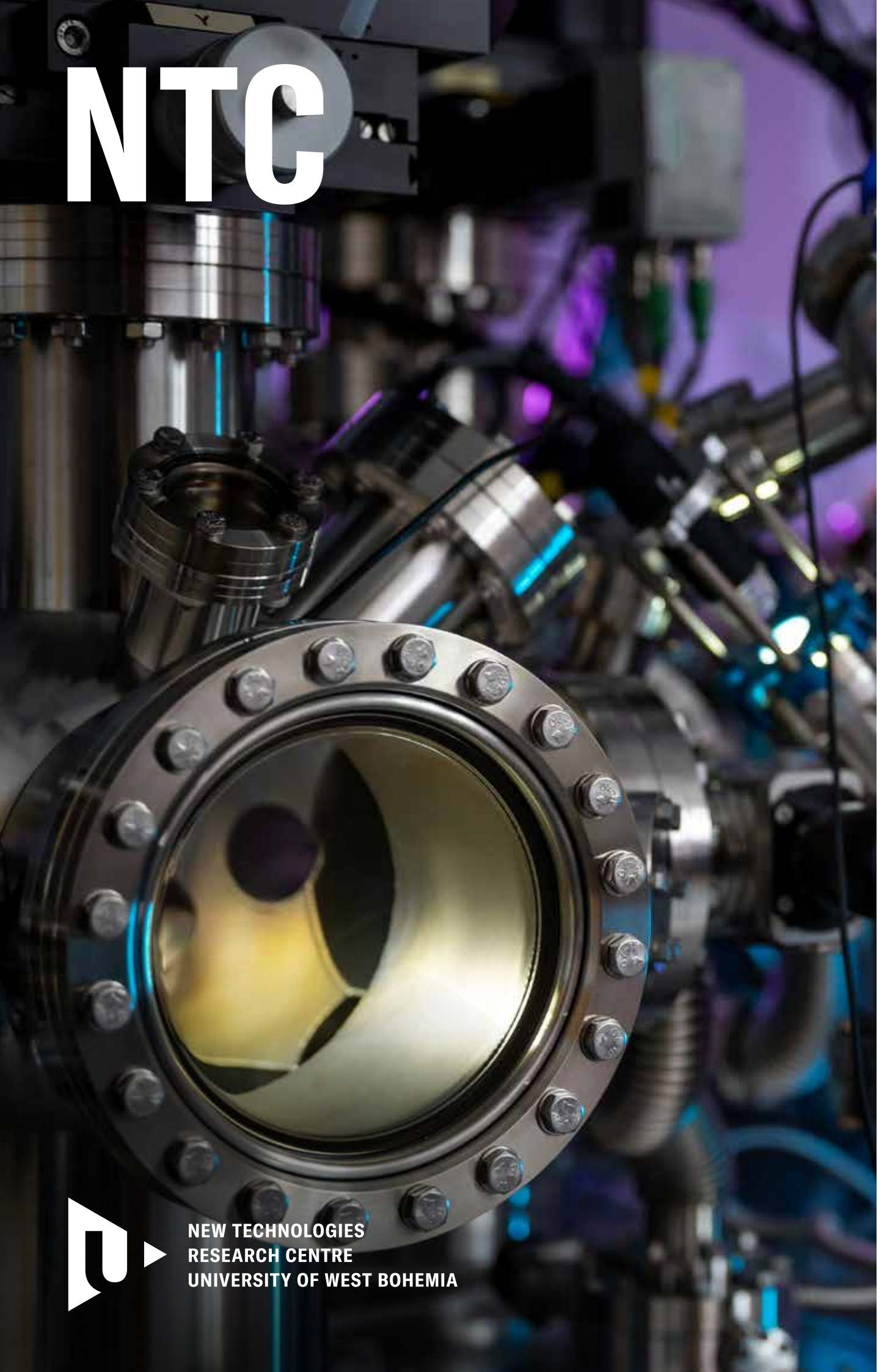

# NTC

NEW TECHNOLOGIES
RESEARCH CENTRE
UNIVERSITY OF WEST BOHEMIA

NTC 2020 ANNUAL REPORT

2020

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NTC 2020 ANNUAL REPORT

Annual report
New Technologies
– Research Centre
University of West Bohemia
2020

2020

# 1 → DIRECTOR’S REPORT

The year 2020 will be remembered as the year of the COVID-19 pandemic. For the NTC, this year was a challenging one. However, it demonstrated that our research centre is perfectly coordinated in terms of teamwork. We have engaged in public support already during the first wave of the COVID pandemic, as our Chemical Processes and Biomaterials research team produced disinfectants. Moreover, the team of Thermomechanics of Technological Processes manufactured 3D-printed protective shields which were distributed to those who needed them. This team also helped with air disinfection with the use of ozone. NTC experts shared their extensive experience with thermographic measuring with the *Ministry of Health*, hospitals, schools and the public. All NTC employees respected the protective measures, they were considerate of each other, quickly adapted to the new situation and used on-line tools. With great pleasure and pride, I can say that our performance, in view of working results, was outstanding. We have successfully implemented many contract research agreements, met our obligations related to Czech and foreign projects and developed international cooperation. I want to thank all NTC members for this wonderful performance.

Last year, the NTC celebrated the 20th anniversary of its founding. Unfortunately, due to the pandemic, we were not able to hold a celebration and thank the "founding fathers", all members of our team and our partners. Therefore, I would like to take this opportunity to express my sincere thanks to all those who contributed to the development of the NTC, as well as to those who cooperate with the centre.

One of the greatest achievements of the NTC and the entire University of West Bohemia in 2020 was the publication of an article by Jan Minár and Saleem Khaan in the January issue of the prestigious journal *Nature*. The results of the work of an international team of scientists, including Minár and Saleem, should contribute to the development of a quantum computer.

I would also like to emphasize the successful completion of the project CENTEM+, which was evaluated as *"excellent"*. The project significantly contributed to the stabilization of the research team both in the area of human resources and the expertise of individual researchers. Thanks to the project, our centre established cooperation with international research institutions and concluded many prestigious contracts. When the project was finished, the organizational structure of the NTC was changed so that it reflected new promising research topics and ensured effective management of research teams.

At the end of June, the NTC was honoured by a visit from the Ambassador of Israel Daniel Meron, together with the Director of the *Czech-Israeli Chamber of Commerce* Pavel Smutný. In October, we established a research centre that unites NTC and the Israeli Ariel University. The centre is based in Pilsen, is headed by Professor Schechter and focuses on renewable energy sources. The NTC Scientific Board welcomed two new members: the Chairman of *Czech-Moravian Trade Unions* Josef Středula and Professor Jiří Vaníček from the *Swiss Federal Institute of Technology Lausanne*.

In 2021, the NTC will focus on the development of research topics and international cooperation. I firmly believe that our great and coordinated team will be as successful as in the previous years.

Petr Kavalíř, Director of the NTC

In 2020, the NTC developed its activities according to the Strategic Plan for the period 2016–2020, which corresponds to the Strategic Plan of the University. The key to the operation of the NTC was the completion of the sustainability project **CENTEM+**, which followed the Centre for New Technologies and Materials Project (CENTEM) from the *Operational Programme Research and Development for Innovation*. CENTEM+ was supported by the National Sustainability Programme (NPU I) for the period 2015–2019. The total amount of recognized project costs was almost 300 million Czech crowns, of which the subsidy amounted to 134 million. In May, an external examination board stated that the project reached, and in most parameters significantly exceeded, all planned goals. In the course of the project, NTC experts and scientists published more than 254 articles in scientific journals. The practical outputs include licensed the vanadium redox flow battery, international patent USA for the *Method of laser beam writing with shifted laser surface texturing and the national patent for Washable high-emissivity colour for non-contact measurement of object temperature by detection of infrared radiation*. Thanks to the achievements, the external examination board evaluated the project as "excellent". With regard to the completion of this project, the teams were reorganised into 6 research groups. The NTC personnel structure in terms of qualification is described in Chart 1.

In addition to CENTEM+, the NTC focused on other projects developed in cooperation with local institutions, such as the *Ministry of Education, Youth and Sports, the Technology Agency of the Czech Republic (TAČR)* and the *Czech Science Foundation (GACR)*. Our researchers continued their work on the EU project **"Affordable High-Performance Green Redox Flow Batteries"** and on the project **"HIGREEW"** in the call **"LC-BAT-4-2019: Advanced Redox Flow Batteries for stationary energy storage"**, which was supported by the H2020 programme. This research project is focused on the development, demonstration and validation of sustainable, affordable and secure advanced redox flow batteries. Another project from the operational programme *"Research, Development and Education"* is the **"Computational and Experimental Design of Advanced Materials with New Functionalities"** obtained from the call No. 02_15_003 "Support of Excellent Research Teams" in Priority Axis 1. The objective of this project is to promote research and development activities focused on material structure, and electrical and optical properties of new materials. In 2020, our centre was involved in three sub-projects within the consortium **"Engineering"** of the project National Competence Centre 1 (NCK1). At the same time, we implemented the project **"Application of Modern Technologies in Medicine and Industry" (AMTMI)** under the call *Pre-Application Research for ITI* in the operational programme "Research, Development and Education". Another project implemented under the call Pre-Application Research for ITI was the **"LabIR-PAV/Pre-Application Research of Infrared Technologies"**. The LabIR-PAV project addresses the interdisciplinary research of pre-application measurement methods focused on the use of infrared radiation for non-contact analysis of thermomechanical processes.

Our research centre not only successfully fulfilled all planned applied results, which were handed over to industrial partners, but also published many high-quality outputs that are important for the evaluation of the centre in terms of research excellence. In addition to grant projects, the NTC has established strong and long-term cooperation with industrial partners in the area of contract problem-oriented research.

The NTC has developed international cooperation and has invited foreign experts to be members of its research teams. In 2020, the NTC employed 16 foreign researchers from 10 different countries. In 2020, the Scientific Board welcomed two new members, in particular, Prof. Vanicek from the *École Polytechnique Fédérale de Lausanne* and the Chairman of the *Czech Moravian Confederation of Trade Unions*, Josef Středula. The Scientific Board appointed five international experts. Thanks to the education of young researchers and targeted strategy focused on the attraction of talents from abroad, the NTC has become an attractive employer. In December 2020, the NTC employed 131 employees (96 men, 35 women).

The Institute promotes not only professional growth but also life-long education and development of managerial and other necessary skills. Emphasis is placed on transparent processes of human resources management. Since 2018, the NTC has been the holder of the prestigious award *HR Excellence in Research*, shortly *HR Award*, which is awarded by the European Commission. Researchers and administrative staff had the opportunity to attend not only professional training workshops but also workshops aimed at the development of soft and managerial skills. After two years, the performance of the NTC was evaluated and NTC management prepared a detailed interim report. In 2020, the Institute focused on the fulfilment of obligations under the award, which include the creation of favourable working conditions for all employees.

At the same time, the NTC was successfully evaluated in terms of sustainability and internationalization. Moreover, it was positively assessed by the *International Evaluation Panel* under the new methodology M17+ issued by the Ministry of Education.

| HUMAN RESOURCES | persons |
|---|---|
| Total | 131 |
| Professors | 6 |
| Associate professors | 9 |
| Ph.D. and CSc. | 59 |
| University students | 46 |
| Grammar school students and others | 11 |

**Tab. 1.** NTC human resources in 2020

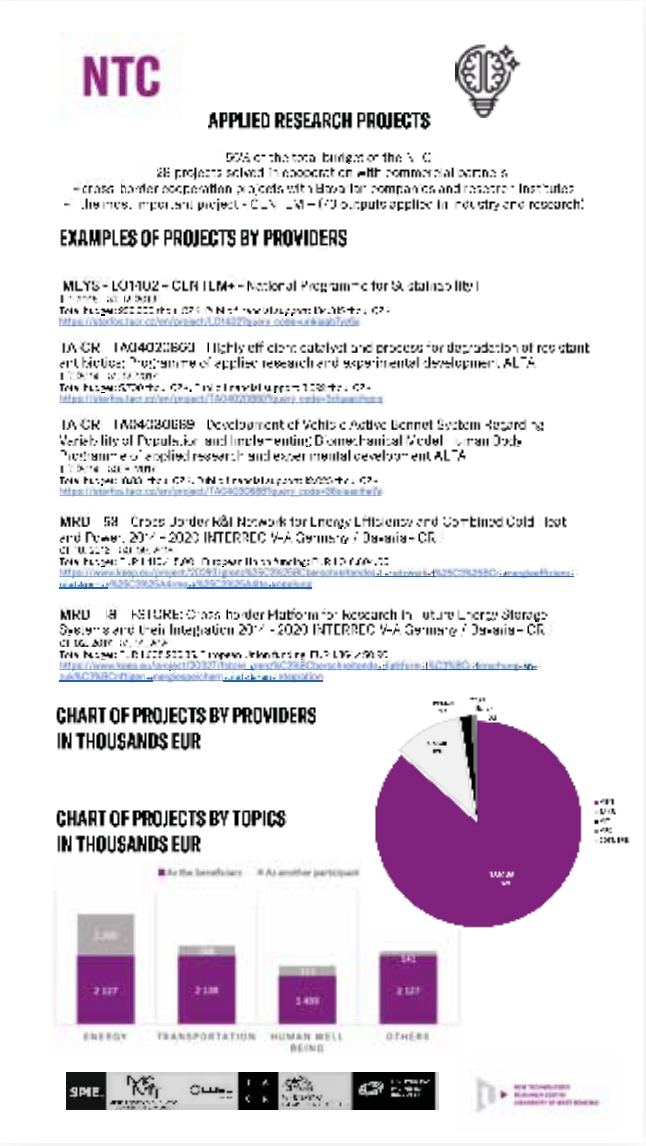



**Fig. 2.** Example of an evaluation card, appendices to the M17 + evaluation. The complete evaluation is available at https://ntc.zcu.cz/en/Research/Evaluation_M17_plus.html

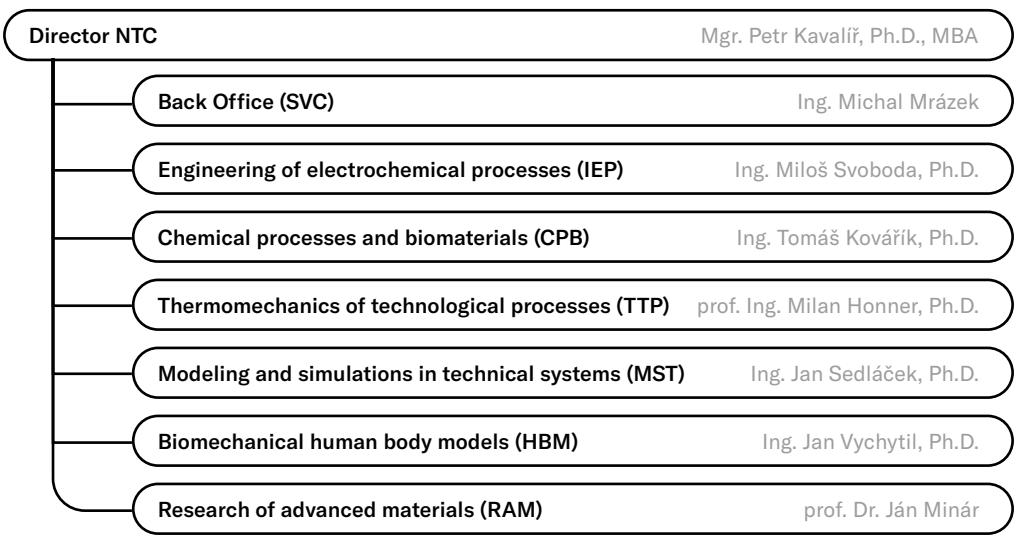



**Fig. 1.** Organizational structure of the NTC in 2020

# CONTRACT RESEARCH

In 2020, the NTC provided mainly research and service activities for its commercial partners. These activities and cooperation with local and foreign companies were strongly affected by the COVID-19 pandemic. In 2020, the NTC worked on 65 contract research contracts and 111 additional activities totalling almost CZK 10.8 million. Key partners include ZF Engineering Plzeň, s.r.o., ŠKODA AUTO, a.s., COMTES FHT a.s., Dobřany, UJP Praha, a.s., MAHLE Behr Holýšov, s.r.o., ZVVZ-Enven Engineering, a.s., Plzeň, Škoda JS, a.s., Plzeň, ČEZ a.s., Praha, Chropyňská strojírna, a.s., Chropyn, Frentech Aerospace s.r.o., Brno, ZVVZ-Even Engineering, Milevsko, AM-CME s.r.o., Plzeň, COMDES CZ s.r.o., Praha, Eurometalgroup s.r.o., Krásná Lípa, JLC service s.r.o., Vavřinec, VZÚ Plzeň s.r.o., Ghent University, Belgium, Škoda transportation a.s., Plzeň, UNO Praha, s.r.o., Thermal Focus BVBA, Belgium, JANTAR Plzeň s.r.o., Ugent-LCT, Belgium, SCG Chemicals (Thailand), Diamorph hob certec, University of Chemistry and Technology in Prague, Faculty of Medicine of Charles University, JABLOTRON ALARMS a.s., Jablonec nad Nisou, Valeo Výměníky Tepla, Žebrák, k.s., Pinlow energy storage, s.r.o., Praha, Institute of Thermomechanics of the Czech Academy of Sciences in Prague and others. All of the above-mentioned contracts were always submitted by the agreed deadlines and in accordance with clients' requirements.

# CENTEM AND THE SUSTAINABILITY PROJECT CENTEM+

The sustainability project **"CENTEM+"** followed the project CENTEM and was supported by the National Programme for Sustainability NPU I for the period 2015–2019. The CENTEM + project is described in more detail in the "NTC in 2020" section above. Other achievements include the implementation of a prestigious project for **"The support of excellent research teams CEDAMNF"** and **"LabIR"** focused on pre-application research. Moreover, the NTC initiated the project **"HORIZON 2020"** entitled **"HIGREEW"**. The external examination board (represented by the Ministry of Education and invited evaluators) assessed the above-mentioned successful activities and the smooth course of the project CENTEM+ as "EXCELLENT".

**Fig. 3** Computational clusters from the Department of Modeling and Simulation of Technical Systems

# PROJECTS

The last year was greatly affected by the COVID-19 pandemic. The NTC managed to respond to the situation and has developed research activities aimed at fighting this disease. The centre launched two projects: **"BETECH"** and **"BETERKA"**. BETECH was aimed at medical thermodiagnostics. The research focused on the measurement of temperature using thermal imagining cameras in places with an increased incidence of people, such as hospitals, big companies, offices, schools and shops. The principal investigators of the project included the NTC, the Faculty of Health Studies and the Faculty of Mechanical Engineering. The Techmania Science Centre also participated in this project. The main result of the project was laboratory testing of new methods focused on the use of thermal imaging cameras to accurately measure the temperature of people. Moreover, the research presented methods for the use of this technology for monitoring people during the COVID-19 pandemic. The project was supported by the amount of CZK 3 million. The project **"Security research for the effective use of thermal imagers in the event of epidemic threats and crisis situations" (BETERKA)** was supported by the Ministry of the Interior within the programme **"Security Research Programme of the Czech Republic in the years 2015–2022"**. The project will be launched in 2021. Like the previous project, this research will be performed in close cooperation with the Techmania Science Centre and will be aimed at thermodiagnostic methods and the use of thermal imagers. The project will search for new solutions and methods for the use of thermal imagers in the activities of individual components of the Integrated Rescue System of the Czech Republic. The financial support amounts to CZK 15 million, of which the NTC receives approximately CZK 10 million.

Another major project initiated in 2020 is the **"NTC Technology Centre Techlab" (NTC Techlab)** which is supported by the Ministry of Industry and Trade within the *Operational Programme Enterprise and Innovations for Competitiveness in the call Infrastructure Services*. The project will be launched at the beginning of the year 2021. The aim is to complement the existing research infrastructure of the NTC (the capacity is approx. CZK 420 million, including laboratory, experimental and computational devices). The result will be a stronger capacity of the centre for collaboration with science and technology companies, SME, technology-oriented companies and application partners. The subject of the project is the purchase of instrumentation and experimental devices, as well as of hardware and software for **NTC Techlab**. The following technologies will be purchased: a deposition device – MBE System; software for the CT and the CT graphic station; the graphic computer server DGX and software for the server; a laboratory furnace; a measuring system/switchboard. The project grant amounts to CZK 10.6 million and the purchase of equipment is co-financed from 50%. The total cost of the project amounts to CZK 21.2 million.

Our researchers continued their work on the project **"AFFORDABLE HIGH-PERFORMANCE GREEN REDOX FLOW BATTERIES" (HIGREEW)** in the call *LC-BAT-4-2019: Advanced Redox Flow Batteries for stationary energy storage*, which was supported by the H2020 programme. This research project is focused on the development, demonstration and validation of sustainable, affordable and secure advanced redox flow batteries. Our partners from the Spanish institute *Centro de Investigación Cooperativa de Energías Alternativas Fundación*, from the French institute *CNRS– Centre National de la Recherche Scientifique* and our industrial partners *Gamesa Electric Sociedad Anónima, Pinflow Energy Storage, s.r.o, Heights UK Limited, C-TECH Innovation Limited* are participating in the project to name a few.

In 2020, the NTC participated in a project supported by the Czech Science Foundation (GACR). Specifically, in the project **"X-Ray Absorption and Dichroic Spectra of Low-Dimensional Systems: Description and Interpretation"** with the reference number 20-18725S. The project grant provided by the Foundation amounted to CZK 0.84 million.

In 2020, our centre was involved in three sub-projects within the consortium **"Engineering"** of the project *National Competence Centre 1 (NCK1)*. The project (reference number TN01000015) is led by Prof. Miroslav Václavík from the Centre for the Development of Engineering Research in Liberec. The project involves 26 other partners such as the

Czech Technical University in Prague, COMTES FHT a.s., the Brno University of Technology, the Institute of Physics of Materials of the Czech Academy of Sciences, and industrial partners such as Wikov Gear s.r.o., TOSHULIN a.s., Škoda Machine Tool a.s., TOS Varnsdorf a.s. And others. The project **"National Centres of Competence" with a focus on ENGINEERING"** involves three sub-projects. The first sub-project deals with the topic **"Optimization of Gearboxes Using Analytical and Numerical Methods with the Support of Experiments"** (e.g. operational conditions, acoustics, durability, strength calculations, etc.). The project is implemented in cooperation with the company Wikov Gear s.r.o. The project includes theoretical analyses including analytical and numerical calculations and experimental research with the validation of computational models. The second sub-project is entitled **"Application of Transition Metal Oxides and Heusler Alloys with Significant Physical Properties Suitable for Applications in Sensors and Actuators"**. The project is focused on theoretical predictions of new materials, characterization of transition metal oxides and Heusler alloys and the manufacturing procedure of sensors and actuators. The third sub-project is developed in cooperation with the company Wikov Gear s.r.o. and focuses on **"The Influence of Production Deviations of the Root of the Tooth on the Bearing Capacity of Gear Wheels"**. This project involves research and solutions to problems associated with the technology of high-speed gear transmissions. The final output will be a method for the evaluation of the influence of production deviations of the root of the tooth on the bearing capacity of gear wheels. In 2020, these sub-projects were supported by a grant totalling CZK 6.1 million.

The Centre also addressed very interesting projects important from the perspective of the future, which are supported by the Technology Agency of the Czech Republic. These application effect projects were launched in cooperation with industrial partners from the programme THÉTA. One of the projects focuses on **"Experimental and Computational Critical Heat Flux Identification of Small Power Output Reactor (SMR) Fuel Rods"**. The project has been developed in cooperation with Škoda JS, a.s. The main objective was the creation of sophisticated methodologies. Based on sophisticated procedures, it is possible to describe local effects related to the critical heat flux, which may occur on the rods during operation. These skills have a huge impact on the acquisition of know-how in the area of the operational safety of reactors in the Czech Republic and abroad. The second project launched in the programme THÉTA was focused on the **"Research and Development of Advanced Flow Energy Storage Technologies"**. The objective of this project is the research and development of technologies for the

**Fig. 4.** Building of the NTC.

storage of electrical energy based on the growing demand for an easy and safe way of storing electricity. Moreover, the project deals with the development of a flow electrochemical energy storage, which seems to be ideal for the storage of surplus electricity generated during windy and sunny days. The project partners are the University of Chemical Technology in Prague and the company EnergyCloud, a.s. Total approved costs of both projects amount to CZK 11 million, of which the NTC received almost CZK 5.9 million.

The last project, which is funded by the Technology Agency of the Czech Republic within the programme TAČR ÉTA, is focused on applied research, specifically on the topic **"Therapeutic Care for the Convicted"**. The project focused on post-penitentiary care and on mapping barriers that hinder the provision of therapeutic care in prison. Moreover, the project dealt with the evaluation of existing therapeutic approaches to the convicted. In 2020, the total approved costs of the project amounted to CZK 0.79 million.

In 2020, the NTC implemented the project **"Application of Modern Technologies in Medicine and Industry" (AMTMI)** under the call *Pre-Application Research for ITI* in the operational programme Research, Development and Education". The research project was carried out in cooperation with the University of West Bohemia (UWB) and the Medical Faculty of the Charles University in Pilsen. UWB was represented by the Faculty of Applied Sciences together with the research centre NTIS and by the research centre NTC. The objective of the project is the creation of methodologies and algorithms to further refine mathematical and experimental modelling of selected tissues and biological fluids. This project targets virtual, personalized and translational medicine. The project also enables the development of biomechanical models of the human body with respect to anthropometry and biomechanical properties.

Another project implemented under the call "Pre-Application Research for ITI" was the **"LabIR-PAV/ Pre-Application Research of Infrared Technologies"**. This project addresses interdisciplinary research of measurement methods focused on the use of infrared radiation for non-contact analysis of thermomechanical processes. The results of the project can be used in laser material-processing technologies, for the detection of optical, thermal and mechanical properties and in the area of non-destructive testing of materials and products.

A project, which the researchers gained within the operational programme Research, Development and Education under the call *No. 02_15_003 "Support of Excellent Research Teams" in Priority Axis 1*, is entitled: **"Computational and Experimental Design of Advanced Materials with New Functionalities"**. The objective of this project is to promote research and development activities focused on material structure, and electrical and optical properties of new materials. The main investigator of the project is the internationally recognized foreign expert Professor Jan Minár. Researchers were able to fully realize their activities thanks to the stabilization of the research team and all laboratories, including the newly equipped laboratory SARPES. A spin- and angle-resolving photoelectron spectrometer from the lab SARPES helps understand the properties of materials by impinging light with sufficient energy which triggers the emission of electrons and particles with unique features. Thanks to this device, scientists are able to study energy and momentum of an electron, and an exceptional quantum property, the so-called spin. In 2020, the total approved costs of the three above-mentioned projects amounted to CZK 30 million.

Another group of projects are projects from the operational programme *Cross-Border Cooperation Programme Czech Republic – Free State of Bavaria - Objective ETC 2014–2020* which was supported by the Ministry of Regional Development. These projects were focused on cross-border cooperation between partners from the Czech Republic and the Free State of Bavaria in the Priority Axis 1 *Research, Technological Development and Innovation*. In 2020, we implemented 3 projects. The first project from the programme ETC 2014–2020 enabled the establishment of a joint research platform between the NTC and the Technology Centre for Energy (TZE) at the University of Applied Sciences in Landshut focusing on research of energy storage systems and their integration with other technologies. This research and cooperation, which was successfully

completed in January 2020, was titled **"FSTORE: Cross-Border Platform for Research in Future Storage Systems and Their Integration"**.
Another project, which was successfully concluded in 2020, is entitled **"Obstetrics 2.0 – Virtual Models for Injury Prevention during Childbirth"**. The main aim of the project was to find the optimal position and locomotion of an obstetrician during manual perineal protection to achieve maximum possible efficiency depending on the anthropometric data of the mother and obstetrician. To achieve the goals, researchers used a virtual musculoskeletal human body model and a detailed upper limb model.
The last project is entitled **"MATEGRA: Advanced Porous Biomaterials Functionalized with Stem Cells to Improve the Osseointegration of Implants"**. The project MATEGRA was focused on was the development, optimization and testing of new types of biocompatible surfaces of titanium implants with the aim to improve osseointegration and bone tissue adhesion. Another goal was the cooperation of research institutions and professional groups and the transfer of knowledge in the development and testing of new porous biomaterials. In 2020, the costs of the projects amounted to CZK 9.1 million.
The last group of research activities was supported by the **"John H. and Amy B. Lawrence Foundation"**. The aim of this project was to promote the involvement of students in scientific research activities in the field of traffic safety. This project was supported by the amount of about CZK 0.53 million.

# COOPERATION WITHIN UWB

As in previous years, in 2020 the NTC cooperated with other faculties and supported the Student Grant Competition. In 2020, the Ministry of Education, Youth and Sport supported 5 projects worth nearly CZK 2.7 million. In these projects it was mainly students of the Faculty of Mechanical Engineering, Faculty of Applied Sciences and the Faculty of Education who participated.

# PROFESSIONAL RESULTS

In 2020, the NTC focused on the high professional level of the publication results, especially in journals included in the database WOS and Scopus in the Q1 and Q2 quartiles. Furthermore, the NTC focused on contract research activities in cooperation with commercial partners. The total volume of publications and the number of applied results achieved in 2020, reported in the Information register of research and development results, are described in Charts 2 and 3.

| Publication Results | Number |
|---|---|
| Article in a journal | 73 |
| Conference contribution | 10 |
| Chapter in a book | 4 |
| Scientific book | 2 |
| Technical reports | 47 |

**Tab. 2.** Publication Results

| Applied Results | Number |
|---|---|
| Functional sample | 9 |
| Authorized software | 3 |
| Proven technology | 5 |
| Prototype | 2 |
| Patent | 1 |
| Patent application - Together with the Holon Institute of Technology, UWB filed a joint patent to the national phase in the UK | 1* |

**Tab. 3:** Applied Results

# EXCELLENT PUBLICATION ACHIEVEMENTS IN 2020

In January 2020, the article *Large magnetic gap at the Dirac point in Bi2Te3/MnBi2Te4 heterostructures* was published in the prestigious journal *Nature*. The article was written by Ján Minár and Saleem Khan from the RAM Department.

The article *SciPy 1.0: fundamental algorithms for scientific computing in Python*, in which the researcher Robert Cimrman from the HBM team participated, was published in the prestigious scientific journal (impact-factor: 35) *Nature Methods* and achieved the status *Hot Paper* and *Highly Cited Paper*.

The article *State of the art recent progress in two-dimensional MXenes based gas sensors and biosensors: A Comprehensive Review* was written by Kalim Deshmukh and Tomáš Kovářík from the CPB team. The result of the research work was a unique publication in the periodical *Coordination Chemistry Reviews*.

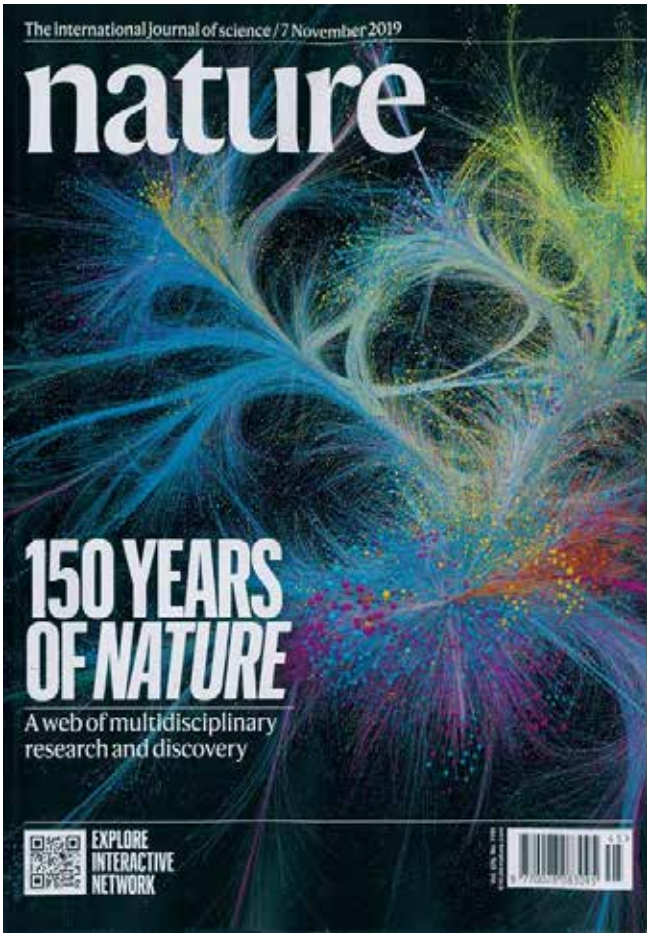
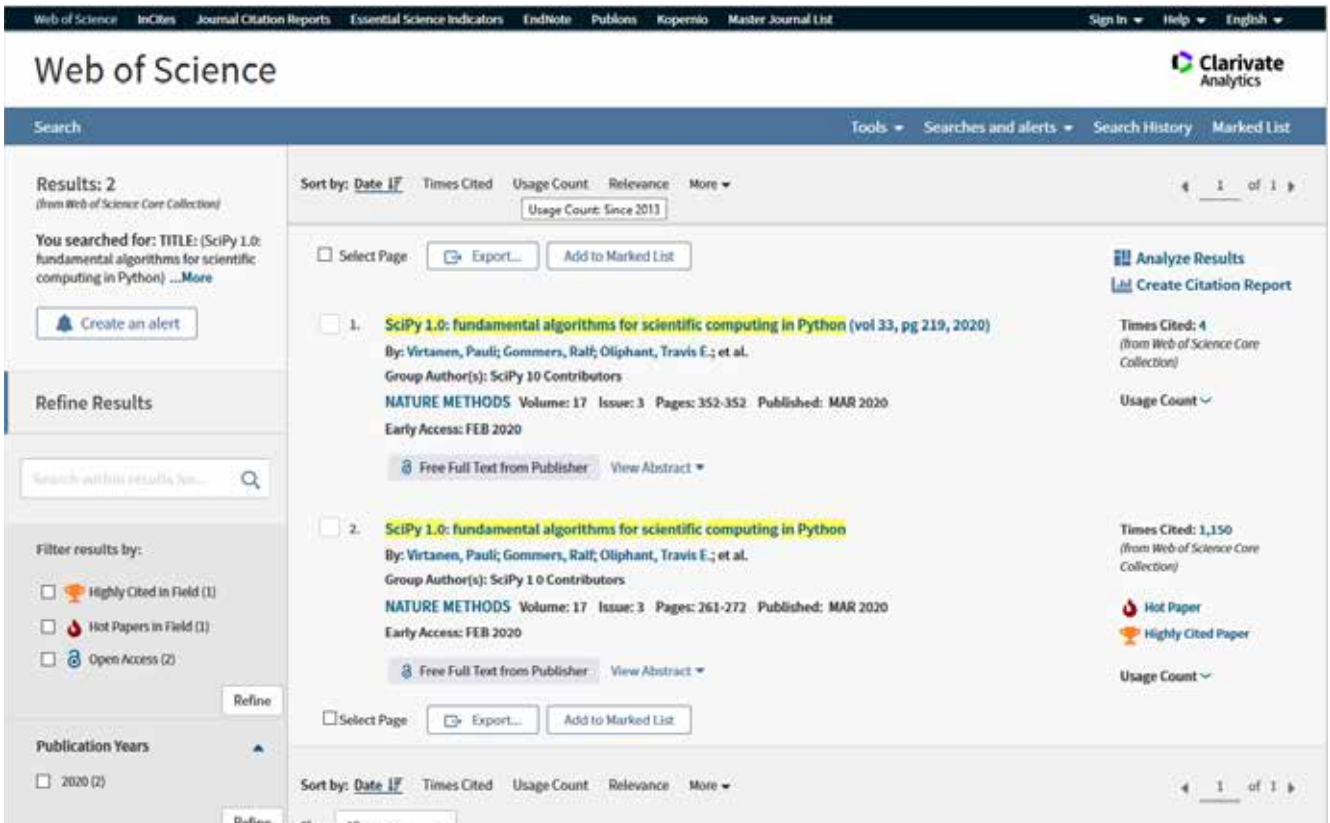



**Fig. 5.** Cover page of the journal Nature, which published the article Large magnetic gap at the Dirac point in Mn-induced Bi2Te3/MnBi2Te4 heterostructures.

**Fig. 6.** Print Screen of Web of Science



# MODELLING AND SIMULATION OF TECHNICAL SYSTEMS (MST)

This team was established on 1 January 2020 by merging two existing departments, namely the Department of Modelling of Deformation and Dynamic Processes and the Department of Modelling and Measurement of Interactions in Technical Systems. The new department unites, both thematically and in terms of staff, teams focused on numerical simulations, applied research and cooperation with industrial partners. In 2020, the newly established team participated in several grant research projects and at the same time developed direct cooperation with traditional and new industrial partners.

In 2020, two research projects, which were supported by the Technology Agency of the Czech Republic, were implemented. The first project **"NCK Engineering"** was implemented together with the company Wikov Gear s.r.o. and has successfully completed various sub-projects. The second project was implemented under the programme THÉTA and was titled **"Experimental and Computational Critical Heat Flux Identification of Small Power Output Reactor Fuel Rods"**. The main beneficiary is ŠKODA JS a.s. The project focuses on experimental and computational analyses of critical heat flux.

The direct collaboration with industrial partners was directed to the areas of power engineering and the automotive industry. In 2020, the centre successfully developed close cooperation with the companies ZF Engineering Plzeň s.r.o. and ČEZ a.s.

As in previous years, in 2020 the team cooperated with university departments. Department employees gave classes at all study levels (at the Faculty of Mechanical Engineering and the Faculty of Electrical Engineering). Moreover, the centre encourages Bachelor's and Master's degree students to participate in its activities, and provides training to doctoral students from the Faculty of Mechanical Engineering.

# BIOMECHANICAL MODELS OF THE HUMAN BODY (HBM)

In 2020, the HBM team focused mainly on ongoing research projects. At the end of the year, the team finished the project **"Obstetrics 2.0 – Virtual Models for Injury Prevention During Childbirth"** supported by the Programme for Cross-Border Cooperation of the Free State of Bavaria – Czech Republic. The project was implemented in cooperation with the Faculty of Medicine in Pilsen and the Ostbayerische Technische Hochschule Regensburg. The result of the project is an optimized approach to manual perineal protection as a method that decreases injury risk during childbirth. The results were presented to the scientific community through publications in prestigious journals and presented at international symposia which were held online because of the COVID-19 pandemic. The project strengthened the cooperation between all partners who decided to participate in the preparation of a new joint project in the context of the continuing programme for cross-border cooperation between the Free State of Bavaria and the Czech Republic.

In 2020, the team focused on an ITI research project: **"Application of Modern Technologies in Medicine and Industry"**. The HBM team focused on the development of computer models of the human body and its parts based on the so-called multi-body structures. The main objective was to then use the models to prevent injuries in transportation, medicine and sports. As part of this project, a workshop entitled *Human Body Models for the Applications in Traffic Safety, Medicine and Sports* took place in February 2020. Researchers from the HBM team presented their findings and results.


**Fig. 7.** Dr. Abbas Talimian gives a lecture on the results of his research at the ITI workshop.

In the course of 2020, the team continued its activities focused on the project **"TL02000205 Therapeutic Care for the Convicted"**. Despite a considerably difficult situation and the impossibility of visits to prisons, we managed to carry out the project in accordance with the plan.

In 2020, international mobility programmes were strongly influenced by the epidemic. Thanks to the project Mobility 3.0, our centre hosted the foreign expert Dr. Abbas Talimian, who was engaged in research activities focused on traffic safety. The HBM Department focused on the presentation of its results, in particular through publications in prestigious scientific journals. Especially important was the publication of the article *SciPy 1.0: Fundamental Algorithms for Scientific Computing in Python* which was prepared by an HBM researcher and was published in the journal *Nature Methods*. It is a prestigious scientific journal with an impact factor-35 (5-year IF in 2018).

On 11 and 12 September 2020, the HBM team presented its research topic at the event *Science and Technology Days* which was held at Republic Square in the city centre. A popularization lecture was held as part of the online event *Night of Scientists*.


**Fig. 8.** NTC department stand – The HBM team at the event Science and Technology Days

# RESEARCH OF ADVANCED MATERIALS (RAM)

In 2020, the main activity of the team was the continuation of the project **"Computational and Experimental Design of Advanced Materials with New Functionalities" (CEDAMNF)** as part of the operational programme Research, Development and Education in the call Support to Excellent Research Teams. The project closely unites theoretical and experimental methods, which makes it unique not only in the Czech Republic but also internationally.

The RAM Department together with the Institute of Physics of the Academy of Sciences participated in a new project supported by the Czech Science Foundation: **"X-Ray Absorption and Dichroic Spectra of Low-Dimensional Systems: Description and Interpretation"**.

The above-mentioned projects resulted in the publication of a number of prestigious articles published in scientific journals, such as *Physical Review Letters, ACS Nano, Physical Review Research*. The published articles show that our researchers established close cooperation with many Professors, namely with Hubert Ebert (LMU, Munich), Karol Hricovini (Cergy-Pontoise University), Simon Mun (Gwangju Institute of Science and Technology), Hugo Dil (EPFL Laussane) and Christina Scheu (MPI Düsseldorf).

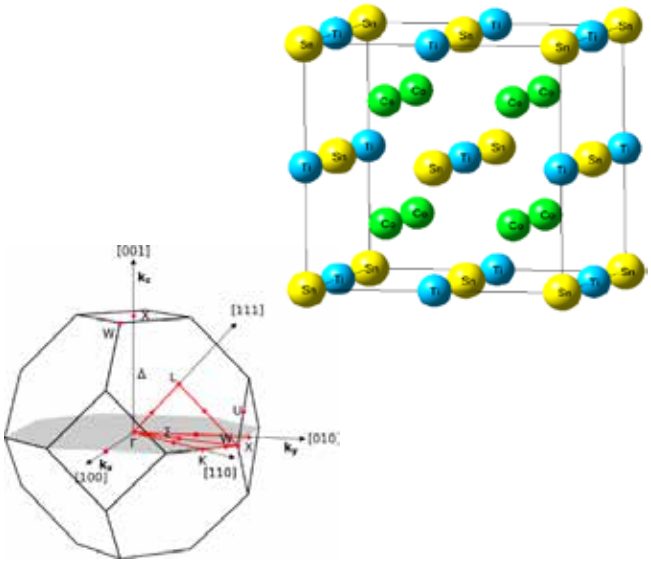



**Fig. 9 b)** Model of the structure Co2Ti(1-x)VxSn and c) the first

Professor Hricovini from the Cergy-Pontoise University and Professor Minár from the RAM Department have made the first steps that could result in cooperation in the area of research of advanced materials. The aims of both experts, who are recognized authorities in their field of expertise, was the creation of a shared laboratory that would be part of an international project funded by the programme Horizon 2020 or Horizon Europe.

In the area of applied research, the RAM Department successfully completed a sub-project implemented within the consortium **"Engineering"** of the programme National Competence Centre 1 (NCK1). The project focused on the research and development of new materials with properties suitable for technological applications. In particular, the project focused on Heusler alloys and transition metal oxides with

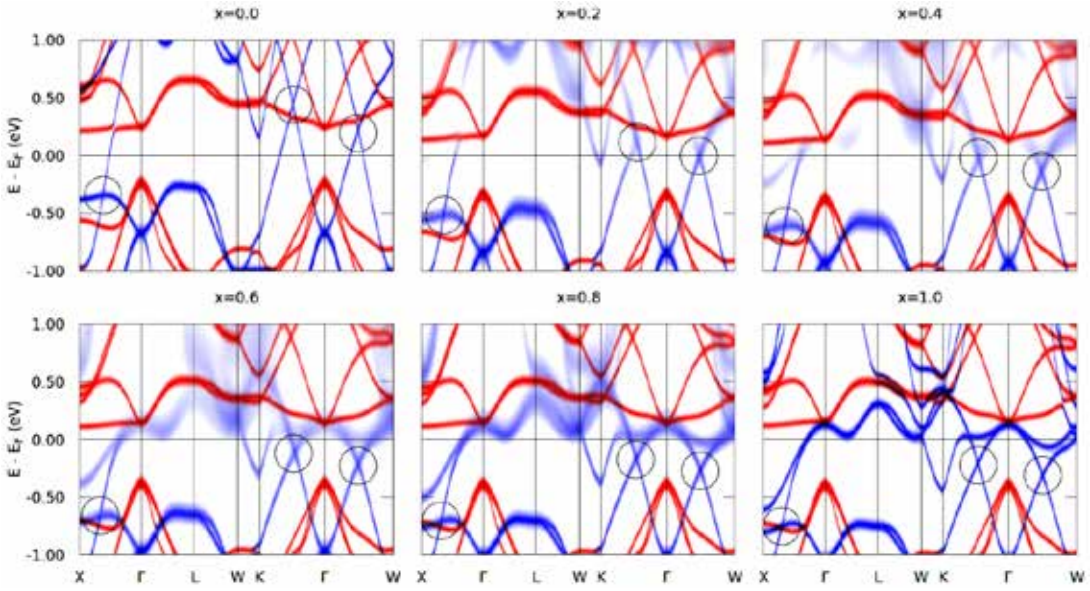
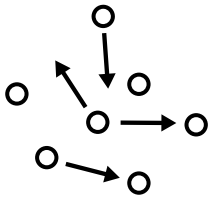



**Fig. 9 a)** Spin resolved electron band structure Co2Ti(1-x) VxSn. Depending on the concentration of vanadium.



piezoelectric properties. The main result of this project was the development of quantum-mechanical multiscale software for predicting the properties of functional materials for sensor applications. The first researchers used the software to study the electronic structure of the Heusler alloy Co2Ti(1-x) VxSn. This ferromagnetic alloy is a semi-metal that is characterized on the Fermi scale by a state of one spin character. The results of the spin differentiated electronic structure in dependence on the concentration of x vanadium are shown in Figures 9a) and 9b). The RAM team also focused on the development of a functional sample of a thin-film sensor/actuator and on technology for its production.

The RAM Department was involved in the organization of two international workshops, *APCOM2020* and *KKRHOC2020*, as well as in the prestigious physics workshop held by the school Les Houches in France. Because of the COVID-19 pandemic, all events will be held in 2021. Members of the research team Fatima Alarab and Jakub Schusser successfully completed their studies. After obtaining their Ph.D. degrees, both of them keep working in science and research and work in prestigious European institutions. Fatima Alarab works at PSI Synchrotron in Switzerland and Jakub Schusser at the Julius Maximilians University in Würzburg, Germany.

Last year, we invested about CZK 14.5 million in the renovation of devices and expansion of the SARPES and XRD laboratories. First of all, we bought a new modern XRD diffractometer from the company Brucker, which enables us to measure the structural properties of materials. Moreover, we purchased a material printer that is perfect for flexible sample contacting. In order to measure electrical properties, we purchased a device that measures the Hall effect. In the SARPES laboratory, we invested in new equipment related to vacuum technology.

The RAM Department, along with other departments (IEP and MST), participated in the preparation and the successful acquisition of the project **"Technology Centre NTC Techlab"**. The objective of this project is the purchase of a deposition device – MBE system. This technology will allow us to prepare layers for semiconductor devices (preparation of very sensitive magnetic sensors and photosensors in the infrared range), which are used in the design of microactuators, high-frequency electronics and biomedical applications.

**Fig. 10.** Transmission electron microscope.

# ENGINEERING OF ELECTROCHEMICAL PROCESSES (IEP)

The year 2020 was the last year of the project FSTORE: **“Cross-border Platform for Research in Future Energy Storage Systems and their Integration”**. Both our team and the team of our German partner completed the final reports and published an article in the *Journal of Energy Storage*.

The research team continued its activities in the project THÉTA (TK02030001): **“Research and Development of Advanced Flow Energy Storage Technologies”**. The UWB is the principal investigator of this project focused on the development of technologies for the storage of electricity using high-capacity cathodes based on oxygen electrodes. The project focuses on two groups of systems: It places two groups of systems: metal-air and organic-air, both of which can be used as low-cost stationary or mobile storage of electricity. The project length is 53 months.

In the course of 2020, we continued our work on the European project HIGREEW **“Affordable High-Performance Green Redox Flow Batteries”**. The research focused on the optimization of components with regard to the use of a new organic-based electrolyte. In cooperation with other partners, we published an article in the prestigious *Journal of Power Sources*.

In the area of contract research, we cooperated with the company Nimetal s.r.o. and focused on the next stage of the development of an experimental line for recycling cadmium.

In collaboration with other research groups, the IEP Department published five impactful articles in 2020. Two of them were published in prestigious journals with impact factor 7+ and 8+, namely by the *Journal of Membrane Science* and *Journal of Power Sources*. In 2019, the volume of contractual cooperation with companies amounted to CZK 1 million.

Also in 2020, the Department participated in activities aimed at bringing scientific topics closer to the general public.

**FIg. 11.** Photo from the Department of Engineering of Electrochemical Process

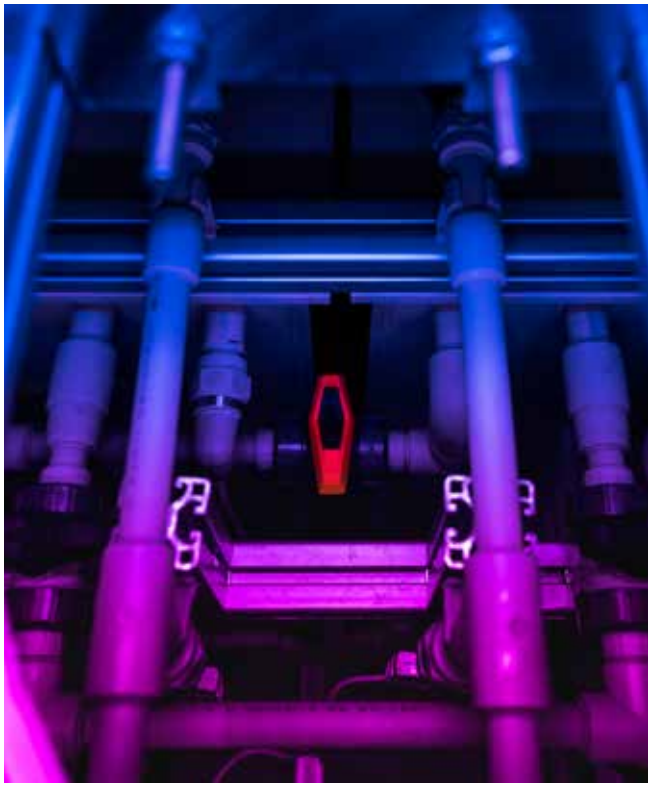


**Fig. 12** Photo from the Department of Chemical Processes and Biomaterials

# CHEMICAL PROCESSES AND BIOMATERIALS (CPB)

At the beginning of 2020, the Department of Engineering of Special Materials (ISM) was renamed the Department of Chemical Processes and Biomaterials (CPB), which accentuated the professional focus of the group in the area of materials chemistry.
The expert group focused on the development and testing of a fuel cell and assembled its experimental set-up, including software performance control for remote connection. In parallel with this activity, the Department cooperated with Unipetrol, ČEZ, ÚJV Řež and VŠCHT and edited the project application concerning the: **"Production and Distribution of Hydrogen for Long-Term Sustainable Mobility Using Electricity from Renewable Sources"**. As part of this cooperation, a unique output was published in the foreign scientific journal *Catalyst Reviews – Science and Engineering* (IF=11.38, AIS=1.86). The group actively participated in the newly formed international consortium established by Prof. A. Sechter: *Joint Research & Development Centre for Renewable Energy (RDCRE)*. The level of incorporation was supported by a new topic investigated in CPB laboratories, specifically the synthesis and characterization of new catalytic materials for advanced fuel cell membranes.
The expert group *Biomaterials* continues its successful cooperation with UKR Regensburg and publishes its research results in the journals *Applied Surface Science* (IF=6.18, AIS=0.77) and *RSC Advances* (IF=3.11, AIS=0.51). In the last year of the project **"MATEGRA"**, the expert group confirmed the successful growth of bone cells on the surface of laser-textured and chemically modified titanium surfaces (Fig. 13a). The project was focused on the chemical activation of titanium surfaces with the aim to improve surface properties and achieve a higher degree of osseointegration of titanium implants (see Fig. 13b). The research results will be published in scientific impacted journals. As part of the project, the group focuses on the synthesis and characterization of porous structures on the basis of bioactive glass prepared by the hydrolysis of silicon-phosphorous sol-gel systems (Fig. 13c).
The research activities in the area of nanocomposite hydrogels demonstrated significant progress. The research was focused on the improvement of the dimensional stability of triple-meshed hydrogels based on Agarose-PVA-PAM (Fig. 13d). The group continued its research activities focused on the characterization of viscoelastic properties using DMA and the determination of conductivity of polymer composites with respect to bound/free water content. In cooperation with JAR, the group filed an international project focused on the development of injection hydrogels for biomedical applications. Moreover, the topic of hydrogel modification using bioactive micro-particles was developed. The result of the research work was a unique publication in the journal *Coordination Chemistry Reviews* (IF=15.36, AIS=2.97) and the study of the incorporation of 2D materials, the so-called Mxenes, into a matrix of biopolymeric hydrogels.

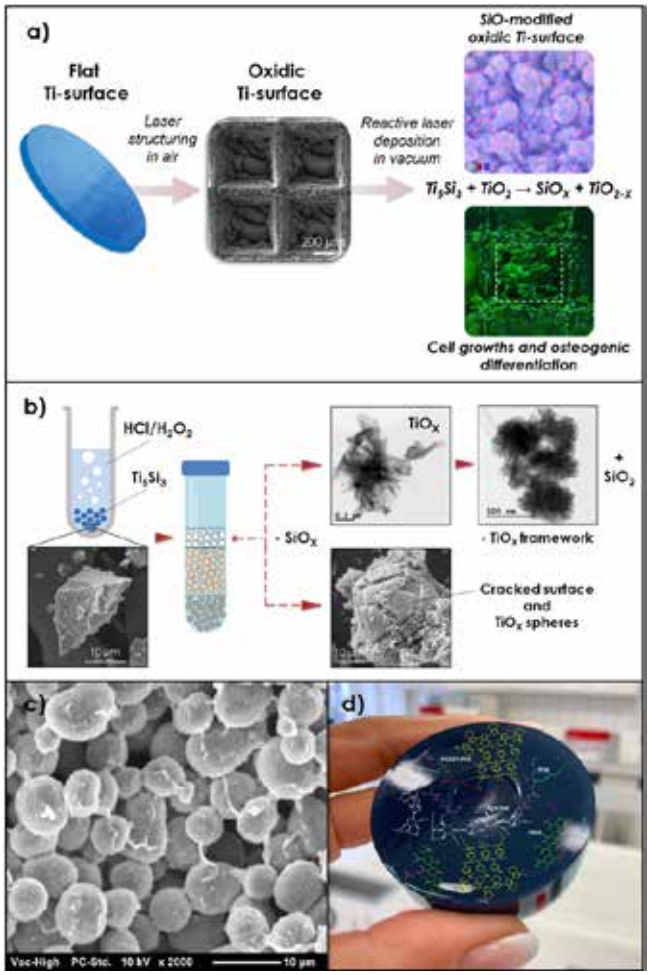



**Fig. 13.** Laser texturing of titanium surfaces (a); Chemical modification of the Ti5Si3 surface (b); Surface morphology of the porous silica-phosphorous bioglass (c); Triple-mashed dimensionally stable hydrogel (d).

# INFRARED TECHNOLOGIES (IR, TTP)

The outbreak of the COVID-19 epidemic was a challenge for the researchers from the Department of Infrared Technologies, as they searched for research topics and solutions with society-wide significance. In the spring, they engaged in the print of 3D face shields, worked on ozone sterilization and focused on the effective use of thermal imagers for temperature measurement. Health thermodiagnostics has become one of the key activities of 2020 and resulted in the project **„Security Research for the Effective Use of Thermal Imagers in the Event of Epidemic Threats and Crisis Situations" (BETERKA)**. Thanks to this project, the Department established close cooperation with the Faculty of Health Care Studies and the Techmania Science Centre.

Research activities in the area of optical properties, specifically *Washable thermographic paints*, won in category I at the world-leading level according to the Methodology M17+. The washable paint was evaluated for its patent-certified uniqueness, as well as for commercialization and promotion of the finished product. Thermal paints for accurate thermographic measurement are distributed around the world under the brand LabIR® and are used in a wide range of areas, from automotive, aviation, space applications, solar energy, electronics, construction, and engineering to medical technology.

Moreover, the Department developed a portable device for thermographic detection of internal material defects, which can detect corrosion damage or changes in pipe thickness. The team led by Ing. Michael Švantner, Ph.D., actively cooperates with industrial partners and develops solutions for specific applications. In January 2020, the team focused on non-destructive testing to detect defects and damage to composite materials as part of a project supported by ESA/ESAC – the European Space Agency.

Doc. Ing. Jiří Martan, Ph.D., and his team measured the accumulation of heat during laser micromachining. They one of the few in the world who can measure temperature in the order of nanoseconds and microseconds using infrared radiometry, and they were the first to measure surface temperature during ultra-short pulsed laser micromachining.

In 2020, the IR Department celebrated the defence of the outstanding thesis written by Mgr. Denys Moskal, CSc., Ph.D., which significantly expanded the limits of laser texturing technology. The defence was followed by another academic success, as the head of the department Ing. Milan Honner, Ph.D. was appointed Professor.

The Infrared Technologies Department has been involved in educational activities. As an approved training centre of the *Association of Technical Diagnostics of the Czech Republic* in the field of thermodiagnostics it offers certification courses for *Thermography Diagnostic Technicians*. The participants are acquainted with thermographic measurement technology and its applications.

The team strives to popularize thermal measurement among pupils and students through the project **"LabIR Edu – Thermal Imaging in Schools"**. Researchers have used their more-than-twenty-years of experience and have developed affordable thermal imagers designed specifically for schools. Imagers are loaned to schools in the Czech Republic. Researchers organize workshops for teachers, explaining their use and creating educational materials. The International Society for Optics and Photonics Technology (SPIE) awarded the project a grant **"Education Outreach"** for the year 2020.

Throughout the summer, thermal imagers developed for the educational project Labiri Edu were seen in the context of an interactive exhibition *BLIK BLIK – Digital Playground*, prepared in the creative zone DEPO2015. A colleague and artistic creator MgA. Jan Jáchim designed an interactive audio-visual exhibition called *The Radiant Smile of a Girl with a Bouquet*. A unique union of science and art was another proof of the innovative interdisciplinary cooperation of the Department in 2020.

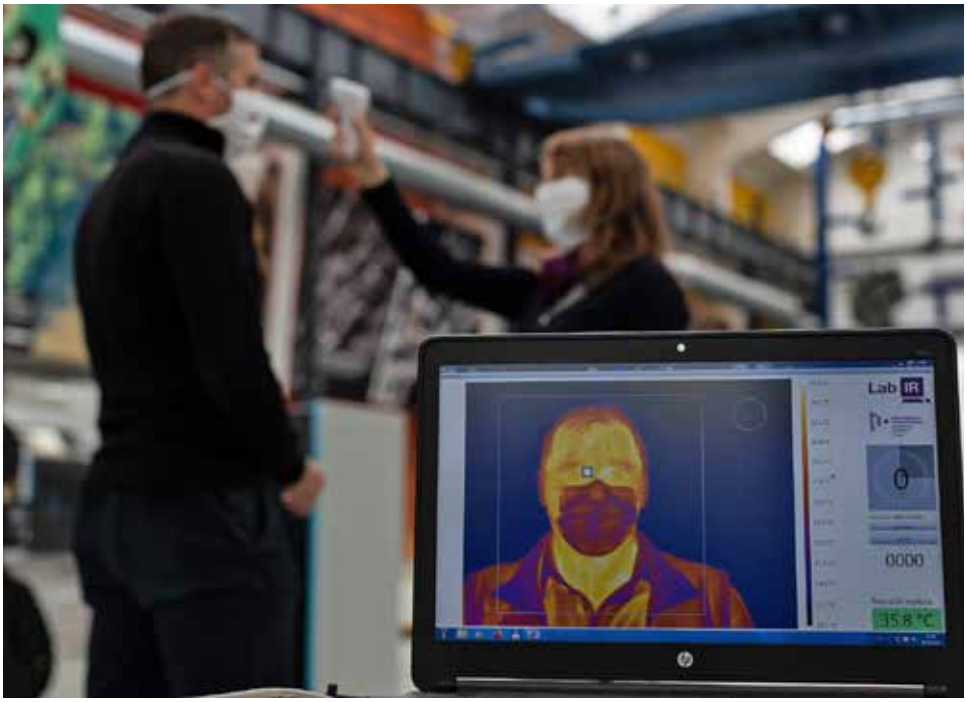



**Fig. 14 a)**
Medical Thermography

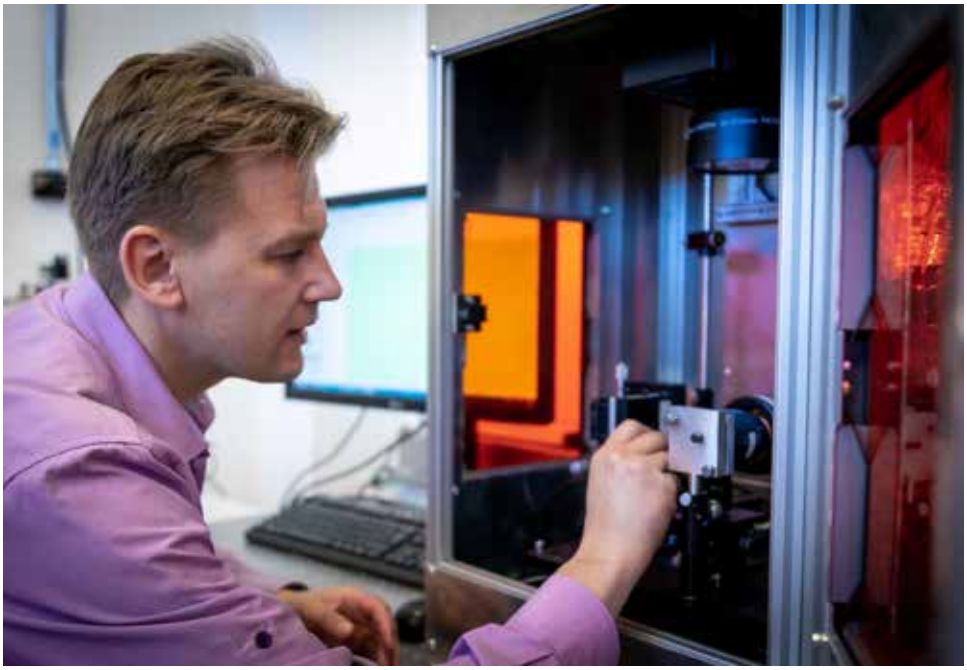


**Fig. 14 b)**
Mgr. Denys Moskal, CSc., Ph.D.

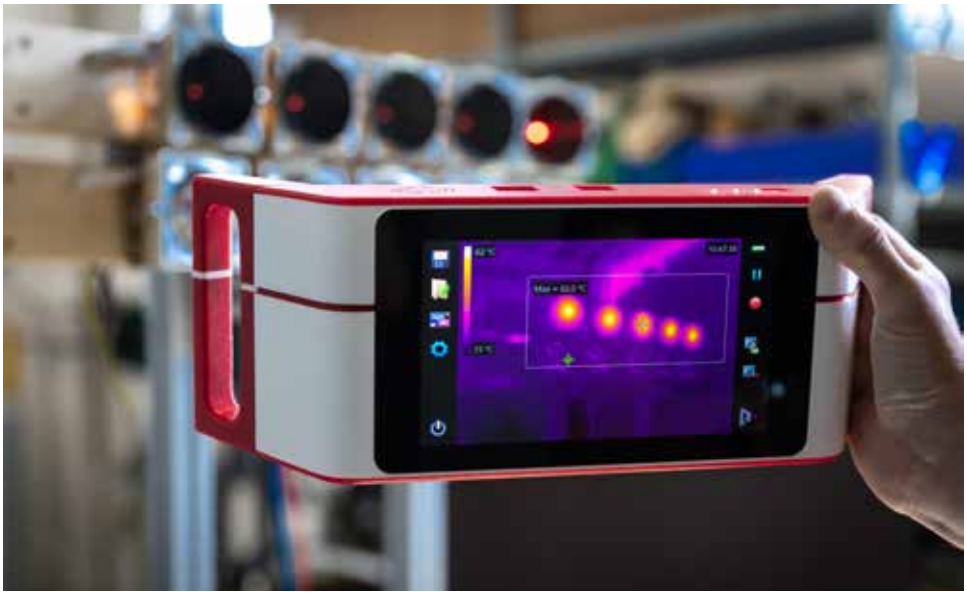


**Fig. 14 c)**
Camera from the project
LabIR Edu

# INTERNATIONAL COOPERATION

In the framework of international cooperation and expansion of activities in the European and global research area, Doc. Ing. Ludek Hynčík, Ph.D., represented the University as the Vice President of Education of the International Federation of Automotive Engineering FISITA – *Fédération Internationale des Sociétés des Techniques de dÍngénieurs l'Automobile*. Moreover, he was a visiting professor at the Chinese *Tianjin University of Science and Technology*. Doc. Ing. Jiří Martan, Ph.D., has been an active member of the European Technology Platform Photonics21 since 2017. Ing. Šárka Houdková Šimůnková, Ph.D., continues as the Vice President of the *European Thermal Spray Association (ETSA)*. Ing. Michal Švantner, Ph.D., is a member of the working group of the *European Committee for Standardization* CEN/TC 138/WG 11 Thermographic testing. Prof. Dr. Jan Minár has been an associate member of *The Centre for NanoScience Munich (CeNS)* since 2015. Mgr. Petr Kavalíř, Ph.D., MBA, represents the NTC in the expert team for Innovation and Technology – *The Business and Industry Advisory Committee to the OECD*.

Regarding workshops, seminars and conferences, most of them were cancelled, held in the online environment, or rescheduled to the future. However, the pandemic did not prevent the NTC to expand international cooperation. NTC researchers and experts on fuel cells from the *Ariel University in Israel* opened in September 2020 a joint *Research and Development Centre for Renewable Energy*. The seat of the Centre, which is led by Prof. Alex Schechter from the Ariel University, is at the NTC in Pilsen. Research activities focus not only on advanced materials and breakthrough fuel cell technology but also on research of energy storage and flow batteries. A research group led by Dr. Alexander Axelevitch of the *Holon Institute of Technology, Israel*, in cooperation with the NTC team focused on advanced materials, filed a joint patent related to increasing the efficiency of solar panels to the *Intellectual Property Office in the UK*. Promising cooperation with Israel was supported by the membership of the NTC in the *Czech-Israeli Chamber of Commerce (ČISOK)* and by the visit of the President of ČISOK, Pavel Smutný, and the Ambassador of Israel, Daniel Meron, to the NTC.

A research group led by Doc. Luďek Hynčík entered into an agreement on promoting cooperation with the research group of Prof. Adam Wittek from the *Faculty of Engineering and Mathematical Science (FEMS) of the University of Western Australia (UWA)*. The agreement concerns the application of computational biomechanics to reduce the risk of injury during childbirth. The content of the agreement was a declaration of mutual cooperation, exchange of experts and grant applications in the field of computational biomechanics.

At the end of November, *CY Cergy Paris Université* held a meeting on the establishment of a joint laboratory for research in advanced materials and possible further synergies, especially concerning the exchange of students between universities.

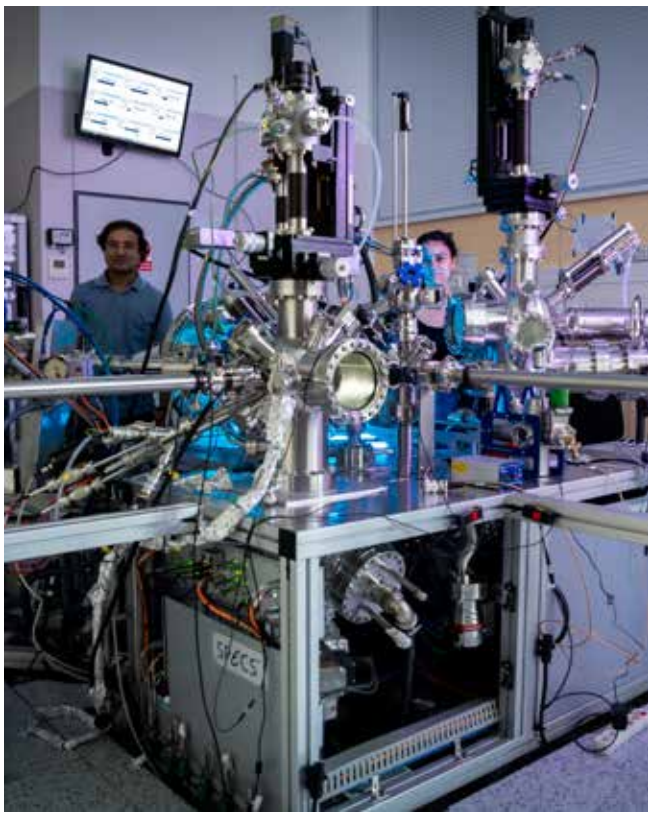


**Fig. 15.** The international team of the Department of Research of Advanced Materials.

# EDUCATION AND SCIENCE POPULARIZATION

Although the NTC does not have its own accreditation for study programmes, it has been dedicated to long-term education and the popularization of science. In 2020, NTC employees guaranteed expert courses at the Faculty of Applied Science, Faculty of Mechanical Engineering and the Faculty of Education, they participated in teaching full-time and distance courses and guided students during projects for their bachelor's, master's and doctoral theses. The NTC supported the mobility programmes of foreign students, even though the cooperation was influenced by the complicated situation related to the COVID-19 pandemic. By involving students in non-technical areas, the NTC strived for an interdisciplinary approach.

Planned events aimed at the promotion of study programmes focused on technical disciplines and scientific popularization events were strongly affected by the COVID measures and were, therefore, held in an online environment. In September, we participated in the event Science and Technology Days, which took place in the centre of Pilsen. The NTC introduced a biomechanical model of the human body and thermal imagers designed especially for schoolchildren. The event Researchers' Night was held online. Vít Nováček from the HBM team explained the fundamental workings of biomechanical models.

The Techmania Science Centre was closed during both pandemic waves. When, after the first wave, the Centre reopened, the NTC installed a thermal imager at the entrance to guarantee greater safety for visitors. A popularization campaign for the promotion of thermal imaging was planned to celebrate the 12th birthday of the Centre, but plans were thwarted by the second wave of the pandemic and so the Infrared Technologies team prepared a short video as part of the online celebration.

The project titled *Thermal Imaging for Schools*, which raises students' awareness of thermal imaging and its application, also continued. In the summer, when the measures were not so strict, researchers with thermal imagers participated in suburban summer camps for children. Thanks to the resources obtained from the *Education Outreach Grant* from the company SPIE, it was possible to support training for teachers on the use of thermal imagers in their classes. Thermal imagers from the NTC have become part of the art exhibition held at the Pilsen Depo 2015 in the framework of the successful event BLIK BLIK.

Already in previous years, the NTC had started training employees of industrial companies in the field of thermomechanics of technological processes and prepared the interested employees for the position of thermography diagnostic technician. In cooperation with the Faculty of Health Care Studies, the NTC organised a workshop for the public titled *A Course of Health Thermodiagnostics for Beginners*. The course was accredited by the Board for Distance and Lifelong Learning. Participants learned to use thermal imagers and protective equipment to protect themselves and the environment from the potentially infected.

The NTC used printed materials, online media, radio, as well its LinkedIn and Twitter accounts to promote its scientific outputs.

**Fig. 16.** Photo from the Department of Biomechanical Human Body Models.

The balanced economy of the NTC was ensured mainly from revenues from subsidy projects of basic and applied research from providers, such as the Ministry of Education, Youth and Sports, the Ministry of Regional Development, the Czech Science Foundation, the Technology Agency of the Czech Republic and UWB in the amount of CZK 67,054,151 and revenues from subsidy funds of the Ministry of Education, Youth and Sports in total amount 63,951,798. Institutional funding was covered by the contribution to the creative and educational activities in the amount CZK 11,294,024 and by the grant for the support of research activities in the amount of CZK 52,657,774. The NTC transferred CZK 1.12 million from the year 2019 to the Fund for earmarked financial resources.

From institutional funds CZK 7,766,000 was used to purchase new machines and devices.

Despite unfavourable conditions caused by the pandemic, the NTC managed to gain new orders in the area of contractual research and the transfer of knowledge in the amount of CZK 9,868,634.

The NTC received financial donations for the support of its research activities amounting to CZK 693,120.

The NTC transferred CZK 3.7 million to the fund of capital assets. The operating fund was increased by CZK 1,730,000 and CZK 2,095,000 was transferred to the Fund for earmarked financial resources at the end of the year.

| GRAPH OF INCOME IN THOUSANDS CZK | |
|---|---|
| Grant programs | 67,054.151 |
| Institutional funds | 52,657.774 |
| Creative and educational activities | 11,294.024 |
| Contract research | 9,868.634 |
| Targeted support fund | 1,120.000 |
| Other income | 693.120 |

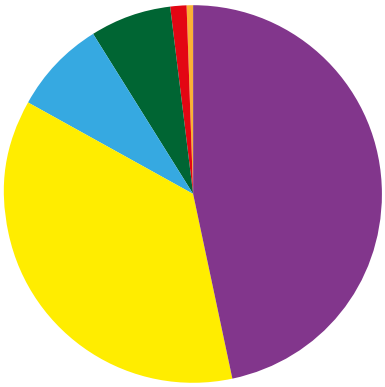


**Fig. 17.** NTC income in thous.CZK

In 2020, the NTC successfully completed a number of projects and contract research orders. The new and ongoing projects are carried out as planned.
In 2021, it will be necessary, also due to the completion of the project CENTEM+, to strengthen competitiveness and to engage in Czech and especially foreign projects, either separately or by participation in consortia. Specifically, we should develop cooperation with the Karlovy Vary region. Moreover, it will also be necessary to focus on contractual research, as well as on commercialization of results through start-ups, spin-offs or other means. As in previous years, in 2021 the key to success will be the fulfilment of important monitoring indicators and the subsequent acquisition of funds for the financing of all projects and further development of NTC.
To maintain competitiveness, it is important to engage foreign experts in research activities, and, of course, to cooperate with relevant international organisations. It will be very important to focus on human resource development.
Based on the analysis of future research and global trends, the NTC team will continue to focus primarily on research and solutions for green technologies and advanced materials in the areas of green energy sources, smart vehicles and the quality of human life and health.