rossiyskaya Gazeta, Gazeta.ru), science, business and tech blogs and magazines (Habr, journals "Expert" and "Stimul"). They were featured in video reports (Channel One Russia, Russia 1, Russia 24, Izvestia, NTV, REN TV, 360, TV BRICS, TV Center) and radio broadcasts (Mayak, BFM.RU, Kommersant, and others).

Skoltech expanded its network. Its representatives participated in large business and academic events, including St. Petersburg International Economic Forum, the Congress of Young Scientists in Sochi, AI Journey Conference. Also, the campus welcomed numerous visitors: officials and diplomats, university administrators, and industry representatives toured Skoltech to gain a first-hand impression of the Institute, labs, and meet with researchers.

Two interdisciplinary projects were launched:

- With the support of the Russian Ministry of Culture, Skoltech and the FANK Science Film Festival organized the first Science Film Lab to help young directors make their first steps in science filmmaking. The lab produced 16 documentary short films featuring Skoltech researchers. More than 100 venues across Russia, from Moscow multiplexes to rural Houses of Culture, screened The Almanac: 16 Ways to Change the World. The Science Doc Lab got shortlisted for the All-Russian Award for Fidelity to Science.

- The collaboration of artists and Skoltech scientists resulted in the exhibition project "Frequencies 3.0: The Magic of Super Technology". The project presented multimedia art objects, interactive installations, and digital and video art. More than 3,000 people visited the exhibition in Khodynka Gallery in Moscow. In December, the exposition moved to the campus.

## Marketing and Brand

The marketing and brand promotion were continued with a variety of activities to highlight Skoltech unique features.

The online campaign for student recruitment was challenging due to restricted access to international promotions channels. However, alternatives were found to ensure a strong digital presence and coverage of the audience.

The social media profile was refreshed with 2 Telegram channels, both in Russian and in English, presence in a popular Zen science blog, and a page on the Reddit. The Telegram channel in Russian became not only one of the main channels for sharing news, but also effective for attracting applicants. Research content on a variety of topics was published in Zen. Skoltech page on Reddit brought 4 mln users worldwide of coverage. Many posts were rated among the most popular content of the week, for example, these are posts on synthesis of $K_2N_6$, an exotic compound containing "rings", analysis of specific labour costs for producing a 1 carat diamond, a gynecological simulator with tactile feedback for practicing outpatient hysteroscopy.

New formats were also piloted: a radio podcast with students, a corporate brochure "Created to Create", and a virtual campus tour.

## Events on Campus

The campus life was vibrant with more than 200 conferences, seminars, visits, executive meetings, community building events. Among the most visible events of the year are the Skolkovo Foundation Board of Trustees attended by Dmitry Medvedev, a foresight session "Financial sovereignty of Russia" and a keynote speech of Dmitry Peskov, a special representative for Digital and Technological Development of the RF President, Skoltech Family Day on the eve of New Year.

The campus was also popular for external clients. 35 events for the Accounting Chamber of the Russian Federation, Sber University, UAK, Rosseti, Evraz, Tinkoff, MTS, LIME, Detsky Mir, Funky Monkey Cola, Yandex, KIA, Mascotte and other companies were organized by the Events team.

# Strategy KPIs 2022

The performance on the Strategy is measured with several key indicators (KPIs), reported to the Board of Trustees, Skolkovo Foundation, Ministry for Finance and Ministry for Economic Development. Reflecting the mission, the KPIs measure academic and technology excellence, success of graduates' employability.

The year results show that despite of the turbulence and negative effects of sanctions, the overall performance was in line with expectations. Some positive progress against the targets is evidenced in the Nature Index publication output and external funding.

| Strategy level KPI[10] | Unit | 2022 result | 2022 plan |
|---|---|---|---|
| Skoltech associated startups in Skolkovo ecosystem, and startups supported by the national institutes of development | Units (cumulative) | **92** | 90 |
| Papers in Nature Index journals, top conferences in Artificial Intelligence (A*) | Unit | **126** | 110 |
| Graduates employed in R&D sector in Russia | % | **71** | 70 |

| Supporting indicator | Unit | 2022 result | 2022 plan |
|---|---|---|---|
| **Papers in WoS, Scopus** | Unit | **1102** | 1100 |
| **Papers in Q1 journals** | % | **65** | 62 |
| **Faculty papers in the annual publication output** | % | **62** | 62 |
| **Skoltech associated startups in Skolkovo** | Unit (cumulative) | **85** | 85 |
| **MSc and PhD alumni** | Persons (cumulative) | **1718** | 1690 |
| **External funding** | % | **38.2%** | 33% |

[10] The indicator of "Impact on economy" measures cumulative result in 2025 as per Strategy KPI system.

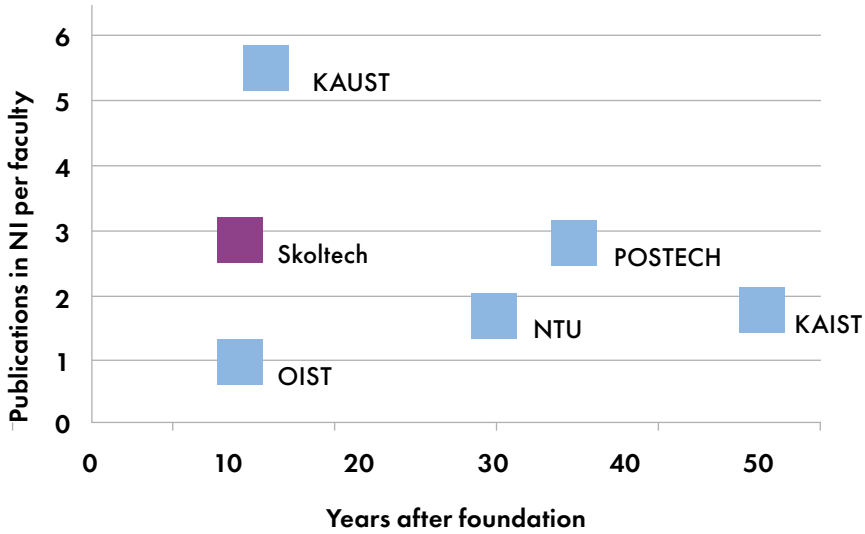
## Benchmarking

Each year Skoltech makes a benchmarking of select indicators. The benchmarking group of universities is chosen in a way to include world leaders, "rising stars" and top national technological universities.

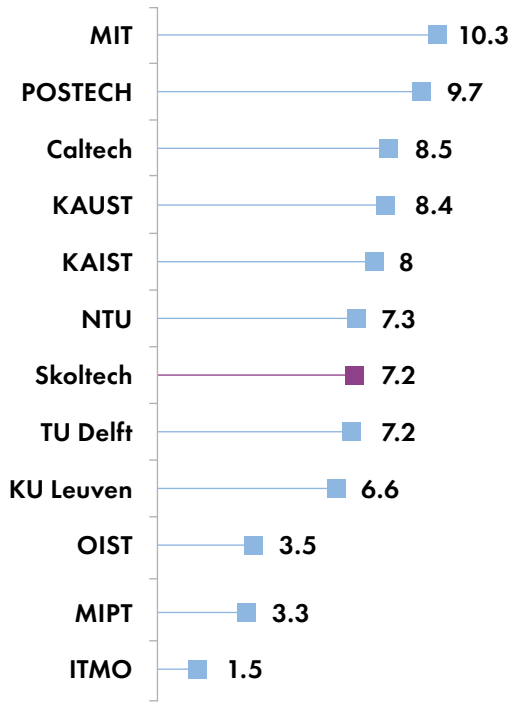
| University | Short title (used in charts further) | Foundation year |
|---|---|---|
| Okinawa Institute of Science and Technology Graduate University | OIST | 2011 |
| King Abdullah University of Science and Technology | KAUST | 2009 |
| Nanyang Technological University | NTU | 1991 |
| Pohang University of Science and Technology | POSTECH | 1986 |
| Korea Advanced Institute of Science and Technology | KAIST | 1971 |
| Moscow Institute of Physics and Technology | MIPT | 1946 |
| St. Petersburg National Research University of Information Technologies, Mechanics and Optics | ITMO | 1900 |
| California Institute of Technology | Caltech | 1891 |
| Massachusetts Institute of Technology | MIT | 1861 |
| Delft University of Technology | TU Delft | 1842 |
| KU Leuven | KU Leuven | 1834 |

The data for the benchmark was extracted from Scopus / SciVal, THE profiles of the universities, official university webpages.

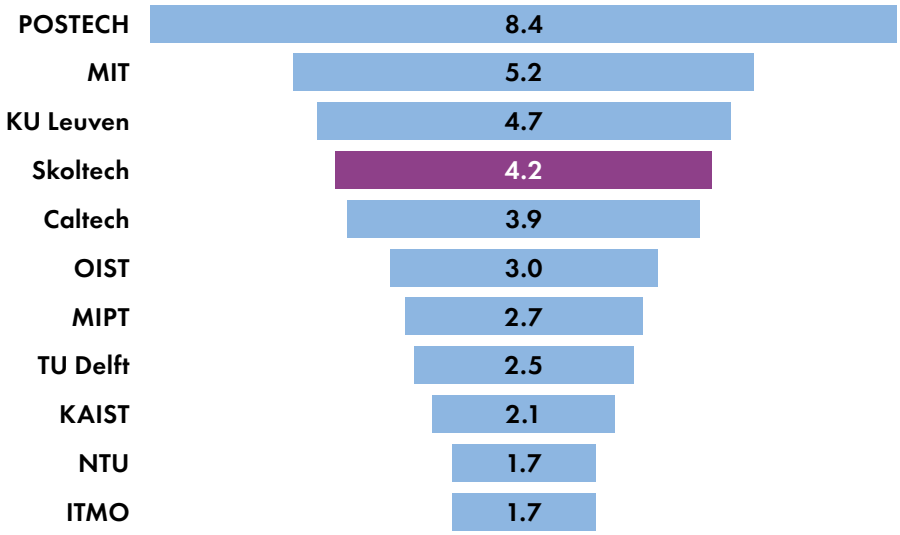
## Nature Index publications per faculty (2019 – 2022)



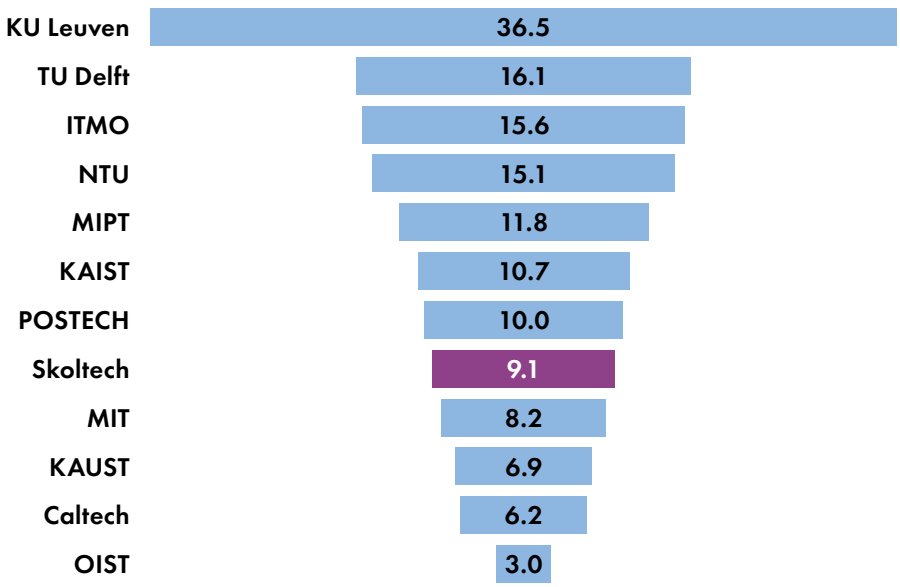

## Academic-corporate collaboration publications 2022 (%)



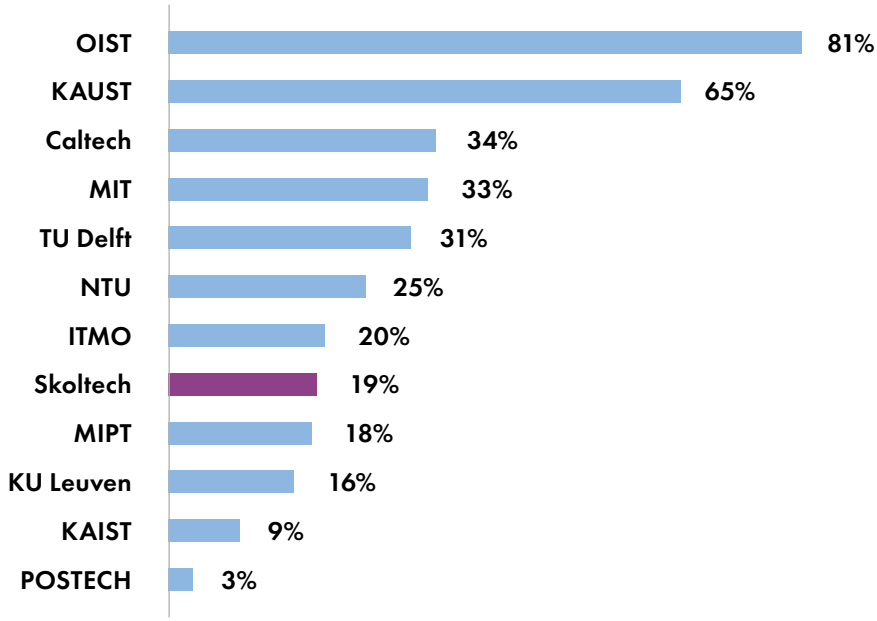
## PhD students per faculty



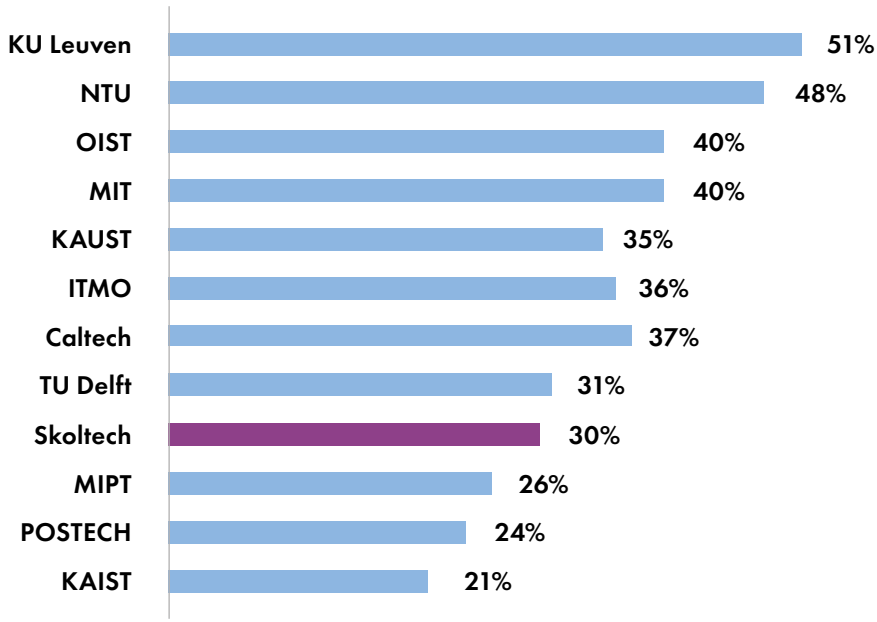

## Student-faculty ratio



## Share of international students




## Share of female students



# Our people

# Personnel

## Who we are

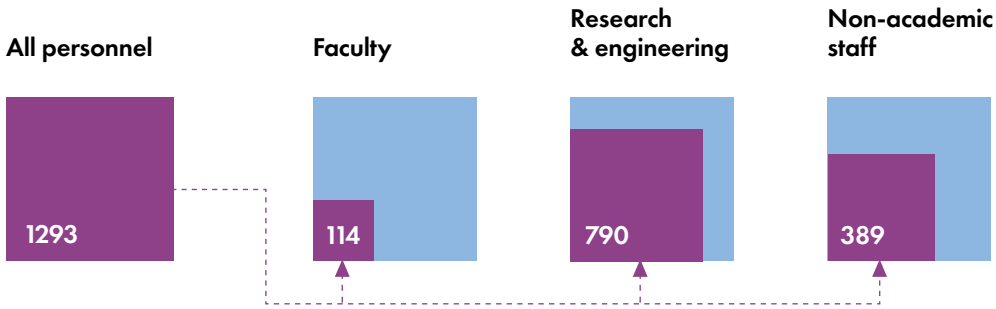
Starting from establishment, Skoltech focus lies in building the international community of motivated and skilled people, who help the Institute to flourish and deliver strategic commitments.

In the past five years, Skoltech has doubled in size, and today has more than 1200 of highly qualified and empowered employees. Skoltech community is multicultural, representing 36 countries, including Argentina, Belgium, Canada, China, France, Ghana, Greece, India, Iran, Italy, Mexico, Nepal, Netherlands, Serbia, Spain, Thailand, United Kingdom, Vietnam, is also balanced in gender and age.

Skoltech faculty, many of whom hold senior positions as recognized leaders in respective fields, hail from various countries and various professional background: academia, industry, entrepreneurship. The 2022 was a challenging year as more than 30 faculty, mainly Full Professors, left Skoltech. At the same time, thanks to senior faculty contribution to the ramp up of Centers and bringing them into full-scale research units, Skoltech succeeded in growing up a new generation of leaders, having appropriate expertise and skills. The core research groups were retained.

As for the structure of personnel, the research and engineering staff compose 70% of the total employees. During the last years, several positive movements were made in recruitment and promotion strategy towards a healthy proportion of academic/non-academic personnel. 78% of all personnel have full-time employment contracts, while part-time contracts are mainly in place for researchers involved in projects funded from grants and contracts. The biggest share of the personnel is in the Centers: Applied AI Center, Bio Center, Petroleum Center, and Wireless Center are the largest ones.

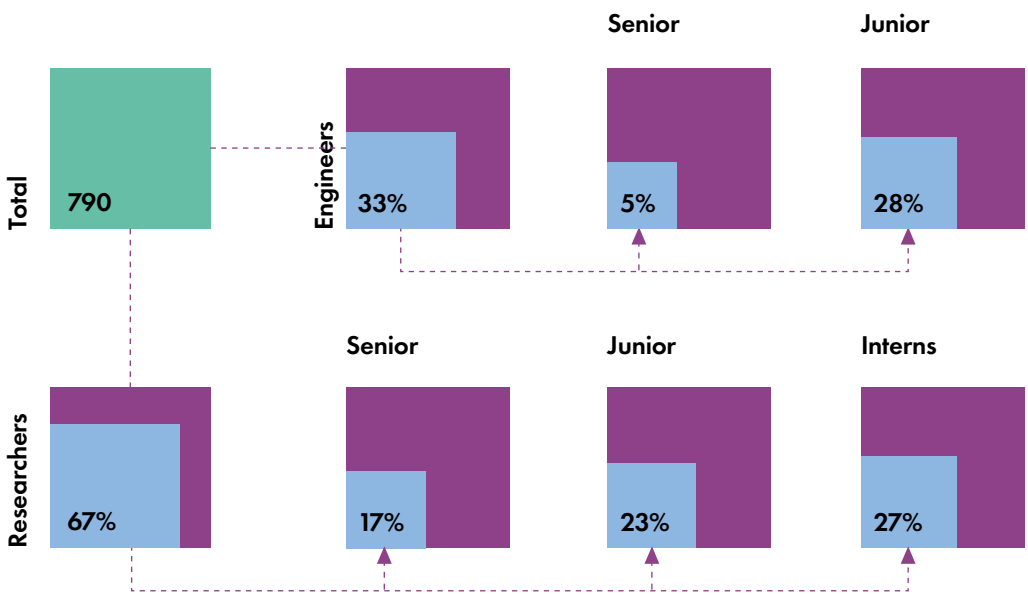
## Personnel categories




### Personnel by gender

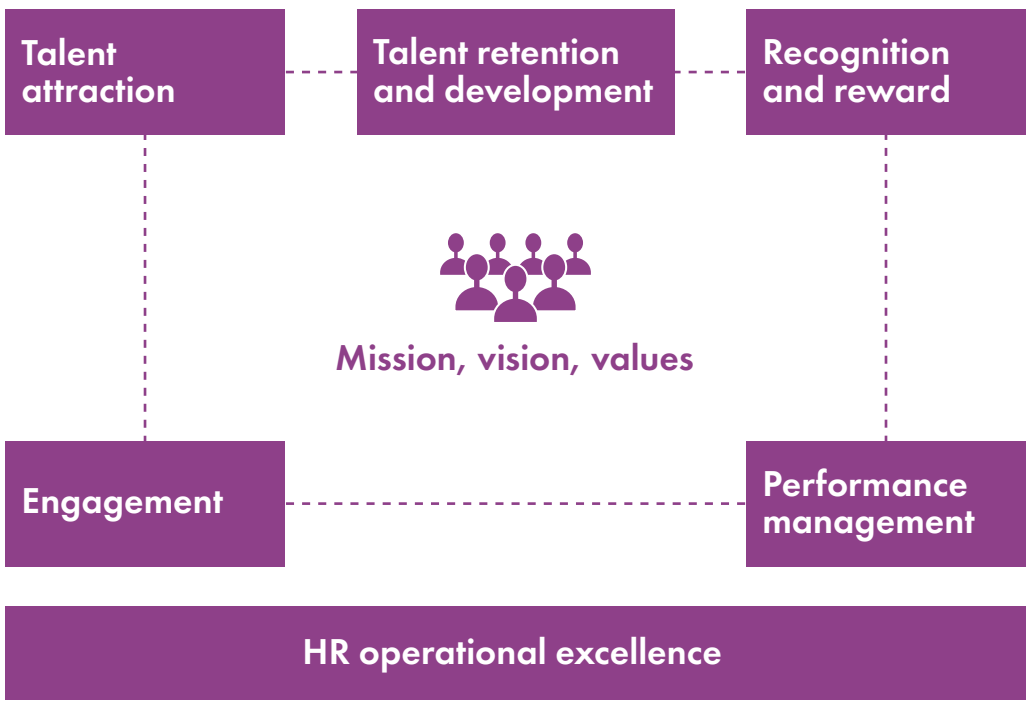
## Personnel by age


## Research and engineering personnel



# People Strategy

The People strategy is built on five overarching pillars – talent attraction, retention and development, recognition and reward, performance management, personnel engagement, and HR operational excellence. Skoltech entered the year with clear and ambitious goals to advance the strategy in all pillars, however, worry burnout and its impact made it more important to improve resilience and capability of people. Talent retention, steps towards the pay for performance along with operational efficiency for immediate external and internal responses, were on the top of the agenda.



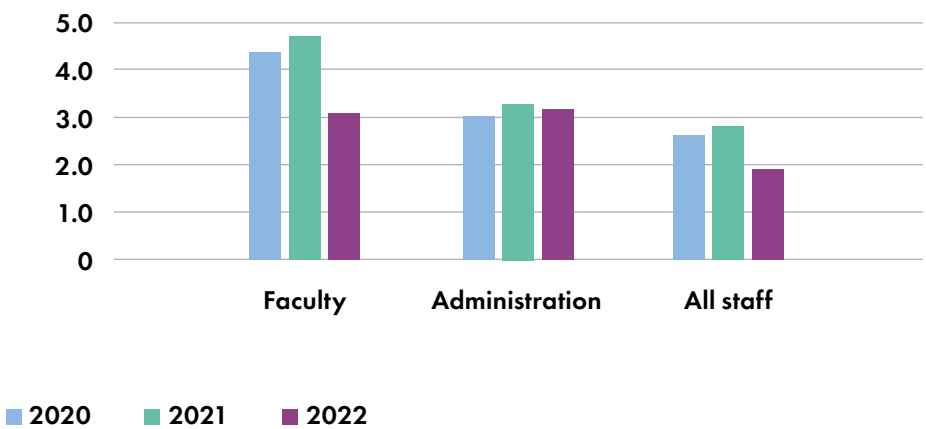
## Talent Retention

The complex situation and a vague outlook made talent retention the first priority.

In the circumstances of senior faculty leaves and overall volatility of academic staff, the immediate actions were taken: Interim Directors from among the research group leaders were appointed to chair the Centers. Centralized decisions, such as long-term contracts for the core staff, along with case-by-case individual solutions were in place to decrease personnel turnover.

The average length of employment, which is one of retention indicators, slightly changed among faculty, mainly due to the contract terminations caused by sanctions. The average length of employment of the whole staff decreased, which is explained by a growing number of researchers and engineers hired for short-term contracts to support sponsored research projects.

### Average length of employment (years)



## Recognition and Reward

The Excellence Recognition Award was introduced to recognize faculty demonstrated contribution to Skoltech excellence in research, teaching, economic impact as well as service.

### Full Professors

Abakumov Artem
Akhatov Iskander
Burnaev Evgeny
Cheremisin Alexey
Drachev Vladimir
Gelfand Mikhail
Gentzbittel Laurent
Krichever Igor
Lagoudakis Pavlos
Lebedev Mikhail
Nasibulin Albert
Nikolaev Evgeny
Oganov Artem
Oseledets Ivan
Osiptsov Andrei
Severinov Konstantin
Spasennykh Mikhail
Stevenson Keith

### Associate Professors

Chudakov Dmitriy
Dylov Dmitry
Ivanov Anton
Lakontsev Dmitriy
Podladchikova Tatiana
Shapeev Alexander
Tsetserukou Dzmitry

### Assistant Professors

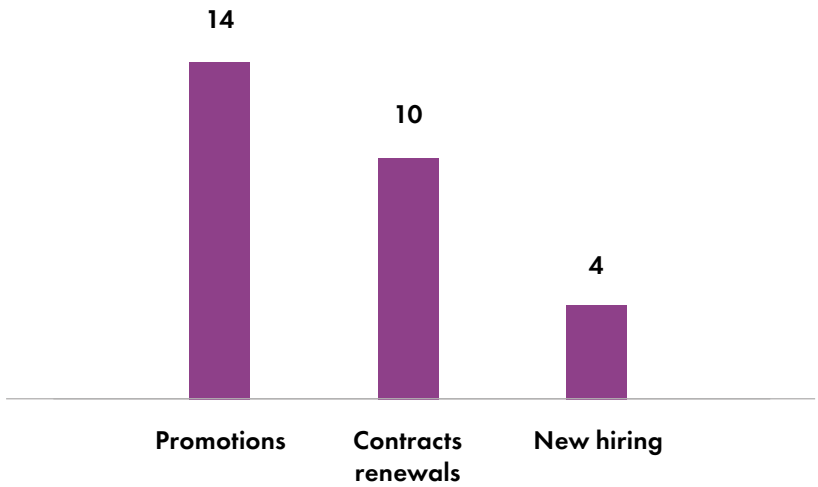
Beliaev Mikhail
Fedotov Stanislav
Khrameeva Ekaterina
Kostyukevich Yury
Kvashnin Aleksandr
Levchenko Sergey
Logacheva Maria
Panchenko Aleksander
Somov Andrey
Zaytsev Aleksey

Skoltech faculty also received a number of external awards:

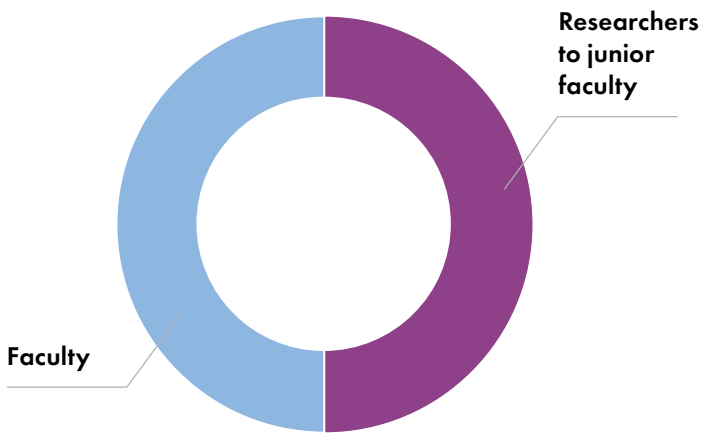
- Prof. Lakontsev awarded with "Technological Breakthrough 2022" in the category "Breakthrough in telecommunications".
- Dr. Shub received the fellowship of "Academician of the International Academy of Telecommunications".
- Prof. Sergiev was elected to the Russian Academy of Sciences as a corresponding member.
- Prof. Gelfand was named the International Society of Computational Biology fellow as well as received the ISCB Presidential Honor for Humanitarian Action.
- Prof. Dylov received the Outstanding Reviewer Award, honorary mention (MICCAI),
- Prof. Titov became 4th out of 10 companies in "Energoproryv 2022" accelerator with his company MIG.

The target promotion program was conducted for young researchers and faculty demonstrated significant contribution to the Centers and Skoltech as a whole. The decisions of the Academic Council were made based on quality of results, plans and their alignment to the Centers' strategies.

## Decisions of Academic Council (Appointment, Promotion and Tenure Committee)




## Promotion decisions



## Pay System Redesign

In line with the plans, the whole Institute shifted to a new pay system in April. The concept was designed accounting international benchmarks, both in academia and business, trends in the job market, as well as Skoltech aspiration to maintain a strong position as employer.

The principles of equality and consistency were ensured with a system of grades, which were fixed as a starting point for base salaries. Base salaries for non-academic staff were set to keep a competitive position on junior and middle grades, while to ensure the "above medium" on grades 14 and higher, where extensive professional and management competencies are required.

The new pay system expanded incentives with new types, including pay for distinguished faculty status, professional competencies, internal projects, bonus for achieving KPI targets, outstanding achievements and 10 years employment at Skoltech.

## Performance Management

The performance appraisal and goal setting cycle was piloted to stimulate open and fair dialogue between supervisors and employees on results and targets from individual perspective, alignment to the goals of the teams and Skoltech at large. The cycle was piloted for all personnel, while the concept was developed in a way to account for academic and non-academic staff. In total, 88% of personnel participated in the process. The vast majority received positive appraisal of supervisors ("meet expectations"), while 4% of personnel received the highest score of "Outstanding performance".

| | |
|---|---|
| **Total employees as of 01/12/2022 (start of appraisal cycle)** | **1173** |
| **Total participants of the cycle** | **1034** |
| Outstanding performance | 4% |
| Exceed expectations | 25% |
| Meet expectations | 70% |
| Require improvement | 1% |
| Below expectations | 0% |

The results of the pilot cycle for administration, researchers and engineers were reviewed by the Personnel Committee, while results of faculty appraisal were reviewed by the Academic Council. Both collegial bodies made recommendations on procedural side to be accounted while planning next steps.

## Personnel Development

Throughout the year, Skoltech offered diverse opportunities to strengthen professional competencies. Investments were made in skills and competencies related to the educational process, internal communications, sanction legislation, finance, audit, procurement, occupational safety, academic writing. The internal PM.Science program was continued to train managers involved in sponsored research projects.
The personnel development program will be expanded in 2023, accounting for results of appraisal and requests for trainings indicated in appraisal forms.

## Employer's Brand

Efforts to make Skoltech employer brand stronger were continued. The key activities included a redesign of Skoltech profile on hh.ru to highlight competitive advantages. The big community event was arranged for all staff and families to celebrate the New Year.
Well-being and health services were also on the HR agenda. Considering international practices and trends, a package for medical services and insurance was extended, while psychosocial support and medical services (including COVID testing) became available for all personnel on campus.

## Occupational Safety

Occupational safety is the essential part of all activities at Skoltech. The Institute continuously improves the quality management system, ensures maximum protection of health and environment, implementing the concept of "zero" injuries.
During the year, intense activities were made to eliminate hazards and reduce occupational risks. In addition to setting policies on occupational and technosphere safety, working conditions were regularly inspected, while a series of special assessments were completed.
Numerous trainings were in place to inform personnel on technosphere safety and improve the overall safety culture. Briefings and seminars on labour protection, fire, environmental, laser, industrial, radiation safety, sanitary and epidemiological requirements, civil defense and emergency situations were organized.

# Students

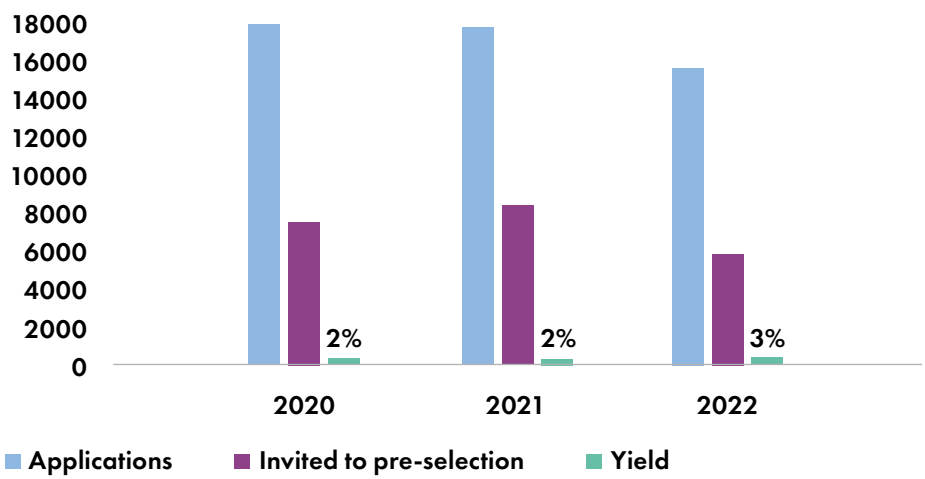
## Talent Recruitment

Skoltech strategic goal is to educate leaders who will demonstrate excellence and make impact in advanced fields of science and technology. Thus, Skoltech recruit talents with high academic results, great potential to advance knowledge, motivation to succeed, and commitment to studies.

The outreach campaign was challenging due to sanctions, limited promotion channels, and travel restrictions. In the context of closed access to international channels, promotion efforts were redirected to Russia. The number of outreach events in national universities was doubled, while Yandex and VK were applied for advancing recruitment campaign. The results showed that a loyal audience (participants of open doors and subscribers to social media pages) showed a better conversion: 46% of applicants received offers were from among Skoltech "followers".

Although the formal statistics of the campaign show a decrease in applications, Skoltech kept a high selection rate (3%), welcoming 409 students (272 MSc and 137 PhD). The academic background of the intake is diverse: top Russian universities, universities in Europe (Newcastle University, University of Roma – La Sapienza, Politecnico di Torino, and TU Bergakademie Freiberg), MENA and Asian regions (University of Delhi, University of Chinese Academy of Sciences, Zewail University of Science and Technology). 20% are internationals from 29 countries, including Germany, Italy, China, India, New Zealand, and Korea.

## Recruitment funnel data



The impression that Skoltech is modern, well-organized, and welcoming has been there since I first saw it at my university presentation and website. As a German, order and structure are very important to me, and I was surprised to find both here. This impression has been with me until finishing the M.Sc. and ultimately led to my application here. Already during my year abroad, a couple of years ago I found love to Russia in more than one way, wishing to study here in a well-equipped, cosmopolitan university. The most decisive point when choosing Skoltech was the opportunity to study in English at a modern institute.

## Christoph Faist

**PhD Petroleum Engineering**

In my 4'th year of MIPT undergraduate studies I thought about coming to Skoltech. Then I started working on a climate and financial risk analysis in Skoltech team and I really liked the orderly and coordinated teamwork on the project. So, I decided that studying at Skoltech would be a good continuation of my education, that it would open up new opportunities, provide many useful acquaintances, and the educational process itself would be enjoyable. Now I can say that I was not wrong about anything.

## Antonina Kurdiukova

**MSc Advanced Computational Science**

On my first visit to Skoltech I really liked the whole concept; it seemed like a place full of highly motivated, creative, and incredibly powerful professionals and scientists, with fascinating innovative projects and incredible opportunities. After completing my bachelor's degree, I went to work to get a real industry experience and to understand what I want to do next. After a couple of years, I realized that my career growth perspectives were limited due to the lack of specific skills and knowledge. I started looking for a master's program and Skoltech quickly came to the top of my list.

## Elizaveta Petrova

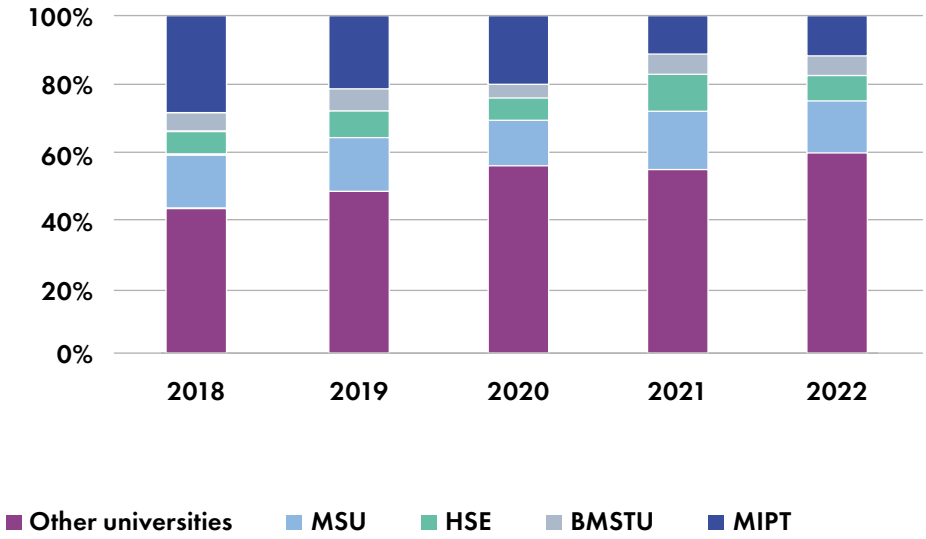
**MSc Life Sciences**

During the selection process for my mobility period, I had the opportunity to select up to 5 destinations. Among them, Skoltech stood out to me because of the wonderful campus, direct interaction with professors and international environment. Italian universities are known for the great focus given mainly to the theory, thus I decided to try an approach focused more on assignments and projects.
I was also interested in getting out of my comfort zone and learning more about new culture and mentality.
The beauty of Skoltech is the community that is established with professors and students. Skoltech is more than a university, it is a network of connections and friendships that goes beyond the normal university environment.

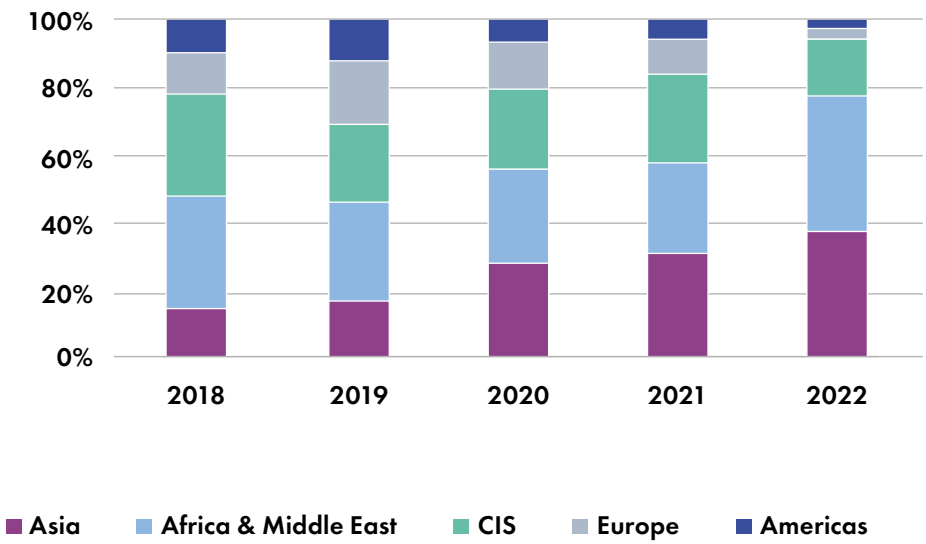
## Luca Breggion

**MSc Engineering Systems, visiting student (Erasmus exchange program)**

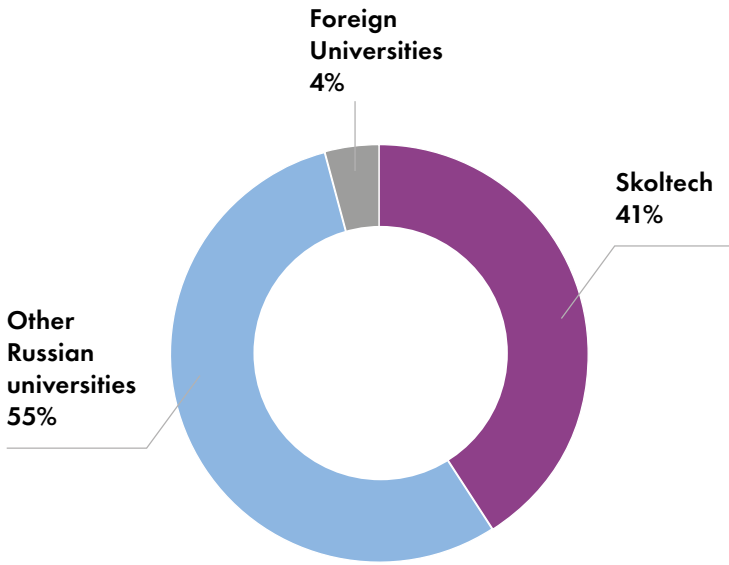
## Intake by university



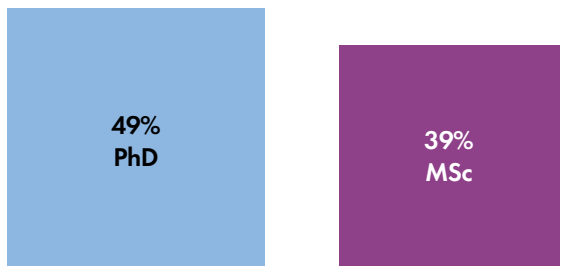

## Internationals in intake



## PhD intake by background




## Intake with Honors Diploma



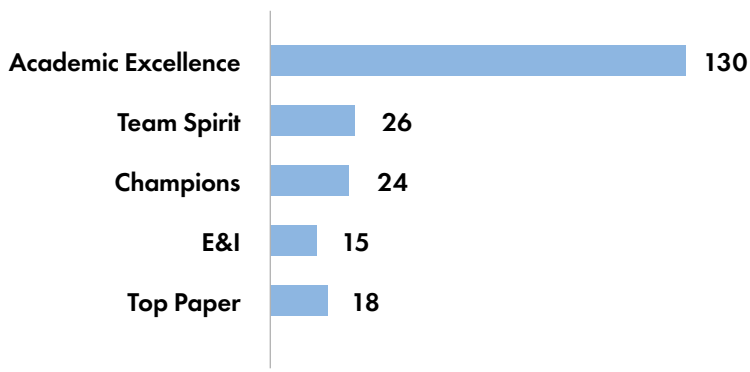
## Student Support and Development

As Skoltech recruits best talents, the supportive environment that helps to improve students' employability, develop professional networks and succeed in the chosen fields, is crucial. The comprehensive support and development program was designed based on best international practices and students' expectations.

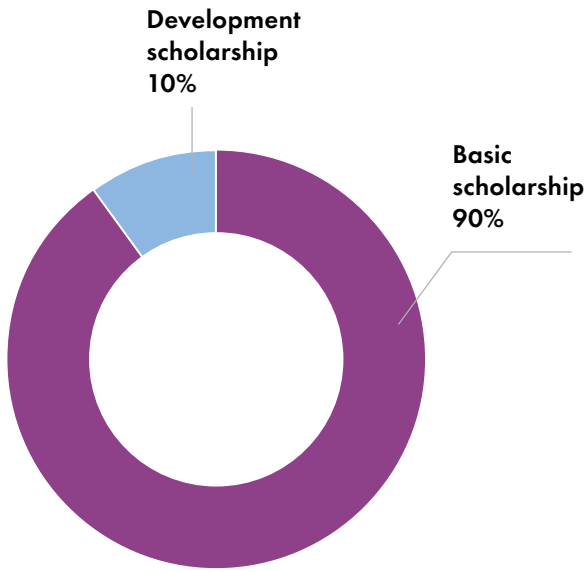
## Scholarships

The new scholarship program, kicked off in 2021, was continued. More than 800 students received basic scholarships set at the competitive level. In addition to basic scholarships, students applied for 'Development' scholarship, which is an incentive tool for results in academia, R&D, entrepreneurship. The majority of such scholarships assigned in 2022 were for academic excellence, awards in STEM contests and competitions, launch of own startups.

### Development scholarships Awarded (in units)



## Scholarship Fund




## Career Support Services

The Career Center continued to provide services to support students' career success: individual consultations, seminars, lectures, sessions with companies, networking events including Career Day and Career Fair.

The network of partners was growing and reached more than 90 companies. Target meetings were organized with representatives of KAMAZ Innovation Center, SberGames, BIOCAD, M&S Decisions, Huawei, Yango, Yandex and other companies. Partners also participated in Career Fair and Career Day.

The online resources on career insights were available and regularly updated. Digests with interviews, vacancies, career events, opportunities for internships were released monthly reaching out more than 2700 students and alumni. New resources were specifically developed for the Class 2022: the Career Book with recommendations on CV, contacts and materials from employers, Job Search Page for international graduates outlining employment opportunities in Russia. Also, the CV Book was developed and circulated to partners.

Kick-off activities were started to open the Ambassadors Club to promote career activities among students. First ambassadors from among MSc students were selected.

## Student Services

Skoltech is dedicated to ensuring that all students have access to support and resources they need to succeed. Student services package includes accommodation and advising on rent, support on migration requirements, official documents processing, mental health, individual consultations with the Career Office, gym access, etc.

Among the major developments of the year was the launch of psychological support, demanded by students. In addition, new procedures were organized to comply with the new migration requirements for foreign students (medical check-ups, photo and dactyloscopy). In the challenging period of the partial mobilization, all students were supported with communication to navigate through issues that may arise.

Student requests were addressed through onsite consultations or online system (HelpDesk). In total, the Student Service Center received more than 1700 requests which were on time responded and supported. Complicated cases were addressed individually with a follow-up support.

## Student Council

Student self-governance is ensured via the Student Council, composed of elected student representatives. In 2022, the Council addressed issues related to student experience, including course evaluation, provision of student spaces, organization of community building events. Through these efforts, the Council is dedicated to ensure that voices and needs of students are heard and addressed in a meaningful and effective manner.

## Awards and Achievements

Skoltech students shone in multiple external and internal awards and competitions demonstrating excellence in academic studies and beyond. Several notable awards are outlined below:

- PhD students Maksim Velikanov, Ruslan Rakhimov, Taras Khakhulin and MSc student Petr Mokrov received the prestigious Yandex Ilya Segalovich Award which Yandex grants for remarkable accomplishments in Computer Science.

- MSc student Vitalii Kazaku became the winner of the Russian national award Student of the Year in the nomination "Intelligence." The contest is organized by the Ministry of Science and Higher Education, the Ministry for Education, Federal Agency for Youth Affairs (Rosmolodezh), the Russia — Land of Opportunity non-profit organization, and the Russian Union of Youth.

Students were also successful in external scholarships awards: 5.8 mln Rub were awarded in total, including scholarships of the RF President, Zhores Alferov Fellowship for young scholars, Tinkoff Scholarship, Vernadsky Foundation Scholarship.

## Scholarships of the President of the Russian Federation

Nikita Kuznetsov
Konstantin Pavlov
Lidia Rumyantseva
Kirill Tyshchuk
Nikita Akhmetov
Igor Kozlovsky
Alexey Kuzin
Anastasia Merdalimova
Nikolay Ovsyannikov
Anastasia Smirnova
Evegeny Statnik
Julijana Cvjetinovic

## Zhores Alferov Fellowships for young scholars in Physics and Nanotechnologies

Nikita Akhmetov

## Scholarship of the President of the Russian Federation for students, and for PhD students for studies abroad

Sergey Perkov
Maxim Mokrousov
Alexey Kuzin

## Tinkoff Scholarship

Polina Karpikova
Kirill Tyshchuk

## Vernadsky Ecology Foundation Scholarship

Vlada Shestakova

Daniil Panov was awarded by DAAD Funding Program Research Grants to conduct experimental research in RWTH (Aachen, Germany).
Ivan Apanasevich won with a team the National Technical Olympiad in Intelligence Robotics organized by the Innopolis University.
Alena Savinykh received the Bronze Prize in All-Russian Yandex Olympiad "I am professional", Computer Science (Robotics).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# Graduates and Alumni

## Graduates 2022

Graduates employment is the indication of competitiveness and relevancy of Skoltech education offer, quality of studies and opportunities provided to enhance professional qualification. Despite a complicated situation on the job market in Russia, the overall indicators of the graduates' employability were better than expected, especially as for employment in R&D sector, presented by large market players.

The share of graduates staying in Russia slightly decreased compared with 2022, which is explained by the fluctuations on the job market. Also, less students decided to continue for PhD in Russia, making choice in favour of international universities.

Skoltech helps our project in two aspects: technological and business. In terms of system development, we have access to the equipment of the Additive Manufacturing Laboratory and Mechanical Testing Laboratory, where we can print and perform mechanical tests. The Center of Entrepreneurship and Innovation actively helps us find investors and potential customers. We participate in pitch sessions and acceleration programs, which the center's employees find for us.In addition, Skoltech gives us the opportunity to involve new students in our project. Now we have two master students in our team. One of whom is designing implants and the other is working on a topological optimization algorithm.

## Dmitry Popov

**PhD-4 in Engineering Systems, Founder, Startup iziCAD**

I'm confident that the skills I've acquired at Skoltech—and will continue to acquire—will support me and help me succeed. In the future, I hope to make available as many as possible technologies for enhanced oil recovery and $CO_2$ sequestration.

## Ayomikun Bello

**2022 MSc graduate and Phd-1 in Petroleum Engineering**
**CTO at Startup Eco-Energy and Research intern at Skoltech**

Skoltech taught me to work under very tight deadlines. Skoltech also taught me to collaborate with different groups of people (I had to do a team project every two months or so).
I also developed strong research skills while at Skoltech, learned to work independently and keep my motivation alive. These are attributes that certainly come into play in my daily activities today.

## Fater Akuhwa

**2021 MSc in Energy Systems | Project Manager, Yandex**

Skoltech gave me a good background that allows me to study state-of-the-art techniques applicable to work problems. At Skoltech I faced many complex concepts and I learned how to deal with them, how to understand them, and I studied to study.

## Olga Novitskaya

**2021 MSc in Data Science, Big Data specialist, Insilico Medicine**

## Alumni

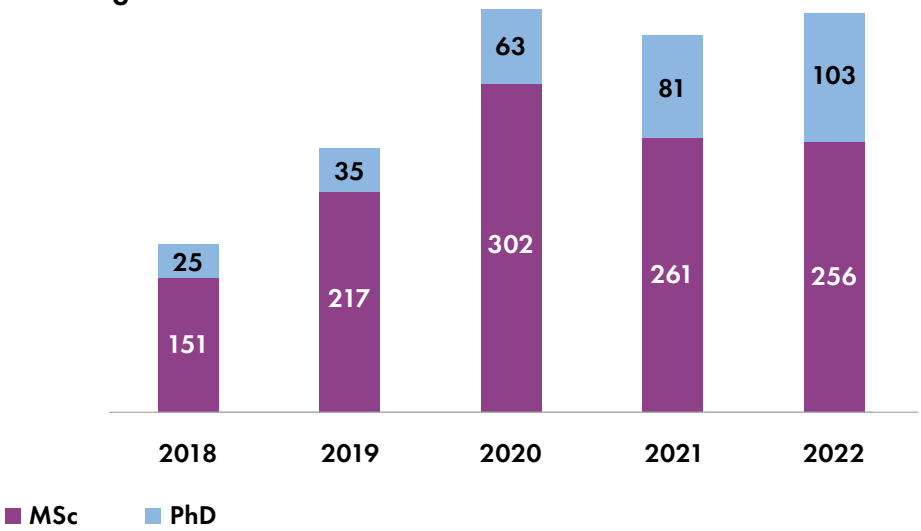
Skoltech strategic goal is to strengthen the culture of giving back, when alumni keep ties with alma mater, being ambassadors of the brand and contributing to its development. During the year a variety of communication channels were offered.

20 alumni participated in Startup Village, presenting their startups and having heads-up with the Center for Entrepreneurship and Innovation and Career Center. To compensate absence of the commencement in 2020-2021, these classes were invited to the commencement ceremony to share joy with the class 2022.

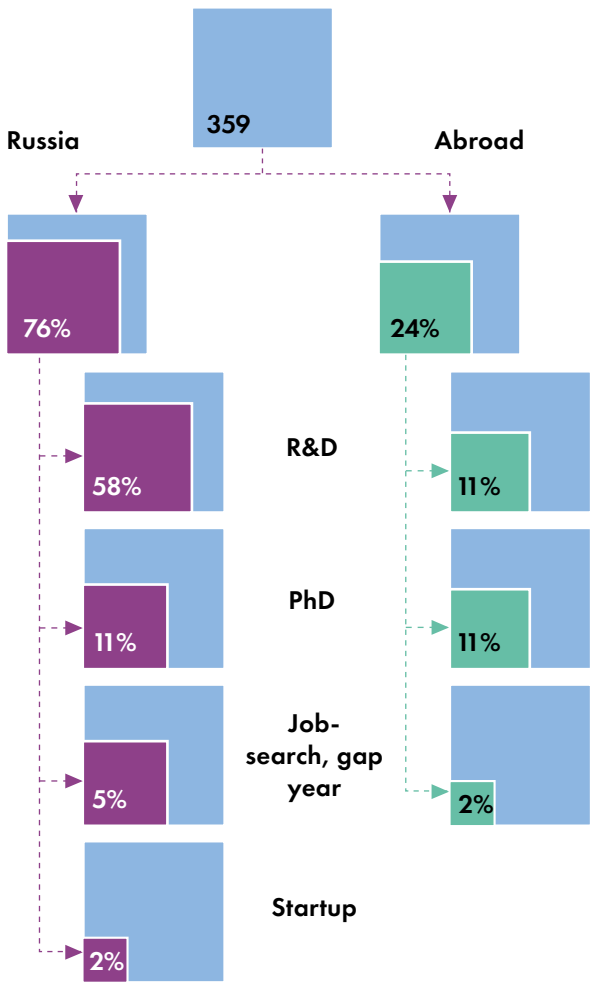
The mentoring program to connect graduates of different years was launched. 30 alumni applied to become mentors on career planning, professional and personal growth. First meetings are planned for spring 2023.

Digital communication was supported through social media and career digests. The first Alumni Digest was released with news about alumni community and Skoltech as a whole. The Alumni Guide was launched as a "basic kit" with all resources that can be relevant to stay connected with Skoltech.

## Annual graduation




## Graduates 2022



# Elvira Muratova

**is a second-year PhD student with a master's degree in Petroleum Engineering. She is the co-founder of Eco Energy company**

# "Working on projects gives me energy, and that's what counts"

## How Skoltech motivates people to create startups

I am from Tyumen, where the oil and gas industry is in high regard. I graduated from a local university with a bachelor's degree in Technical Physics, and any physics in our region is, one way or another, connected to oil and gas. In Tyumen, I was working on gas hydrates. Then I saw that I could do the same at Skoltech and decided to enroll in their master's program but failed, even though I had previously won the "I am a Professional" contest, which was supposed to help

with admission to grad school… But Skoltech is a special place with a tougher selection process, so my past successes didn't help. However, I didn't let my efforts go to waste and tried enrolling in Skoltech again a year later. This time, I succeeded.

Here at Skoltech, I became interested in startups. I think I took every available course on innovation and tech business. During one of the courses, I met professor Aleksandr Chekanov and joined Aya and Kenneth from Nigeria. Their home country has a big problem with fuel. Electricity is scarce, and the locals are trying to somehow solve the problem with improvised means, so Aya and Kenneth have decided to create portable biogas reactors.

Our device looks like a shipping container, about six meters long and two meters wide. This container is loaded with waste and a special set of bacteria which triggers a cascade of biochemical reactions, decomposing the waste and producing biogas. The methane is immediately captured and is either stored or used immediately to generate electricity. But most importantly, methane, a powerful greenhouse gas, doesn't escape into the atmosphere. The leftovers can serve as organic fertilizer, which can also be sold.

One of the advantages of our container is that it can be used in cold climates. We have presented our device at various competitions, participated in various accelerators, and have already partnered with Gazpromneft-Snabzheniye and Messoyakhaneftegaz. We are discussing with them the certification and testing of our containers in Dzerzhinsk, near Moscow, before they are shipped to Messoyakha. Our containers are also anticipated at the Youth for Technology Foundation in Africa. Kenneth has also applied for participation in an accelerator in Dubai, and at the end of 2022, we became Skolkovo residents.

I like that the postgraduate program allows me to combine scientific work on gas hydrates with my startup activities. It would have been harder if I had a full-time job. Launching a startup is always difficult, but I prefer to think that it's now or never. Besides, it's not like we lose anything by doing what we do. Working on projects gives me energy, and that's what counts.

In addition to her studies and business activities, Elvira Muratova educates others and promotes technopreneurship. In her talks, she debunks the myth that the tech company niche is reserved for the likes of Elon Musk and Tesla and that you need a unique idea or a lot of money to create a startup. She says that the main thing is for your idea to be in demand here and now and that competition only makes any product better.

# “What I love about my work is the intersection of applied and research sciences and business”

## How Skoltech students are transforming life around them

# Artem Yakimchuk

**graduate of the Materials Technology Center, first-year PhD student. Founder of the Programming School and three other startups**

My family has a background in construction and installing heating networks, so when it came to choosing a university and career path, I initially thought of also going into construction. However, my parents advised me to consider robotics, and I could always come back to construction if I changed my mind. So, I enrolled in the Robotics Department at Bauman University and steeres away from construction.

Later on, I joined the master’s program at the Skoltech Materials Technology Center and together with my friends from Bauman, we launched our first startup - ”Formatika” programming school on the basis of my own school where I studied in Moscow. We tested different formats and realized that there was a high demand for our services and with our background we could offer higher quality programming education than others on the market.

Just before the pandemic hit, we finished testing, almost broke even and decided to pivot to online formats to scale our business. We ran social media ads and recruited students, and at our peak, we had about 100 students enrolled simultaneously.

About a year ago, we faced challenges with buying advertising in social media

where we used to recruit students from before. We had to choose between registering a company abroad or coming up with an alternative solution. Since I stayed in Russia, I decided to take the school offline once again and now it operates based on the Skolkovo Gymnasium. Most of our teachers are from Skoltech and it happens that the talented university students are teaching the talented school kids creating this synergy and establishing good atmosphere.

Now that the school is running smoothly, I also take on new projects. I have three other startups, two of which are still in the early stages and one is almost fully developed. One of them is called "Kasanie" (Touch), where we create digital business cards. When you touch the card with your phone's NFC chip, my profile appears with all my contact details, social media accounts, and you can even transfer money to me. The business card looks like a phone sticker.

Another developing startup, which originated from the programming school, is a subscription payment service. I used to bill parents for classes every month, but many of them forgot to pay in time and it caused delays in teachers' salary payments. I was looking for a way to optimize the system so that there were no financial errors and I wouldn't have to bill the parents. So, we came up with a solution inspired by subscription services like Yandex. Music, where money is regularly deducted from the user's account and credited to the bank account.

We studied these systems with the Skoltech students and created one. This solution has not only been convenient for us but also in demand among other online schools' association members. Currently, we are developing a single platform that allows entrepreneurs to sign up people and bill them on a subscription basis.

The latest startup, that is also still in its early stages, combines "Kasanie" with a subscription-based payment service. We are creating NFC tablets that can be used in cafes and restaurants for bill payments, tips, loyalty program enrollment, menu browsing, and even subscribing to social networks. Similar to a digital business card, but for cafes and with payment capabilities. We partnered with a factory in Zelenograd to produce the chip plates and collaborated with "UCASSA" service as an acquiring service. Our plates can already be found in some cafes in Moscow.

What I love about my work is the intersection of applied and research sciences and business. I enjoy the idea of using research-intensive technologies to create startups, generate income, and simplify tasks for people or solve complex challenges.

Artem is currently involved in the development of four projects while also pursuing his studies at Skoltech PhD program. His research focuses on gas-thermal spraying and robotics, and he is also involved in teaching various courses. During his master's program, he had the opportunity to intern in Germany, and he feels it is important to share this experience with his students. Artem aspires to defend his doctor of science dissertation and be recognized in Forbes' "30 under 30" list. He is currently 26 years old.

## Artyom Bochkarev

**is a graduate of the Data Science master's program (2018). Head of Data Science at AliExpress**

# "The complicated math I've been studying for so long could lead to the company making more money"

## How Skoltech motivates people to create startups

In the third year of my undergraduate studies at MIPT, there is an assignment to departments, so I chose the department of intellectual data analysis. This is in fact what machine learning is all about. That's how I started to dive into this subject. After my undergraduate degree, I enrolled in the dual-degree program, which was then between MIPT and Skoltech. I studied Data Science at Skoltech.

The summer after my freshman year, I interned at S7 thanks to Skoltech. My team and I solved several practical problems, one of which was about predicting travel purpose. The essence of the task was to recommend something in the marketing mail to S7 users, and to do that we wanted to understand why were people flying in the first place. Say, to recommend a hotel to a person who is going on vacation, and to recommend something else, such as a rental car to a person going on a business trip. And a person visiting his relatives doesn't need any recommendations. We collected data based on Internet surveys: when a user bought tickets, a question about the

purpose of the trip popped up, and then we, having the results of the survey and a set of standard data, tried to make an algorithm that would predict the purpose of the trip. It was a training project as part of the internship – I don't know if anything came out of it. But the defense of the project based on the results of the internship was successful.

My friends and I tried to get a job with S7, but there were no open positions. I ended up joining OZON as a junior developer at Machine Learning in January 2018. I met my supervisor at a project defense at Skoltech. Industry representatives are usually invited tostudent projects' defences, and then I came for an interview at OZON –and she was there.

At OZON, I worked on predictive models, and algorithms for selecting recommendations, and algorithms for optimal organization of the warehouse and order collection. Product Matching is a project that I took to a new level at OZON. These are algorithms that search and aggregate similar products within the same marketplace or help compare prices with competitors. By then I was already a team lead.

I left OZON in 2020, by then I was already the leader of two teams – my original team and the search team. At AliExpress, they offered me a position to manage all of Machine Learning, which was a new level. Initially the team had maybe 6 or 7 people, but now it has grown to 20–25. And we do all the basic Data Science in the company: search, recommendations, pricing, moderation of goods, anti-fraud [detection of fraudulent schemes – editor's note], and matching, like in OZON.

I am proud of our work at AliExpress. We have significantly improved the algorithms of the Russian search and selection of recommendations. Right now, we are developing an algorithm to translate the names of products. The funny names on the site are the result of an machine translation from Chinese to English and then from English to Russian. As a result of double translation, we have a name of30 words that sometimes contradict each other.

We are now learning algorithms to generate product names that would be palatable to native speakers. It won't really be a translator, it generates names using additional information about products and characteristics. We did a test: we showed people the old and new headlines, and most found that the new ones were better. We really believe in this project.

Data Science is a cool field where you can touch and feel the results of your work. That's probably why I left science for the industry. I like the fact that all the complicated mathematics I've been studying for so long can also lead to a company attracting more users, and, as a result, making more money, and making it easier and more convenient for people. All that is not some kind of magic, but it's all done with mathematical methods and a brain.

According to Artyom Bochkaryov, Skoltech has been his "playground," where he could try his hand at science and industry, understand what was closer to his heart, and acquire the initial asset of business connections that made starting a career easier.

# “Skoltech was a place where I could develop the skills and knowledge needed to pursue my dreams”

## From childhood fascination to aerospace PhD scholar

## Salman Ali Thepdawala

**MSc graduate Space and Engineering Systems (2021)**

Looking back at my childhood, I realize that my fascination with aerospace had been a long-standing one. I had always been drawn to airplanes, rockets, and space travel. As a child, I would spend hours poring over books about space and aviation, dreaming about exploring the vast expanse of the universe. So, it was only natural that I would consider pursuing a career in this field.

However, growing up in Pakistan, there was a perception that there weren’t many opportunities for those who wanted to pursue a career in aerospace. Despite this, I was fortunate to have parents and teachers who were always supportive of me and encouraged me to take up the challenge.

As I progressed in my studies, I found myself torn between aeronautics and space engineering. I eventually chose to study aerospace in Pakistan, hoping that this would give me a better understanding of both fields. However, it wasn’t until my undergrad exchange semester in the United States that I truly discovered my passion for astronautics.

During my time in the US, I had the opportunity to take some courses in space research and work on

space-related projects. It was then that I realized that astronautics was something that I could do without getting bored easily. Upon returning to Pakistan, I started looking for places where I could pursue my dream of becoming an astronautics expert.

Initially, I didn't consider Russia as a potential destination for my studies. However, after learning that the US had restrictions on non-US citizens working in the space industry, I began to explore other options. I had heard about Skoltech from some friends and decided to look into it further. I reached out to some seniors and a Russian friend of mine who had studied in the US, and they all spoke highly of the university.

I was also intrigued to learn that Skoltech was founded in collaboration with MIT, one of the most prestigious universities in the world. I saw this as a sign that Skoltech was a place where I could receive a high-quality education and develop the skills and knowledge needed to pursue my dreams.

My experience at Skoltech was nothing short of amazing. It was the best two years of my master's degree, and I learned so much during my time there. I was able to make friends from all over the world, and I am still in touch with many of them today. We keep in touch through social media, and we often update each other on our lives and careers.

Unfortunately, the COVID-19 pandemic disrupted many aspects of my life and studies, but I am grateful for the experience, nonetheless. It was at Skoltech that I truly realized the importance of networking and building relationships with people in the industry.

After completing my master's degree, I decided to pursue a PhD in aerospace. I am currently a Munich aerospace PhD scholar at the University of the Federal Armed Forces of Germany. My research focuses on AI-based on-board collision avoidance and large satellite systems. This field is incredibly exciting, and I feel privileged to be a part of it.

In addition to my studies, I am also affiliated with some startups in Munich that are working on innovative projects in the space industry. It is fascinating to be involved in these projects and to see how new technologies are being developed to enhance space exploration and travel.

Although I am currently based in Munich, I am open to opportunities to work or study in Russia. If the right opportunity presents itself, I would be happy to return to Skoltech or to work with other organizations in Russia. I have seen many examples of people who are involved in the industry and who also teach on the side, and I would be interested in pursuing similar opportunities in the future.

This year Salman won the European Space Leaders Award and will be sponsored to attend the European Space Generation Workshop in Bari. Every year the Space Generation Advisory Council selects up to 5 young specialists in the space industry to give this award, and this time Salman got among them.

# Artyom Mikelov

**has a master's degree in Life Science (2018) and PhD degree in Life Sciences (2022).**

## How Skoltech changed the life of a consulting company manager

"Science offers plenty of challenges, and I wanted to challenge my brain."

My first degree was in management. I graduated from the HSE Management Department, but already by the end of the third year of my bachelor's degree I knew I was leaning more towards technology. Of all the technology branches, biotechnology interested me the most: I had the feeling it was about to really take off. Many of the investments made into this area since the late 1960s, maybe even a little earlier, are only now beginning to bear fruit (show results?). I started thinking about how I could get into the biotech industry.

At first, I decided to enter the industry as a manager and enrolled in Financial University's master's program Innovation Management and Entrepreneurship.

But, frankly, it paled in comparison with the HSE's program and didn't bring me any closer to my goal which was technology. At the same time, I started working in consulting, building a successful career at the Accenture international agency.

It was fun. I had interesting tasks and a great team, but I wanted something different. I wanted more science and technology. I think that was the moment when I realized I wanted to be more than a manager in a technology company—I wanted to get into science. Because science offers plenty of challenges, and I wanted to challenge my brain. I felt like I wasn't making enough mental effort in consulting. I wanted to look for answers to questions no human has been able to answer yet.

I realized I didn't just want to go into the biotech industry—I wanted to dive deep into science. So I started thinking about how to do it and looking at online courses. It was around 2014, meaning bioinformatics courses and programs were starting to emerge on the Internet. There were many courses in English on Coursera, and the St. Petersburg Bioinformatics Institute, to which I am immensely grateful, started to release courses in Russian. I began to study in my spare time, at night.

In 2015, I was determined to enroll. I even considered getting a bachelor's degree at Moscow State University. There was also the HSE's newly minted bioinformatics program run by Professor Gelfand. But when I started reading about Skoltech, I knew it was the perfect place for me. A lot of it is still touch and go, including the university's structure. The campus is unfinished. But it's all very lively and interesting. Besides, it is a rare occasion on which I can study for free. In Russia, you can get a regular master's degree for free only once, and I doubt I could have afforded the 300,000-400,000 rubles a year it would have cost me to attend another master's program. I'm embarrassed to say I learned about Skoltech from an ad on VKontakte.

I was thinking about enrollment strategically, with an eye to the future. "Where do I see myself in ten years?" I could get promoted to a senior manager or maybe even a junior partner at Accenture and make big money, comparable to what a Skoltech professor makes, topped with a pile of bonuses, insurance, and other pleasantries. But I would be doing the same things I'm doing now. Would that make me happy? And so, at the age of 25, I quit my fairly decent job in consulting, where my career was on the rise, lost quite a bit of money, and started doing what I was passionate about. I've thought about whether I made the right choice many times. Going back, I'd do it again. I'm thrilled with how great it has all worked out.

In November 2022, Artyom Mikelov successfully pre-defended his PhD thesis on immunological memory and is currently preparing to defend it. The defense will take place on April 25 at Skoltech. In parallel, Artem is working as a senior bioinformatician at MiLaboratories, software of which is used by most pharma giants in their immunological research.

# Governance


Skoltech
class of
2022

# Governing Bodies

Skoltech was established by the General Meeting of Founders in 2011. Since then, the governing system grew into a solid framework with clear lines of authorities. The strategic goal lies in maintaining the system well focused and effective. This includes a systematic review of policies, increase quality of documents for review to ensure a well-grounded base for decisions.

Skoltech governance framework is regulated by the Charter. The governing bodies, each within the assigned scope of authorities, support a strategic planning, decision-making and effective management of the Institute. Skoltech governance is based on the following principles:

- The President directly reports to the Board of Trustees, while the Board reports to the General Meeting of Founders,
- authorities of the governing bodies are clearly distinguished to avoid duplication of decision-making,
- Skoltech is transparent for all stakeholders, information submitted for decision-making is reliable and provided on time. Any member of a governing body can request additional details if required for a proper decision making.

### General Meeting of Founders

The General meeting of Founders is the highest body, empowered to approve the Charter, appoint the Board of Trustees, establishment of Skoltech affiliated companies and Skoltech membership in legal entities.

## Founders

Foundation for Support to Small Innovative Enterprises in Science and Technology
Moscow Institute of Physics and Technology
New Economic School
Osipyan Institute of Solid State Physics (RAS)
Rusnano
Russian Venture Company (RVC)
Sberbank Russia
Skolkovo Moscow School of Management
State corporation of development VEB.RF
Tomsk Polytechnic University

### Board of Trustees

The Board provides overall oversight of Skoltech strategic development, at the same time ensuring that ongoing activities are properly implemented. It approves the Strategy, KPIs, Financial plan, and respective annual reporting. The Board also monitors new concepts / initiatives which influence the Strategy, so that Skoltech keeps its model against the mission and vision.

In 2022 the Board held four meetings. In addition to the regular agenda, such as approval of reporting, the Board appointed new members of the Academic Council.

The July meeting concerned consultations on the response to sanctions: the Board supported measures to retain staff, restructure of the student recruitment campaign, as well as new vectors in the international agenda. The Board also discussed the President's concept "Skolkovo 2.0" which is a view on the new role of Skolkovo project in the national agenda.

In light of the SDN sanctions, the Board composition was significantly changed. Several members terminated membership. As of December 30, 2022, the Board was composed of seven members:

**Viktor Vekselberg**
Chairman of the Board of Trustees. Member of the Skolkovo Foundation Board of Directors.
Chairman of the Board of Directors of Renova Group of companies

**Simon Bradley**
Founder and CEO of Percent-Edge

**Tony F. Chan**
President of King Abdullah University of Science and Technology

**Alexander Kuleshov**
Skoltech President

**Irina Okladnikova**
Deputy Minister of Finance of the Russian Federation

**Anastasia Rakova**
Deputy Mayor of Moscow

**Alexander Vedyakhin**
First Deputy Chairman of the Executive Board of SberBank

In addition to formal meetings, heads-up updates were organized by the Chairman of the Board, President and Senior Vice Presidents.

Senior Vice President for Development, Alexander Safonov continued to serve as the Executive Secretary to the General Meeting of Founders and the Board of Trustees.

## Academic Council

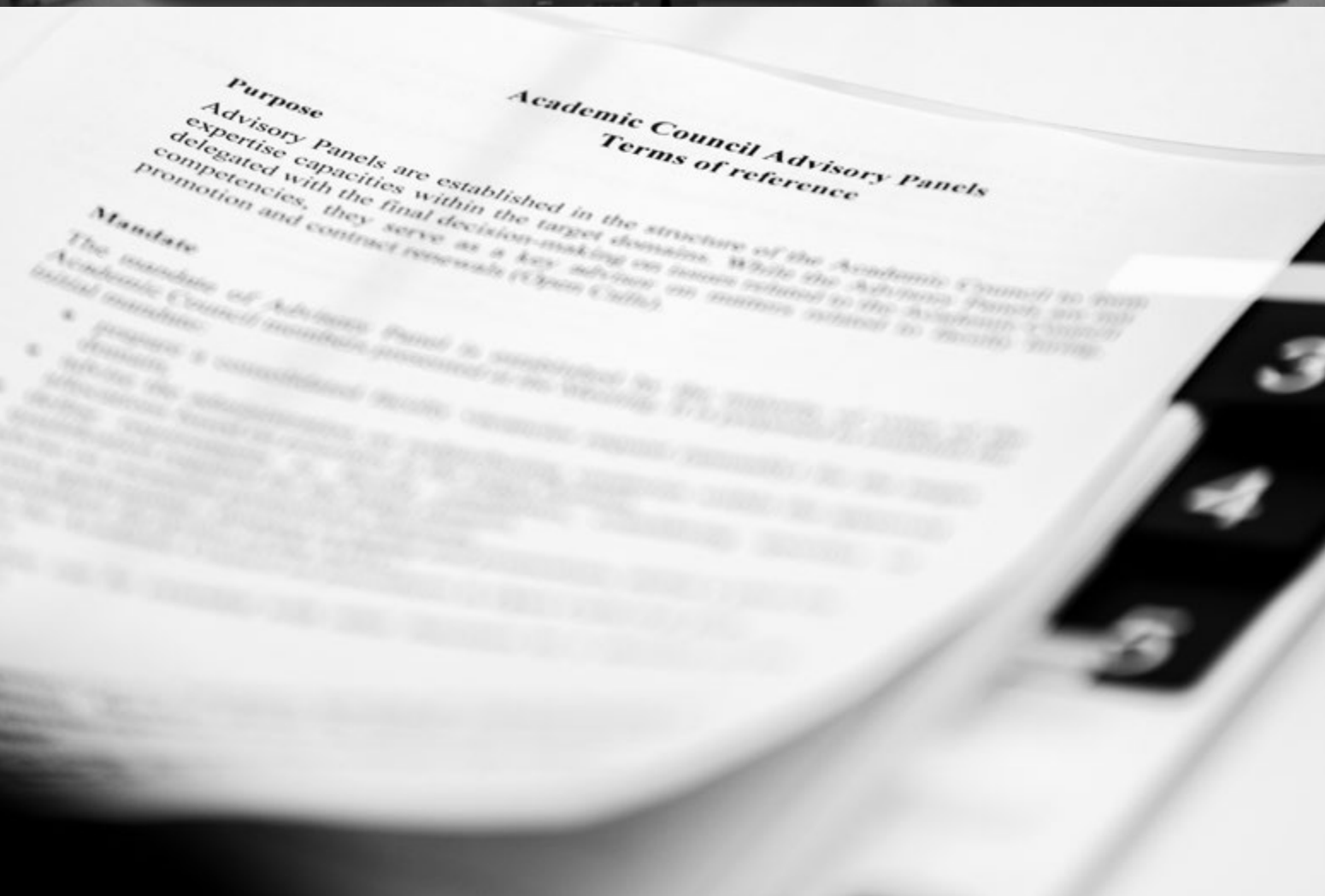
The Academic Council provides governance for scientific, research and development, and education activities ensuring their highest quality and integrity.

The Council had a planned rotation in September. The new composition, appointed in line with the principles for succession, is a balance of faculty, representing CREIs and Project Centers, Center for Entrepreneurship and Innovation, executive management and Skolkovo Foundation.

## Academic Council

Alexander Kuleshov, President
Artem Abakumov, Full Professor
Andrzej Cichocki, Full Professor
Clement Fortin, Full Professor
Mikhail Gelfand, Full Professor
Dmitry Kulish, Professor of the Practice
Pavlos Lagoudakis, Full Professor
Andrei Osiptsov, Full Professor
Grigory Kabatyansky, Vice President for Science and Academic Relations
Alexey Ponomarev, Senior Vice President for Industrial Cooperation
Alexander Safonov, Senior Vice President for Development
Alexander Fertman, Director on Science and Education, Skolkovo Foundation


Year Highlights
Year Highlights
Year Highlights


Academic Council Advisory Panels
Terms of reference
Purpose
Mandate

In light of the new procedures for faculty appointment, the Council established Advisory Panels in the Target Domains with a mandate to plan vacancies, screen dossiers and provide a short list of candidates for the Appointment, Promotion and Tenure Committee and Academic Council.

The other items of the agenda included updates in the People strategy, Bachelor programs concept, establishment of the Project Center for Applied Photonics and Quantum Technologies, launch of Skoltech-MIPT-ITMO Photonics Initiative.

In the end-of-year meeting, the Council unanimously supported the President's proposal to award the Center for Advanced Studies with the name of Prof. Igor Krichever in memory of outstanding contribution made to the Center's foundation and bringing it to the world league of research centers.

The Educational Committee, composed of the program leaders, faculty of the Center for Entrepreneurship and Innovation, oversees all aspects of teaching and learning, as well as student recruitment, working closely with the Student Department and the Education Department. The Committee's goal is to guarantee that Skoltech fulfills its mission: educating the next generation of science, technology and business leaders with the provision of a unique and valued pedagogical offer, widely recognized in Russia and abroad. For that purpose, the Committee meets once a month, ensuring quality control and improvement of all Skoltech educational programs considering opportunities, constraints and needs. In 2022, the Committee reviewed and approved proposals for professional education programs, and oversaw the revision of doctoral programs to comply with the new federal requirements. Importantly, the Committee considered data on students' learning, performance and graduation, as well as applications from overseas during the Covid period; this raised subsequent discussions on programs update and recruitment planning. In 2023, in addition to traditional duties (including analysis, recommendations, and approval of programs revisions, updates on admission, nominating students for awards and prizes), the Committee considers new programs to equip our future graduates with new skills that the industry is seeking, in e.g., applied computational mechanics, and photonics and optical engineering. A new "2+3" year format for PhD studies will be discussed to offer the best students a special track to pursue postgraduate training. A particular attention will be paid to development of BSc programs.

**Prof. Henni Ouerdane, Digital Engineering Center, Chair of the Education Committee**

## Academic Council Committees

The Committees met regularly to address agenda on faculty appointment and promotion, education, research and innovation domains.

The Education Committee had 14 meetings to review MSc and PhD programs development, policy making (PhD defenses, e-learning, etc.), reports on defenses, outreach and recruitment, as well as plans of the Centre of Teaching and Learning Excellence. Several decisions were made on approval of professional education programs.

The Appointment, Promotion and Tenure Committee held 8 meetings to review dossiers of candidates to faculty positions and nominations to awards. In September, considering a new faculty appointment procedure, the Committee adjusted its procedures.

The Research and Innovation Committee held 6 absentee meetings to approve reports on projects performed within large initiatives, such as Federal project "Artificial Intelligence", Federal project in development of genetic technologies.

### Education Committee

**Prof. Henni Ouerdane (Chair)**

Prof. Dmitry Aksenov
Prof. Georgii Bazykin
Prof. Nikolay Brilliantov
Prof. Alexei Buchachenko
Prof. Alexey Cheremisin
Prof. Alexey Frolov
Prof. Nikolay Gippius
Prof. Elena Gryazina
Prof. Ivan Oseledets
Prof. Alexander Safonov
Prof. Natalia Strushkevich
Prof. Alexey Nikolaev
Prof. Anton Zabrodin

### Appointment, Promotion and Tenure Committee

**Prof. Nikolai Gippius (Chair)**

Prof. Artem Abakumov
Prof. Andzei Cichocki
Prof. Clement Fortin
Prof. Mikhail Gelfand
Prof. Dmitry Kulish
Prof. Pavlos Lagoudakis
Prof. Andrei Osiptsov

### Research and Innovation Committee

**Prof. Dmitry Lakontsev (Chair)**

Prof. Dmitry Dylov
Prof. Laurent Gentzbittel
Prof. Andrey Somov
Prof. Pavel Dorozhkin
Prof. Maria Logacheva
Prof. Gleb Sukhorukov
Prof. Ivan Sergeichev
Prof. Viktoria Nikitina
Prof. Alexander Kvashnin
Dr. Nikolay Suetin
Dr. Alexander Fertman
Dr. Mael Brossard

# Executive Management

The executive management is responsible for organizing and managing Skoltech day-to-day operations in respective directions. The authorities and responsibilities of the executive management are defined by the President in the corresponding policy.

Major changes were introduced with regards to reporting lines of the Centers, which became subordinated directly to the President. To ensure supervision of full student lifecycle, starting from outreach to studies and further alumni community, the Educational Department was transferred to Senior Vice President for Development domain.

**Academic management appointments were made in the Centers:**

Prof. Khaitovich appointed as Director of Neuro Center,
Prof. Sergeichev appointed as Director of Materials Center,
Prof. Podladchikova appointed as Director of Digital Engineering Center,
Prof. Drachev appointed as Director of Physics Center,
Prof. Lagoudakis appointed as Director of Photonics Center,
Prof. Marshakov appointed as Director of Center for Advanced Studies.

**Management Communication**

In the context of challenges 2022, communication from the executive management was of a special importance. The target President's addresses concerned restrictions and their impact, termination of the agreement with the MIT, sanctions and ways to adapt.

In August, under the initiative of Senior Vice President for Development, the All-hands meeting "Skoltech today, tomorrow and beyond" was held to brief the community on actions taken to respond the challenges, as well as provide guidance on further plans.

A faculty meeting was held in December where the President and Senior Vice President Development shared status of the Strategy and KPIs, also outlined targets for 2023.

The communication lines with Directors of the Centers were supported through meetings on the pay system, KPIs, goal setting and performance appraisal, the educational offer, and operational updates.

## Committees and Working Groups

The executive management is supported by committees and working groups operating as advisory bodies.

The Strategy working group is the principal body, facilitating the strategic report and planning cycle. The membership of the group was extended with Vice Presidents in Target Domains, to have representation of the academic management. The agenda was dominated with budget planning, and KPI targets. Also, the group reviewed the report on MIT agreement, a proposal on rotation of the Academic Council.

The Personnel Committee was established to facilitate the People strategy. The Committee addressed the new pay system and job grades, nominations for bonus payments, results of performance appraisal and goal setting cycle.

The Scholarship Council, chaired by Clement Fortin, Dean of Education, brought into full operation the framework of new scholarship policy, designing and launching the development scholarship.

The IT Committee advised on priorities for development of IT landscape, considering rationale and alignment to the Strategy.

Dozens of working groups were involved in policy making. Policies related to senior management responsibilities, Centers, collegial bodies, PhD defenses were updated, while policies for the new pay system, KPIs scorecards, goal setting and performance appraisal, faculty appointments were designed from scratch. The operational management block was supported with new procedures for procurement, document flow, accounting. A large number of policies was issued on safety measures in laboratories.

## Organizational Structure

Throughout the year several structural changes were conducted.

The Project Center for Applied Photonics and Quantum Technologies was established under the Chair Prof. Pavel Dorozhkin. The Center will focus on design of technologies in photonic integrated circuits, microwave photonics, scientific and analytical instrumentation, components for future telecom and 6G wireless networks. As for education, the Center will enrich Photonics & Quantum Materials, Engineering Systems, IoT & Wireless Technologies programs, also develop professional education courses.

The Project Support Department was established in Senior Vice President for Industrial Cooperation domain to maintain Institute's wide framework on projects activities. As the first activities, the Department implemented project monitoring procedures to assess and address risks related to sanctions, as well as systematize projects based on TRL.

The Internal Control and Audit Department was established in direct supervision of the President and functional subordination of the Board of Trustees. The Department will focus on design and implementation of the internal control system, also conduct audit and risk management. The short-term goals include policy making, update of risk-based control procedures, and testing of controls in operational processes.

The consolidation of functions for sponsored research and academic relations was made by establishment of the Research Initiatives Support Department under supervision of Vice President for Science and Academic Relations. The Department will continue to ensure operational support on grant activities, develop and facilitate internal funding programs, as well as facilitate Institute's partnerships.

The change management function was ramped up in the Institutional Development Department with a goal to increase efficiency of organizational transformation and core processes.


Skoltech

# Organizational chart

**President**
Alexander Kuleshov

**VP Photonics**
Pavlos Lagoudakis

**VP Biomedical Research**
Mikhail Gelfand

Internal Control

## Development

**VP Communications and Community Development**
Alexey Sitnikov

Strategic Communications

**Senior VP Development**
Alexander Safonov

**Dean of Education**
Clement Fortin

Education

**Dean of Students**
Denis Stolyarov

Student Affairs

HR

Institutional Development

## Research & Academic Relations

Centers

Project Centers

Research Facilities

**VP Science and Academic Relations**
Grigory Kabatyansky

Research Initiatives Support

## Technology & Business Developmentt

**Senior VP Industrial Cooperation**
Alexey Ponomarev

STD Analysis

Industrial Progravms

Project support

**VP Entrepreneurship and Innovation**
Lawrence Stein

CEI

## Operational Management

**Senior VP Finance & Operations**
Tatyana Zakharova

Finance

Legal

Procurement

IT

**Advisor for Security**
Andrey Simonov

Security

Campus

# Operational Management and Treasure report

# Message from Senior Vice President for Finance and Operations

**Skoltech as successful institution with a sound properly resourced financial base – is our priority. The Institute must remain financially sustainable whilst continuing to invest in the infrastructure.**

In 2022, Skoltech took all measures to successfully manage risks and ensure sustainable operations in uncertainties, marked by geopolitical context, SDN sanctions, inflationary pressure and other factors. Our high operational performance combined with effective use of funds allowed to navigate through complexities, remaining relevant and confirming our position for further development. I am pleased to share results of operational and financial performance of 2022.

Despite all challenges, Skoltech managed to increase attracted funding by more than 20% compared with 2021, obtain a maximum income from endowment, maintain all resources required for delivery of high-quality education program, support campus environment, continue the capital construction program and make progress towards fiscal stability.
Our conservative operating philosophy and financial plan were carefully revised, putting a number of priorities on top:

- implementing the new motivation policy, considering negative effect of sanctions,
- working out a treasury policy and bank management, i.e. setting payments through new banks and international agents, improving quality of administrative services,
- mitigating severe complications in procurement and logistics of goods and services on the global market. The Procurement Department worked on finding alternatives in both logistics and import substitution,
- leading audit management and accountability,
- ensuring testing of controls in operational processes, recommendations on results in terms of updating processes, policies and support methodological documents,
- improving operational efficiency of key control procedures.

Skoltech followed the Policy on Internal Control, that complies with general practices and standards, regulatory requirements and contributes to achievement of business goals. Executive management is responsible for both internal controls and mitigating actions related to risk management in respective areas under supervision. Throughout the year, the Institute operations continuously monitored effectiveness of controls: internal control and audit were predominantly assigned to areas of higher risk and, to extent considered necessary, to financial and operational controls and processes, with available resource reservation for ad hoc and follow-up assignments.

Looking ahead, we have a clear responsibility to steward Skoltech operations and finance to ensure achievement of strategic objectives. Skoltech as successful institution with a sound properly resourced financial base – is our priority. The Institute must remain financially sustainable whilst continuing to invest in the infrastructure.

I would like to sincerely thank all of Skoltech teams working in operations and financial management for professionalism and excellent work in stabilizing operations and budget in the fast-happening changes in the world. I also thank Skoltech stakeholders and business partners for ongoing support to initiate and execute right measures.

**Tatyana Zakharova,**
**Senior Vice President for Finance and Operations**

## Operational Management

The geopolitical challenges and inclusion of Skoltech into SDN list significantly influenced the core operational processes such as payments, procurement, travel services, IT business applications and infrastructure. To adapt and ensure sustainability of operations, several measures were implemented:

- payment mechanisms through new banks and international agents were set,
- procurement processes to compensate restrictions were adapted,
- sanctioned vendors and providers of IT equipment and software were replaced with alternative solutions,
- international travel services were ensured via transition to sales channel in collaboration with authorized travel providers,
- foreign employees and students were regularly advised on the changing legislation for banking transactions and foreign currency.

On top of adaptation to the challenges, regular activities were successfully implemented to support the Strategy and maximize operational efficiency.

Thus, Skoltech received the unqualified (positive) opinion from the independent auditor for 2021 Financial Statement according to IFRS and RAS, and from the Skolkovo Foundation for target use of the Foundation Grant. The plan of corrective actions to follow the audit by the Foundation for 2021 was fully implemented.

In line with the IT landscape roadmap, the transition to the new payroll program was implemented to support a smooth implementation of the Interim policy on pay and social allowances.

In the coming year, Skoltech will continue activities to ensure financial and operational sustainability. The priority tasks include a continuous import substitution of IT software, further streamlining of procurement considering sanctions, development of adaptable and tailored package of administrative services suitable for a "live strategy" under rapidly changing conditions.

## Financial Highlights[9]

During the fiscal year of 2022, the Institute demonstrated a strong financial performance and stability to support core activities and enable achievement of the Strategy targets in turbulent geopolitical and economic conditions.

| (in millions of rubles) | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|
| **Total Funding** | 7,026 | 8,313 | 8,984 | 10,224 | **10,387** |
| **Operating Expenses** | 5,557 | 6,620 | 7,204 | 7,499 | **7,778** |
| **Capital Expenses** | 689 | 800 | 1,083 | 806 | **874** |
| **Endowment Net Assets** | 4,559 | 4,775 | 4,787 | 4,634 | **4,929** |

On August 2, 2022, Skoltech was included in the SDN list by the US Office of Foreign Assets Control, that affected all activities. The sanctions led to refusal of services from both foreign and Russian customers to avoid potential secondary sanctions, as well as refusal of foreign companies-licensees to pay fees for IP. Despite negative factors in the national economy, in 2022 Skoltech had sufficient funding to continue operations and the capital construction program, mainly by funding from the Skolkovo Foundation, and could increase a share of attracted funding.

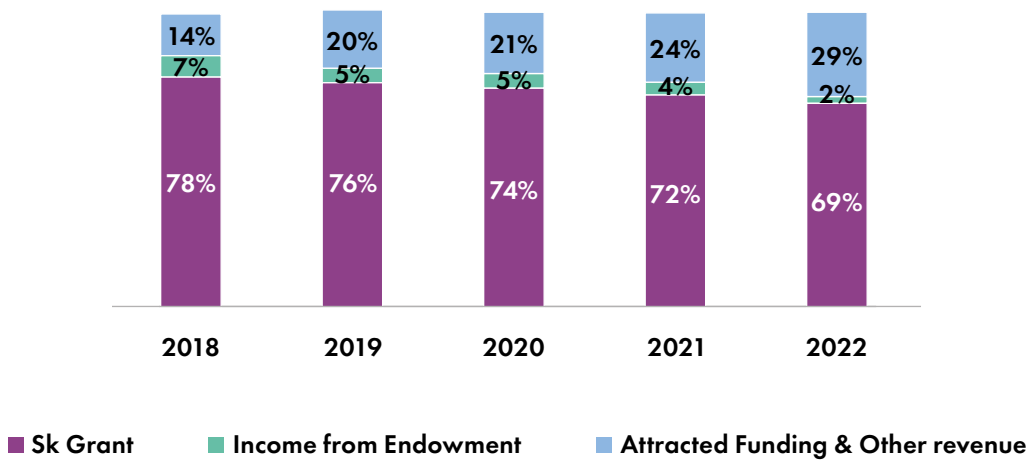
| (in millions of rubles) | 2021 | 2022 | Change % |
|---|---|---|---|
| **Attracted Funding incl. other revenue** | **2,466** | **2,973** | **21%** |
| **Attracted Funding** | **2,345** | **2,755** | **17%** |
| Sponsored Research Contracts | 1,122 | 1,317 | 17% |
| Grants | 1,128 | 1,285 | 14% |
| Professional Education | 62 | 121 | 96% |
| Shared Facilities | 34 | 33 | -3% |
| **Other revenue** | **121** | **218** | **81%** |

[9] The presented financial (treasury) report is for the year ended December 21, 2022 and prepared based on the cash method.

## Funding

The structure of funding is represented by the Skolkovo Foundation Grant, distributed income from Endowment, attracted funding and other revenue. In 2022 the Skolkovo Foundation grant (total 7187 mln Rub), allocated to finance development and ongoing operations, remained the largest part of the total funding (69%). The five-year graph below shows a trend of the increasing share of attracted funding and other revenue in the overall funding structure.

### Funding structure




Despite of a challenging and unstable year, Skoltech closed the year with total funding from various sources resulted to 10 387 mln Rub. The increase of 164 mln Rub, or 2% vs fiscal 2021, was driven by attracted grants and contracts and other revenue sources.

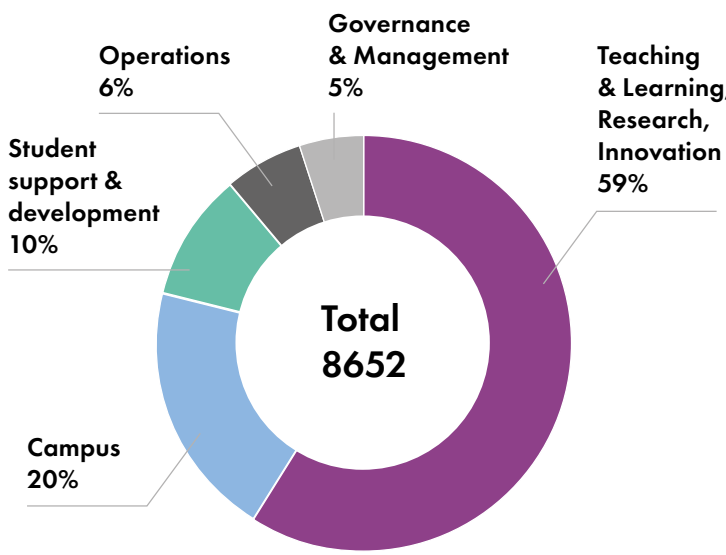
In fiscal 2022, funding from the Skolkovo grant including carry forward balance of unused cash from 2021, resulted to 7 187 mln Rub, with a minor decrease of 2% vs fiscal 2021. Carry forward balance consisted of the restricted grant for infrastructure in the amount of 1 397 mln Rub and 469 mln Rub of 2021 operating budget unused cash including returned prepayments from the Massachusetts Institute of Technology due to termination of the partnership agreement.

The attracted funding incl. other revenue demonstrated the increase of 21%, amounted to 2 973 mln Rub, that is the outstanding result to be achieved in a more typical year. The funding came from grants and R&D contracts, professional education programs, consulting and license agreements. Other revenue is represented mainly by the interest income from bank deposits (68 mln Rub) and sublease contracts (99 mln Rub).

The total distributed income from Endowment in 2022 incl. carry forwarded balances from 2021 was 228 mln Rub. 43% decrease vs fiscal 2021 was driven by a low annual return on investment in 2021 resulted to 160 mln Rub distributed to Skoltech in 2022 comparing to 317 mln Rub in 2021.

## Consolidated Expenses

The consolidated expenses totaled 8 652 mln Rub, including operating expenses of 7 778 mln Rub and capital expenses totaled 874 mln Rub. The structure of expenses did not change significantly comparing to 2021, as outlined in the chart below.



## Operating Expenses

In terms of operating expenditures, negative consequences of sanctions against Russia and inclusion of Skoltech to the SDN list resulted in the following:

› limitations with faculty recruitment, mainly foreign staff due to the risk of secondary sanctions,
› difficulties with payments in foreign currency for foreign-made research equipment and software, which has no analogues in Russia, as well as for professional services and subscriptions to databases;
› change in geography of student academic mobility.

279 mln Rub, or 4% increase of consolidated operating expenses in 2022 vs fiscal 2021, was primarily driven by expenses related to delivery of external contracts and grants, which is aligned with attracted revenues. At the same time, expenditures funded from Skolkovo grant decreased by 8 % comparing to fiscal 2021, to 4 926 mln Rub, as a direct result of the sanctions.

In 2022, **personnel costs** remained the Institute's primary resources, representing 60% of the total operating expenses. The costs included salaries, social taxes, bonuses, medical insurance, reimbursement of accommodation and benefits in kind, personal consulting agreements. The total personnel related costs increased by 503 mln Rub, or 12% comparing to fiscal 2021. The increase is driven by salaries of staff recruited to conduct projects supported with attracted research contracts and grants.

Increase of **professional services costs** by 52% is driven by increasing demand in subcontractors to deliver attracted research contracts and grants.

**Joint research program** decreased 460 mln Rub, or 73%, vs fiscal 2021 mainly due to the termination of the agreement with MIT. The corresponding notification was sent on February 25, 2022, followed by the return of prepayments. At the same time, the Institute continues to support partnerships with international and Russian institutes, e.g. program with the University of Sharjah.

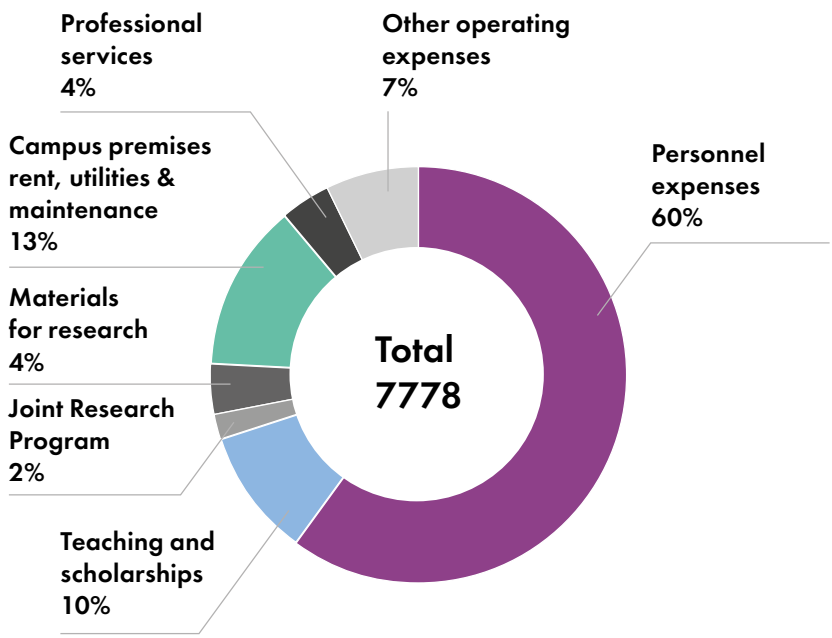
**Teaching and scholarships** decreased 17 mln Rub, or 2% vs fiscal 2021, mainly due to implementation of the new scholarship policy allowed to optimize stipend expenses.

**Campus premises rent, utilities and maintenance costs** included costs to rent campus laboratory and office premises, costs for repair and maintenance of engineering systems, utilities, cleaning of premises and territories, security. The increase of 277 mln Rub, or 36%, comparing to fiscal 2021 occurred due to campus utilities expenses, which were paid by the Skolkovo Foundation in January

– May 2021, and since June 2021 were handed over to Skoltech. In 2022 those expenses were at the full expense of Skoltech.

**Other operating costs** included business trips and events, software and IT equipment maintenance, operating rent of equipment, PR and marketing, library, taxes and charges etc. The decrease of 104 mln Rub, or 17%, is mainly driven by the SDN list restrictions led to the limited access to foreign originated software, subscriptions to databases, licenses and other supplies and services.

## Operating expenses

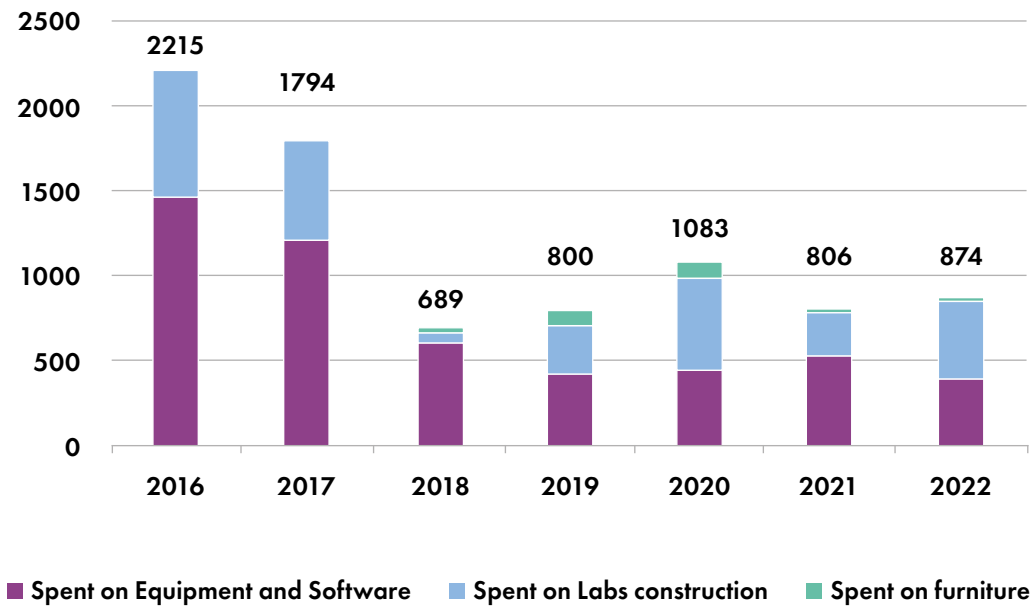


## Capital Expenses

In accordance with one of the Institute's strategic goals, it incurred capital expenditure, including the construction of campus and development of laboratory infrastructure. In fiscal 2022, capital expenses totaled 874 mln Rub, including expenses on research equipment and software totaled 388 mln Rub, 456 mln Rub spent on construction of laboratories and 30 mln Rub on furniture. Investment into laboratory infrastructure was limited by SDN sanctions and led to decrease in equipment and SW expenses by 26% comparing to the previous year.

In 2022 Skoltech continued to deliver the capital program. In 2022 construction schedule of some laboratories was postponed to the next year due to the shifts in the payment schedule from the Skolkovo Foundation in Q1 and Q2, 2022. The construction of laboratories is funded from the Skolkovo Foundation Grant.

### Capital expenses



## Endowment

The Endowment Fund was established to enhance Skoltech financial independence and support for implementation of the Strategy. The primary goal of the Endowment Fund investment policy is to ensure reliability, liquidity, yield and diversification of investments. Endowment funds are managed by professional asset management companies which are Management Company Alfa Capital and Management Company VTB Capital Asset Management. In accordance with the Investment Declaration approved by the Management Board of the Endowment Fund, investments can be made into the state bonds of the Russian Federation, Russian corporate bonds and in Russian Rubles in state-owned banks.

The Endowment Fund as of 31 December 2022 amounts to 4 929 mln Rub vs 4 634 mln Rub as of 31 December 2021. The following assets comprise the portfolio of the Endowment Fund as of December 31, 2022:

| Net assets | TOTAL | |
|---|---|---|
| | mln Rub | % |
| Russian government bonds | 571 | 12% |
| Corporate bonds | 4,358 | 88% |
| Cash and cash equivalents | 0 | 0% |
| Other receivables/payables | 0 | 0% |
| **Total** | **4,929** | **100%** |

As of 31 December 2022, analysis of the structure of the Endowment Fund portfolio (including bonds, cash in bank) shows that corporate bonds share represents 88 % of the total portfolio, government bonds represent 12%, at the same range as in fiscal 2021. Cash in bank and other assets and liabilities represent less than 1% of the total portfolio.

The situation on financial markets in Russia in 2022 was affected by external and internal political situation creating a challenging environment for investments. Thanks to the conservative investment strategy, the dramatic events on the stock market in Russia had no impact on the profitability of the endowment investment portfolio. The investment strategy was based on the instruments with a duration of under 1 year to mitigate high risks on financial markets. Short-term bonds that matured in 2022 were reinvested in bonds with higher yields.

By 31, December 2022, the annualized return on investment in fiscal 2022 resulted to 10.15%, significantly surpassed annual return of fiscal 2021 by 6.6 % points: 458 mln Rub of return comparing to 163 mln Rub in 2021.

| | 2021 | 2022 | Change |
|---|---|---|---|
| Annual return from investment activities | 163 | 458 | 295 |
| Annual return % | 3.52% | 10.15% | 6.63% |

# Campus


ENTREPRENEU
NBIOMEDICIN
GVSKOLTECHB
IECPIORRJU(D
NNIFJBAGRKE
EEEMRITYOBV
ERNANOEFJRV
RGCTESGLEAR
IYEEPYYLJIB
(NEUROSCIENC
GFCIMPACTRE
BQUANTUMARO
QKELINNOVAT
PHYSICSEEXC

Skoltech modern campus of 134,000 square meters is located in the heart of Skolkovo, with a good train connection to the city centre. The design concept of the campus, developed by the world-renowned Swiss architects Herzog and de-Meuron, is driven by creation of modern, high-quality and vibrant environment for teaching and learning, research, and community building.

Considering the laboratory construction schedule, in 2022 some premises of the Energy Center and Bio Center were transferred to the campus. The design concepts for campus elements, including Kolmogorov VR Museum, Alumni Wall, entrance zone and reception, canteen were developed.

The campus construction team was also invited in the expert role for the project of design a modern campus in Chelyabinsk to share best practices on specifics of planning world level university campuses. The team's expertise was highly appreciated by the regional Government and the Ministry of Education.

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The information in the Report
is correct as of April, 2023.
Skoltech reserves the right
to amend information
in the Report.