Questionnaire
Summary of the main activities of a research institute of the Slovak Academy of Sciences

Period: January 1, 2016 - December 31, 2021

1. Basic information on the institute:

1.1. Legal name and address

Institute of Physics of Slovak Academy of Sciences
Dúbravská cesta 9, 845 11 Bratislava
Slovakia

1.2. URL of the institute web site

https://fu.sav.sk/

1.3. Executive body of the institute and its composition

Directoriat	Name	Year of birth	Years in the position, from - to
Director	Mário Ziman	1977	okt/2019 -
	Stanislav Hlaváč	1947	may/2011 - sept/2019
Deputy director	Andrej Gendiar	1973	okt/2019 -
	Peter Švec	1955	may/2011 - sept/2019
Scientific secretary	Erik Bartoš	1976	mar/2014 -

1.4. Head of the Scientific Board – Štefan Gmuca

1.4.1 Composition of the International Advisory Board

prof. Dr. Jaroslav Fabian (University Regensburg, Germany)
prof. Dr. Jürgen Eckert (University of Leoben, Austria)
prof. dr hab. Robert Kamiński (Inst. of Nuclear Physics, Cracow, Poland)

1.5. Basic information on the research personnel

1.5.1 Fulltime equivalent work capacity of all employees (FTE all), FTE of employees with university degrees engaged in research projects (FTE researchers)

2016		2017		2018		2019		2020		2021		2016-2021	
FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	FTE all	FTE researchers	average FTE all per year	average FTE researchers per year
81.60	62.92	85.18	65.92	82.27	64.44	76.36	59.01	77.71	62.20	77.73	60.52	**80.14**	**62.50**

1.6. Basic information on the funding of the institute

1.6.1. Institutional salary budget, other salary budget[1], non-salary budget[2]

Salary budget	2016	2017	2018	2019	2020	2021	average
Institutional salary budget *[EUR]*	1,338,718	1,571,639	1,665,603	1,768,527	1,994,183	1,933,778	**1,712,075**
Other salary budget *[EUR]*	455,093	366,005	385,692	257,395	248,271	266,709	**329,861**
Total salary budget *[EUR]*	1,793,811	1,937,644	2,051,295	2,025,922	2,242,453	2,200,487	**2,041,935**
Non-salary budget *[EUR]*	1,321,758	1,197,165	1,375,046	1,333,084	1,038,228	1,576,081	**1,306,894**

1.7. Mission Statement of the Institute as presented in the Foundation Charter indicating the years when it was adopted and revised

The Foundation Charter valid during the period (thus before the transformation since 2022) was revised in July 2018 (unsuccessful transformation), however, its legality is a question for curious experts. Nevertheless, the main missions of the institute are so far robust with respect to legal changes and include

- **research and development** in areas of **physics and engineering**
- **management of research infrastructure**
- **training and education** of students in areas of physics and physical engineering
- create **research partnerships** with academic and industry sector
- **dissemination and exploitation of research** results from the area of physics and physical engineering

1.8. Summary of R&D activity pursued by the institute during the evaluation period in both national and international contexts. Describe the scientific importance and societal impact of each important result/discovery. Explain on general level – the information should be understandable for a non-specialist (recommended 5 pages, max. 10 pages for larger institutes with more than 50 average FTE researchers per year as per Table 1.5.1.)

The research at the Institute of Physics of Slovak Academy of Sciences is primarily of a **foundational character**, thus, aiming to **deepen our understanding** of the physics of natural processes and **develop innovative** experimental and theoretical **methods and tools** applicable also beyond the basic research. In particular, our research interests are addressing the global challenges of **innovative materials, energy** and **security**. During the period 2016-2021 we published altogether more than 600 research papers, approximately 50 of them in the high-profile highly impacted journals. We contributed mainly to the following research areas

- theoretical and computational material physics
- metal physics
- nanomaterials and nanostructures
- nuclear and particle physics
- quantum technologies

THEORETICAL AND COMPUTATIONAL MATERIAL PHYSICS

[1] Salary budget originating outside the regular budgetary resources of the organization, e.g. from the project funding.

[2] Includes Goods and Services and PhD fellowships

Although the physical principles shaping our world are understood in many details, it is typically required to discover new mathematical "tricks" in order to make direct predictions. Our researchers are exploiting both **analytical** (approximative and exact) and **computational methods** to describe **properties of materials and processes**, thus, providing us with the origins of particular features and phenomena, but often also helping experimentalists to interpret the data. During the period 2016-2021 the most representative achievements include investigation of **microscopic models of colloidal systems** and ***ab initio* simulations of atomic force microscopy**.

COLLOIDAL SYSTEMS

The **self-assembly** of colloidal systems opens the way to the synthesis of materials that considerably **widen the class of known natural crystals**, among which are opals or butterfly wings. From an academic perspective, these new, complex structures allow for detailed and original studies of fundamental processes like nucleation, glass transition, or low-dimensional statistical physics. Skillfully combined with progress in particle synthesis, self-assembly has led to a wealth of applications such as patterned magnetic systems or band gap materials used in displays, optical devices, photochemistry, and biological sensors.

When macromolecules (colloids) are placed into water their surfaces are revealing charged particles interacting through Coulomb forces. We investigated the **physics of the emergent electric bilayer** appearing in the neighbourhood of colloids and the **mutual interactions between colloids** due to presence of mobile particles, especially the anomalous attraction of equally charged colloids at low temperatures. Our research effort resulted in **exact solutions** for such systems independent of the temperature. Combining analytical calculations and computational techniques of evolutionary and Monte Carlo types, we reported a **remarkable structural variability** of **Wigner bilayer ground states**, when charges are confined between parallel charged plates [Antlanger et al, Phys. Rev. Lett. 117, 118002 (2016)]. In a **solvent like water** a pillar for the theoretical description of the structure of mobile ions in the vicinity of charged colloids, the so-called electric double layer, is provided by the **Poisson-Boltzmann theory**. We provided **exact analytical solutions** to this nonlinear mean-field approach [L. Šamaj, E. Trizac, Phys. Rev. E 100, 042611 (2019)]. While previously known solutions were for homogeneously charged objects, the cases we worked out exhibit a modulated surface charge on the macroion (wall) surface. When dealing with **colloidal particles suspended in a fluid**, we frequently face the problem of **sorting** them according to their physical properties, like density, size, shape, surface charge, or chirality. The sorting is then achieved by the interplay of hydrodynamic forces, diffusion, and external forces. We showed how the inertial hydrodynamic effects can be applied to form a **hydrodynamic ratchet** [F. Slanina, P. Kalinay, Phys. Rev. E 100, 032606 (2019)]. In this setting, colloidal suspension flows through a tube of periodically varying diameter.

AB INITIO SIMULATIONS FOR ATOMIC FORCE MICROSCOPY

The research team focused on computational material science led by I. Štich has achieved several key discoveries by **interpreting experimental data** with the help of **ab initio computational methods**. For example we investigated low-temperature **manipulations of Co atoms** by atomic force microscopy in ultrahigh vacuum on an oxidized copper surface. The combination of experiments with our simulations [Y. Kinoshita, R. Turanský, Nano Letters 16, 7490 (2016)] showed that **spin state is mechanically modified** and affected by lateral manipulations of neighbouring Co adatoms. The simulations also showed that Co atom can be trapped in Friedel "trap", which is of importance for future **spintronic applications**.

Noncontact **atomic force microscopy** (AFM) is an excellent tool not only for characterizing the atomic order on a surface but also for detecting the exchange, electrostatic, and chemical force interactions between the AFM tip and the sample surface. The **conventional AFM**, in which the force sensor oscillates perpendicular to the surface, reflects only the surface-normal component of the tip force and **ignores the surface-parallel components**. However, probing physical quantities on the nanoscale that have **directionality**, such as magnetic moments, electric dipoles, or the force response of a surface, **is essential** for characterizing functionalized materials for nanotechnological device applications. Currently, such physical quantities are usually experimentally obtained as scalars. To investigate the physical properties of a surface on the

nanoscale in depth, these properties must be measured as vectors. Combining the experimental data and DFT simulations [Y. Naitoh, R. Turanský, Nature Physics 13, 663 (2017)] we demonstrated the **first vector-force detection method**, based on **multi-frequency atomic force microscopy**. Access to the atomic-scale force distribution on the surface will enable better **understanding of nanoscale surface morphologies**, chemical composition and reactions, probing nanostructures via atomic or molecular manipulation, and provide **insights into the behaviour of nano-machines** on substrates

Structural superlubricity describes the state of **virtually frictionless** sliding if two atomically flat interfaces are incommensurate, that is, they share no common periodicity. Despite the exciting prospects of this **low friction phenomenon**, there are physical limitations to the existence of this state. Theory predicts that the contact size is one fundamental limit, where the critical size threshold mainly depends on the interplay between lateral contact compliance and interface interaction energies. We provided **experimental evidence** for this size threshold by measuring the sliding friction force of differently sized antimony particles on MoS_2. We discovered [D.Dietzel, J. Brndiar, et al, ACS Nano 11, 7642 (2017)] that superlubric sliding with the **characteristic linear decrease of shear stress** with contact size **prevails for small particles** with contact areas below 15 000 nm^2. **Larger particles**, however, show a transition toward **constant shear stress** behavior. In contrast, Sb particles on graphite show **superlubricity over the whole size range**. Our ***ab initio* simulations** revealed that the chemical interaction energies for Sb/MoS_2 are much stronger than for Sb/HOPG and can therefore **explain the different friction properties** as well as the critical size thresholds. These are radically new observations that significantly **question the existing model** of structural superlubricity.

METAL PHYSICS

The research team of the Department of Metal Physics let by P. Švec was successfully implementing several **H2020 European projects**, namely

- Hybrid Electric Energy Integrated Cluster concerning Renewable Fuels
- Valuable products from algae using new magnetic cultivation and extraction techniques, success story https://www.bbi.europa.eu/projects/valuemag

These projects have shaped the research objectives and resulted in internationally recognized research contributions. In summary, new knowledge and methods in the field of **preparation and unconventional processing** of selected systems of intermetallics, amorphous, nanocrystalline and complex metallic alloys have lead to general advances in knowledge and specifically also to **new materials** with exceptional properties suitable for applications in Industry 4.0 in the fields of hydrogen and acetylene **catalysis**, of magnetic materials for **energy** and of **sensors** and other applications in cutting-edge industrial technologies. The obtained results were transferred into **two patents** describing the preparation of unique double and multilayer **rapidly quenched metallic glasses** and the shaping of planar **rapidly quenched ribbons** into three-dimensional objects without loss of elasticity and amorphous state.

MANGANASE-BASED MAGNETIC MATERIALS

Permanent magnets are a crucial element in several **high-tech markets** such as energy and transport sectors, medical technologies and a broad range of electronic products. In addition, they play a very important role in efforts focused on an increased use of low carbon technologies to ensure a high living standard. However, Europe does not own the natural resources, which might result in a future bottleneck to the supply-chain. The European project NEXMAG (New Exchange-Coupled Manganese-Based Magnetic Materials) has focused on the **development of permanent magnetic properties** in Mn-based alloys. The whole project was selected as M.ERA.Net success story project *https://m-era.net/success-stories/new-exchange-coupled-manganese-based-magnetic-materials-nexmag).*

Within this project we have developed new systems of **rapidly quenched** magnetically soft materials without strategic elements with increased value of saturation magnetization and controllable shape of the hysteresis loop achieving ultralow coercivity. We have prepared **new alloys based on Mn(Al, Bi)**, which belong to the promising systems of permanent **magnets without rare earth elements**. We have developed and implemented new methods of

unconventional processing of amorphous and nanocrystalline materials, enabling control of magnetic and mechanical properties of developed materials, including their shape and thickness. We have made significant progress in the development and application of special heat treatment techniques in high magnetic fields for targeted modification of properties of new materials. In particular, isotropic nanocrystalline MnAl particles have been synthesized by gas-atomization with permanent magnet properties tailored through a rapid-milling method followed by annealing at reduced temperatures [J. Rial, P. Švec, et al. Acta Materialia 157, 42-52 (2018)]. **Unprecedented short milling times** of 90 and 270 s have been used in the milling process. The study has resulted in the possibility of **tuning magnetization and coercivity** by nanostructuring and phase transformation **in a controlled manner**. The metastable Al-Mn alloys were prepared in the form of metallic ribbons by planar flow casting and consequently used for elaboration of hard magnets [I.Janotová, Journal of Alloys and Compounds 707, 137-141 (2017)]. The formation and evolution of **crystalline phases** was shown by direct structure observation using **transmission electron microscopy** and by X-ray diffraction methods.

CATALYSIS WITH METAL SURFACES

Significant progress has been achieved in **understanding catalytic reactions on the surfaces** of nanoporous Au and intermetallics based on Pd and Cu, leading to the explanation of selective hydrogenation, dehydrogenation and oxidation in these structures. [M. Krajčí, J. Hafner, ChemCatChem 8, 34-48, (2016)]. We investigated the possibility of **quasi-periodic arrangements** in numerous systems based on Al-Pd-Cu and Al-Cu-Fe, the phenomena of stability and the causes of local disorder and new arrangements in Al-Si- (Fe, Co, Ni) systems, we identified new phases formed in these systems. We have made significant progress in atomically resolved structure analysis of the investigated systems and its interpretation. By exploiting this expertise we have **discovered a new ordering phenomenon** in amorphous remains of rapidly quenched Al-Ni/Co-REM system after primary crystallization.

NANOMATERIALS AND NANOSTRUCTURES

During the 2016-2021 accreditation period, research at the Department of Multilayers and Nanostructures (DMN) was focused on the **preparation of low-dimensional (LD) nanoscale materials** and their potential **applications in photovoltaics, gas sensors and theranostics.** Fundamental phenomena of low-dimensional materials, such as liquid-phase exfoliation, self-assembly, and related phenomena were explored. Simultaneously, new approaches to complex characterization of these materials, including in situ and in-operando studies were developed. The main research topics are addressed below.

LOW DIMENSIONAL MATERIALS

Low-dimensional materials exhibit unique properties not available in bulk materials. Our research was focused on the preparation and studies of metallic and metal oxide nanoparticles and 2D nanosheets like MoS_2 , graphene/graphene oxide and recently MXenes. The **liquid-phase exfoliation** (LPE) technique was refined to produce large amounts of 2D materials such as graphene, MoS_2, etc. with low size dispersion. The quality of the **synthesized nanoparticles and 2D nanosheets** prepared by LPE enabled us the preparation of their ordered mono- and few-layer assemblies on large areas at the liquid/air interface via a modified Langmuir Schaeffer technique. By adjusting the liquid subphase, even amphiphilic materials such as graphene oxide could be self-assembled on a large scale and transferred to a solid substrate. Such assemblies allowed us to study individual nanoparticle/nanosheet properties as well as their collective behavior. The assemblies of **metal oxide nanoparticles** transferred to a solid substrate exhibited **excellent sensing properties** and we demonstrated they can be employed in simple and cheap gas **sensors in healthcare** or public safety applications. The detection of acetone in exhaled air (diabetes detection) [Capone, S. et al., Sensors Actuators, B Chem. 243, (2017)] or NO_2 detection in public places (NO_2 gas is a **marker of explosives**) are two examples. The individual 2D nanosheets of reduced graphene oxide and MoS_2 were functionalized with specific biomolecules for **targeted treatment of cancer cells** in human body. This strategy of active targeting allows an effective nanotherapeutic approach while ensuring the integrity of the surrounding healthy tissue. We started this research during the accreditation period in collaboration with Biomedical Center SAS. The **interaction between the functionalized 2D nanoplatform and living cell** was studied at cellular level by label-free imaging via Raman confocal microscopy [Eliášová Sohová, M. et al.,

Analyst 143, 3686–3692 (2018)]. The internalization of the nanoplatform in cancer cells was found, which proves the viability of this approach.

SOLAR CELLS

Environment-friendly source of electric energy is one of the main challenge of our society. At the institute we are actively involved in the development of solar cells based on **perovskite materials** that have been on the rise over the past decade, breaking the records of silicon technology by offering much lower prices [Huang, F., et al. Energy Environ. Sci. 12, 518–549 (2019)]. At present, this technology has emerged as one of the most promising technologies of the future in the area of **sustainable energy**. The perovskite materials have the potential to revolutionize the solar industry by greatly increasing efficiency and reducing the cost of manufacturing solar panels. Our research has focused on a gradual **improvement of the power conversion efficiency** (PCE) of perovskite solar cells by using low-dimensional materials such as **carbon nanodots**, MXenes, etc. Within international collaboration, we have **increased the PCE and stability** of the perovskite solar cell with embedded carbon nanodots in a particular layer [Subair, R. et al., Sol. Energy 189, (2019)]. No less important was the study of the **effects of chemical additives** on the growth of 3D and 2D perovskite films and the use of this knowledge for the production of high-efficiency solar cells [Wang, M. et al. J. Mater. Chem. A 6, 15386–15394 (2018), Huang, F. et al. Chem. Eng. J. 394, (2020)]. Finally, we have significantly contributed to the **real-time observation of perovskite film formation** using in-situ X-ray scattering and photoluminescence. In this way, we have revealed the **role of grain boundaries** in the non-radiative recombination of photogenerated charge carriers in perovskite films. These studies enabled us to determine the most effective strategies for **reducing the defect densities** to increase the PCE in organic-based photovoltaic applications in general.

ENERGY-RESOLVED SPECTROSCOPY

Advanced analysis and measurement of density of states (DOS) are critical for developing new photoactive materials for future solar cells. In our research group, we have **developed a new method** to quantify DOS within the highest occupied and the lowest unoccupied molecular orbitals (HOMO-LUMO) including defect states. The technique, termed the **energy-resolved electrochemical impedance spectroscopy (ER-EIS)**, can determine the DOS within HOMO and LUMO in a highly dynamic range comparable to a vacuum-based tandem of photoelectron spectroscopy (PES) and inverse photoemission spectroscopy (IPES). In particular, we extensively studied the effects of changes in the **electronic structure of organic semiconductors** on charge transport [Athanasopoulos, S. et al. Adv. Energy Mater. 9, 1900814 (2019), Karki, A. et al., Adv. Energy Mater. 2001203 (2020) doi:10.1002/aenm.202001203]. The main goal of the developed ER-EIS analysis is to **trace the origin of the differences in device photophysics**, in particular, the subtle differences in energetics and morphology of photoactive materials and to improve device performance based on this knowledge.

INNOVATIVE X-RAY OPTICS

Recent advances in high-brilliance laboratory X-ray sources based on micro-focused electron beams and diamond-based or liquid metal jet-based anodes have stimulated the development of dedicated X-ray optics for **high-resolution and high-flux applications**. We have made two important advances in this field. We developed procedures based on **massive parallel computing**, which enabled us to **design tailored channel-cut Germanium monochromators** providing the highest performance for a given microfocus X-ray source [Nádaždy, P. et al. J. Appl. Crystallogr. 52, 498–506 (2019), Nadazdy, P. et al., J. Appl. Crystallogr. 54, 730–738 (2021)]. Their combination with the built-in reflective optics in the present microfocus X-ray sources represents a **new type of the reflective-diffractive optics** for the next generation of laboratory X-ray sources. This design was **patented as a utility model** in 2021 and was evaluated as the most representative result of the Institute in applied research.

For the fabrication of the designed monochromators, we **developed technology of deterministic nanomachining based on single-point diamond turning** (SPDT) [Jergel, M. et al. Int. J. Adv. Manuf. Technology 96, 3603-3617 (2018)] in collaboration with a **SME partner** - Integra TDS Ltd., which specializes in customized production of innovative X-ray optics. The first prototype of the tailored Ge monochromator fabricated in this company according to our design has been recently **installed in the X-ray laboratory of Tel Aviv University**. We have developed a **new approach to fabricating scatter-free pinholes** for X-ray applications based on single-crystal Ge.

Laser drilling combined with anisotropic etching led to the development of a facile technology to fabricate scatter-free pinholes in a high-throughput process. Our X-ray solutions have been sold to academic partners as well as to commercial global X-ray companies such as Rigaku Ltd.

NUCLEAR AND PARTICLE PHYSICS

The profile research program in nuclear physics is addressing the questions on **the shape of atomic nuclei**, especially, during the period 2016-2021 the research team of the Department of Nuclear Physics at the Institute of Physics became widely recognised by its investigation of **neutron-deficient odd-Au isotopes**. The group leader Dr. Venhart is acting as spokesperson of the associated international collaborations performing experiments at the Accelerator laboratory of the University of Jyväskylä (JYFL) in Finland and CERN in Switzerland. This research program has **attracted students** and resulted in 3 PhD, 5 master, 5 bachelor theses and internships of foreign students (Belgium (1), Spain (1), UK (1), Brazil (1), France (8)) at the Institute of Physics. In 2018, the group and its program underwent **evaluation by the RECFA** (Restricted European Committee for Future Accelerators), which stated high quality of the research. The spectra acquired with the originally designed **TATRA spectrometer** appear in the "Nuclear Data: A Primer" textbook as an example of an innovative approach in the gamma-ray spectroscopy. Series of biennial international ISTROS conferences was established in Slovakia and approximately 50 science-to-public activities were done within the framework of the above program. The research outcomes resulted in **V4 Academies Young Researcher Award** for A. Herzáň (2019) and **Prize of Slovak Academy of Sciences for Development of research infrastructure** for the research team (2021).

ATOMIC NUCLEUS

The **complexities of the atomic nucleus** as a many-body system arise from the interplay between single-particle and collective degrees of freedom. This is particularly apparent in heavy nuclei near closed shells where near degenerate spherical and deformed intrinsic configurations can coexist at low-excitation energies. This **shape coexistence** arises from the opposing tendencies of shell structure and residual interactions that promote sphericity and deformation, respectively, and is especially sensitive to the arrangement of nucleons at the Fermi surface. Based on the $1h_{11/2}$ proton-hole configuration in an extremely neutron-deficient ^{177}Au isotope we **discover of strongly-coupled rotational band** that has no presence in heavier odd-Au isotopes and indicates a major structural change in underlying configuration. Such a change is unexpected and cannot be explained by any existing nuclear structure theory. [M. Venhart et al., Phys. Rev. C **95**, 061302(R) (2017).] In a different experiment **we discover a strong mixing between weakly and strongly-deformed configurations** in ^{177}Au [M. Venhart et al., Phys. Lett. B **806**, 135488 (2020).]. In general, mixing in heavier odd-Au isotopes is weak. Observed decay pattern suggests a major structural change in extremely neutron-deficient isotopes. Both experiments were performed at **JYFL, Finland**.

The research team has developed and built at the Institute of Physics a unique **spectrometer TATRA** that has been transferred and used in studies of ^{181,183}Au performed at **CERN-ISOLDE facility**. Due to excellent energy resolution of this spectrometer both for gamma rays and conversion electrons, extensive level schemes could be established. They not only extended the existing systematics, established in heavier isotopes, but also **revealed previously unknown structures**. Study has clearly demonstrated the power of the novel Broad-Energy Germanium detector (BEGe). It was clearly shown that it was insufficient resolution of detectors that caused serious failures of research groups in the past. [M. Venhart et al., J. Phys. G: Nucl. and Part. Phys. **44**, 074003 (2017), and M. Sedlák et al., Eur. Phys. J. A **56**, 161 (2020).]

Apart of experimental activities in this area we also developed **new Skyrme QRPA computer codes** for calculation of excited states and giant resonances in atomic nuclei, both spherical and axially deformed [A. Repko et al., Phys. Rev. C 99, 044307 (2019).]. In collaboration with Prague and Dubna, we revealed a special vortical excitation mode in ^{24}Mg [V. O. Nesterenko et al., Phys. Rev. Lett. 120, 182501 (2018).], and proposed certain experimental signatures for its verification. In particular, the programs were enhanced with the calculation of effective currents and electron-scattering form factors [V. O. Nesterenko et al., Phys. Rev. C 100, 064302 (2019).]. A

large part of published results dealt with **toroidal/vortical modes of nuclear excitations**, which constitute an important subject of study, with aim to better understand the properties of nuclear matter, including an outreach to astrophysics. Developed codes are at state-of-the-art level, since only a few research groups worldwide are able to employ QRPA for calculations in deformed nuclei.

POSITRON ANNIHILATION APPLICATIONS

The study of **cryoprotective mixtures** and their physical properties is of great practical importance for medicine and biology. Our laboratory of positron annihilation has contributed in an unconventional way to the knowledge of several properties of model cryoprotectants through **measurements of free-volume by positronium probes** [K. Čechová et al., RSC Advances **9**, 34299-34310 (2019)]. The second area of research in our positron annihilation group was confined systems. An example of a possible use of the investigated confined systems are composites based on standard inorganic SiO_2 matrices, such as silica gels with MnO_2 entrapment. Such a composite makes it possible to separate and determine the amount of radium ^{226}Ra in water samples. The proposed method of determining this one of the most toxic alpha-emitters in the environment could be a very cheap alternative to the extraction of ^{226}Ra by chromatographic methods that use expensive resins.

STRUCTURE OF NON-ELEMENTARY PARTICLES

Researchers from the Department of Theoretical Physics developed a **unitary and analytical model of electromagnetic structure of hadrons** to make theoretical **predictions for form factors** characterising the scattering of elementary particles. For example, utilising the analytical properties of the **scalar and isovector form factors** of charged pions together with the most accurate data on the S and P wave of **pion-pion elastic scattering**, obtained from imperfect experimental data by the Spanish group Garcia-Martin-Kamiński-Peláez-Yndurain from Madrid, a fully solvable mathematical scheme was developed, providing for the first time a completely model-independent method for determining the mass and total decay widths of f0(500) and rho0(770) resonances [Dubnička et al., Phys. Rev. D 94, 054036 (2016)].

INTERNATIONAL PARTICLE PHYSICS FACILITIES

Our collaboration with big nuclear facilities included **CERN in Geneva**, **JINR in Dubna** and **GSI in Darmstadt**, although it was of relatively narrow nature regarding the number of involved researchers. We are not participating in any of the big CERN collaborations and our connection there is purely through small focused experiments independent of these collaborations as described before. Two of our researchers are involved in **HADES collaboration at GSI**. Within this collaboration the physics generated out of relativistic collisions of gold atoms is investigated. For example, one of the key results obtained within this collaboration was the observation of **virtual photon emission from baryon-rich QCD matter** [HADES collaboration, Nature Physics 15, 1040-1045 (2019)]. Emerging **electron–positron pairs** from the decay of virtual photons **provide information about the properties of QCD matter** at various stages including the one the universe was filled about 10 μs after the Big Bang. Its bulk properties were shown to be similar to the **dense matter formed in the final state of a neutron star merger**. The Department of Theoretical Physics in collaboration with **JINR in Dubna** analysed **weak decays of heavy mesons** [e.g., Dubnička et al., Phys. Rev. D 96, 076017 (2017)] **and tetraquarks**. This very interesting and active field of research is considered to have the potential for manifestation of **new physics phenomena** and was investigated using the so-called **covariant quark model**. The research helped to understand the nature of the studied particles and indicated that, for given processes, no new physics explanation is needed.

QUANTUM TECHNOLOGIES

The use of quantum phenomena of randomness, uncertainty and nonlocality of individual quantum systems has the potential to dramatically change all aspects of modern technologies. This area

has attracted attention in the last decades of the previous century, when it was shown that quantum computers can **compromise security** of current communication protocols, but quantum bits also provide **unconditionally secure solutions** enabling the distribution of quantum keys, thus, realization of mathematically secure symmetric cryptosystems. Researchers at the Research Center for Quantum Information have achieved internationally recognized results and also contributed actively to the establishment of the **European Quantum Flagship** launched in October 2018 (kick-off in Vienna) and resulted from previous coordination action projects coordinated from Bratislava. Prof. Bužek is member of the **strategic advisory board** of Quantum Flagship*. During the period 2016-2021 **internationalized the research team** - approximately 41% of total FTE of researchers (including PhD students) with Slovak origin and remaining FTE was composed by researchers from 8 different countries (India, Iran, United Kingdom, Brasil, Finland, Mexico, France, Czech). The most important results are described below.

*(https://qt.eu/about-quantum-flagship/introduction-to-the-quantum-flagship/sab-strategic-advisory-board/)

QUANTUM DYNAMICS AND INCOMPATIBILITY

Regarding the basic research in the area of quantum information theory (theoretical framework for quantum technologies) we focused on investigations of structural properties and **limitations of quantum dynamics** and investigation of **phenomena of incompatibility** [Heinosaari et al., J. Phys. A 49, 123001 (2016)]. Using the mathematical language of **higher-order quantum structures** we identified qualitative differences between **incompatibility of observables** of quantum processes and observables of quantum systems [Sedlák et al., Phys. Rev. A 93, 052323 (2016)]. This motivated [Plávala M., Ziman M. Phys. Lett. A 384, 126323 (2019)] the discovery of physical **realization of Popescu-Rohrlich box** - gedanken device from theories extending quantum physics exhibiting algebraically **strongest possible Einstein-Podoloski-Rosen correlations**, thus, maximizing the phenomena of nonlocality and providing further advantages for information processing. Let us stress that this realization exhibits **subsystems nonlocality**, however, the nature of quantum processes and the short range nature of existing interactions does not allow for truly spatial nonlocality.

The most important result exploiting the framework of higher-order structures is addressing the limitations on **quantum learning** [Sedlák et al, Phys. Rev. Lett. 122, 170502 (2019)], i.e. the task of storing an unknown quantum process in the state of quantum memory and later exploiting a programmable quantum processor to retrieve its action. After deriving new results in algebraic combinatorics we were able to design an **optimal storing and retrieving device** maximizing the success probability of retrieval of one use of the process out of N uses of the device in the storing (training) phase. This device has several applications in processing of quantum processes and motivated further studies. It is closely related to **probabilistic perfect alignment** of reference frames and **probabilistic port-based teleportation**. The derived size of the memory system exponentially **improves the known upper bound** on the size of the program register needed for probabilistic programmable quantum processors.

When speaking of **quantum processes** we may consider two different situations: discrete state transformations described by **quantum channels**, or continuous time evolution associated with **quantum dynamical maps**. Our research in this area was focused on the **mutual divisibility relations** of these two concepts [D. Davalos, M. Ziman, et al. Quantum 3, 144 (2019)] and their simulations by means of **simple collision models** [S.N.Filippov et al., Phys. Rev. A 96, 032111 (2017)]. Divisibility is related to the question how a given quantum process can be composed of other quantum processes. Surprisingly, there are channels that are indivisible. In particular, we used various divisibility classes for quantum dynamical maps to introduce an analogous concept for quantum channels through their simulability by means of dynamical maps. This provides **new characterisation of quantum dynamical maps** being a one-parametric subset (“trajectory”) inside the set of quantum channels. These dynamical trajectories are undergoing **divisibility transitions between different divisibility classes of channels**. For example, the implementation of indivisible quantum channels necessarily requires to pass all such transitions.

QUANTUM MEASUREMENTS

Following the main paradigm of next generation quantum technologies the new impetus in **quantum thermodynamics** aims to understand how quantum phenomena of individual quantum systems affect the behavior of quantum thermodynamical (manybody) systems and processes. Our interest was in the exploitation of the framework of quantum measurement theory (including higher-order quantum structures) in the **analysis of thermodynamical measurements**. In particular, we investigated how the conservation laws affect the measurements of thermal properties, but also open questions related to incompatibility of thermal measurements. For example, **thermodynamic uncertainty relations** express a trade-off between precision, defined as the noise-to-signal ratio of a generic current, and the amount of associated entropy production. These results have deep consequences for **autonomous heat engines** operating at steady state, imposing an upper bound for their efficiency in terms of the power yield and its fluctuations. We analyzed [H. Miller, H. Mohammady, et al., Phys. Rev. Lett. 126, 210693 (2021)] a different class of heat engines, namely, those which are operating in the periodic slow-driving regime and showed that an alternative uncertainty relation is satisfied. It is less restrictive than that of steady-state engines and allows for engines that produce finite power, with small power fluctuations, to **operate close to reversibility**. The bound further incorporates the effect of quantum fluctuations, which **reduces engine efficiency** relative to the average power and reliability.

The potential advantage of quantum technologies can be almost always traced back to phenomena of quantum entanglement. Therefore, it is of interest to understand how quantum entangled states are produced and certified. In particular, the existence of **entanglement of highly-dimensional quantum systems** is of interest for development of practical **quantum communication security** protocols. Our colleague was a member of the international team [Bavaresco et al., Nature Physics 14, 1032–1037 (2018)] that proposed a **novel and efficient certification procedure** using measurements in just two bases.

QUANTUM SIMULATIONS

The application of **quantum-entanglement simulation methods**, namely, Tensor Networks, in the context of classical and quantum systems, has been gaining traction in recent years. The **Tensor Networks** have been arising as a universal language in almost all disciplines of contemporary physics, ranging from atomic and condensed matter physics to high-energy physics. We have been **proposing efficient algorithms** (namely, the **Higher-Order Tensor Renormalization Group** and the **Corner Transfer Matrix Renormalization Group**) which provide deeper insight into the quantum entanglement of many interacting particles. When the number of particles is infinite, we have methods to quantify the amount of entanglement. The entanglement is a direct byproduct of the Tensor Networks. Having studied phase diagrams, the **entanglement entropy** is an appropriate quantity to be analyzed at **phase transitions**. It turns out that the entanglement entropy logarithmically diverges with respect to the increasing number of particles when the correlations become strong at criticality. Such analysis helps us understand the interacting systems on large scales. We have been investigating systems in which the particles form structures whose spatial geometry of the interparticle interactions are modeled by the Tensor Networks. For this reason, we have focused our interest on the **geometrical concepts of interactions**. Hence, we specified three main fields, where the interactions have the potential to bring novel knowledge into the light. It is the **anti-de Sitter spatial geometry** of the Tensor Networks which has successfully found its application in quantum gravity, the **fractal spatial geometry** of interactions [J. Genzor et al, Phys. Rev. E 93, 012141 (2016)], and the **higher-dimensional symmetries** SU(n) of the particles, which are of great interest in solid-state physics [Ueda et al, Phys. Rev. E101, 062111 (2020)] and exhibit all types of phase transitions (discontinuous, continuous, and Kosterlits-Thouless).

QUANTUM COMPUTING

The main qualitative benefit of quantum computing is in the **qualitative reduction of computation complexity** of particular families of problems. We focused on the complexity of simulations and verification of properties of simple (local Hamiltonian) many-body quantum systems. **Quantum Monte Carlo** (QMC) methods are the gold standard for studying equilibrium properties of quantum many-body systems. However, in many interesting situations, QMC methods are faced with a sign problem, causing the severe limitation of an exponential increase in the runtime of the QMC algorithm. We developed (in collaboration) a systematic, generally applicable, and practically feasible methodology for **easing the sign problem** by efficiently computable basis changes and used it to rigorously assess the sign problem. Our framework introduced **measures of non-stoquasticity** that—as we demonstrated analytically and numerically—at the same time provided a practically relevant and efficiently computable figure of merit for the severity of the sign problem. Complementing this pragmatic mindset, we proved that easing the sign problem in terms of those measures is generally an **NP-complete task for nearest-neighbor Hamiltonians** and simple basis choices by a **reduction to the MAXCUT-problem** [D. Hangleitner et al., Science Advances 33, (2020)].

2. Partial indicators of main activities:

2.1. Research output

2.1.1 Principal types of research output of the institute:

95 %	international basic research
5 %	international applied research
0 %	regional basic research
0 %	regional applied research

2.1.2 List of selected publications documenting the most important results of basic research. The total number of publications should not exceed the number of average FTE researchers per year. The principal research outputs (max. 10% of the total number of selected publications, including Digital Object Identifier – DOI if available) should be underlined. Authors from the evaluated organizations should be underlined.

The list is ordered almost randomly. Attention is paid to the impact of the research in particular research areas. The principal research outputs are highlighted.

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JOSS, D. T. - KÖSTER, U. - KREIM, S. - LIBERATI, V. - LUNNEY, D. - LYNCH, K. M. - MANEA, V. - MARSH, B. A. - MARTINEZ PALENZUELA, Y. - MOLKANOV, P. L. - MOSAT, P. - NEIDHERR, D. - O'NEILL, G. G. - PAGE, R. D. - PROCTER, T. J. - RAPISARDA, E. - ROSENBUSCH, M. - ROTHE, S. - SANDHU, K. - SCHWEIKHARD, L. - SELIVERSTOV, M. D. - SELS, S. - SPAGNOLETTI, P. - TRUESDALE, V. L. - VAN BEVEREN, C. - VAN DUPPEN, P. - VEINHARD, M. - VENHART, Martin - VESELSKÝ, Martin - WEARING, F. - WELKER, A. - WIENHOLTZ, F. - WOLF, R. N. - ZEMLYANOY, S. G. - ZUBERT, K. Change in structure between the I=1/2 states in Tl-181 and (177)(,)(179)AU. In Physics Letters B, 2018, vol. 786, p. 355 - 363. https://doi.org/10.1016/j.physletb.2018.10.005 [IF 4.254, 16 citations]

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2.1.3 List of monographs/books published abroad

No outcome of this type in the considered period.

2.1.4 List of monographs/books published in Slovakia

LUBY, Štefan. Nanosvet na dlani [in Slovak, translation: The Nanoworld in the palm of your hand]. Bratislava, Veda, 2016. 178 pages, ISBN 978-80-224-1548-4

2.1.5 List of other scientific outputs specifically important for the institute, max. 10 items for institute with less than 50 average FTE researchers per year, 20 for institutes with 50 – 100 average FTE researchers per year and so on

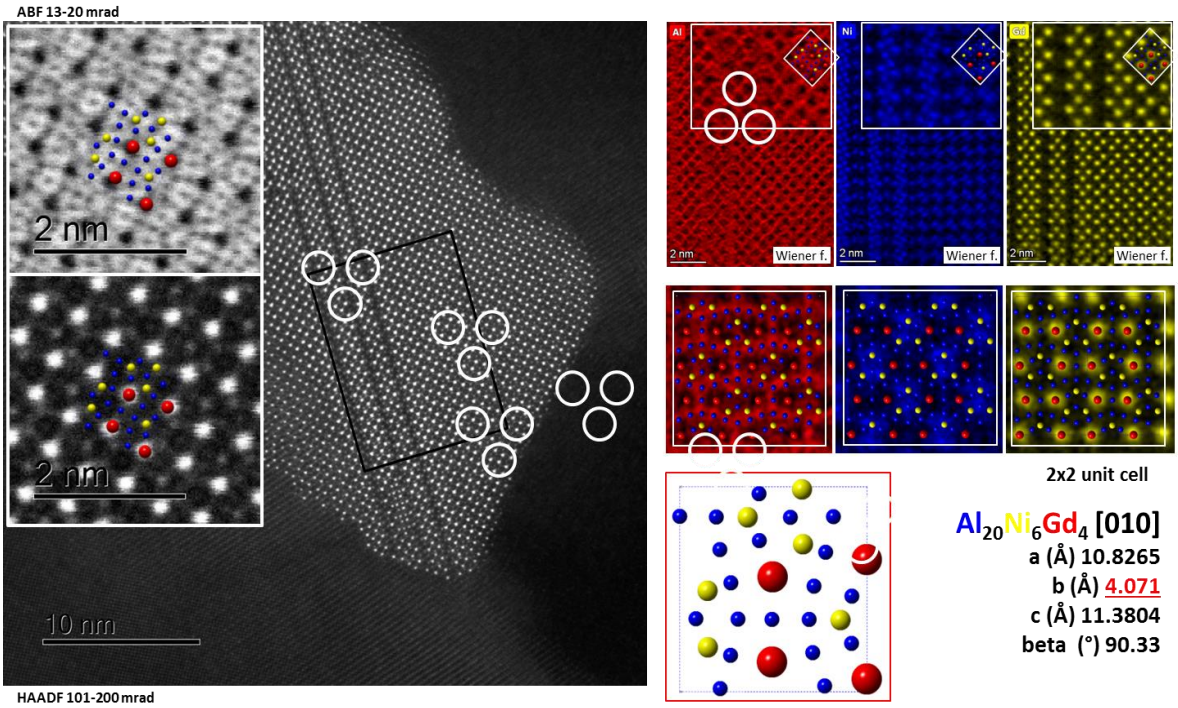
- The research team of Peter Švec participated in the industry-oriented european H2020 project VALUEMAG - **Valuable products from algae using new magnetic cultivation and extraction techniques**, H2020-BBI-JTI-2016 (BIO BASED INDUSTRIES PPP). It was a common project of 11 partners supervised by NTUA Athens, Greece, 04/2017 – 03/2020. The VALUEMAG project's main objective was to develop an advanced magnetic method for micro-algae cultivation and to utilise this knowledge to produce micro-algae for food, cosmetic and nutraceutical use at minimum possible cost. The whole project was selected

as **success story project** (https://www.bbi.europa.eu/projects/valuemag). We contributed to the determination of parameters of uptake of magnetic nanoparticles from algal cells. In particular,

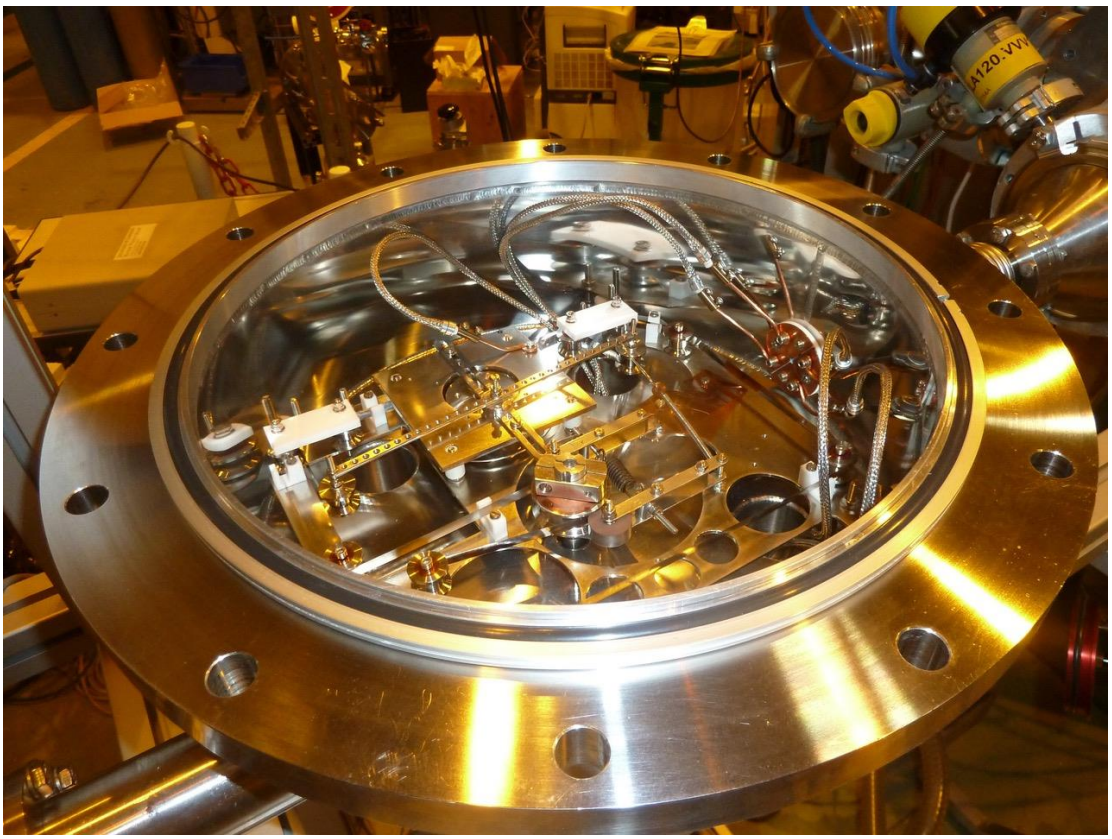
- High-throughput structural and morphological characterization of developed Fe3O4 nanoparticles with functionalized shell.
- Design and tuning of physical parameters of electroporation process to optimize uptake of nanoparticles of functionalized Fe3O4 by algae.
- Systematic assessment of the success of uptake process by methods of transmission and environmental scanning electron microscopy.
- Contribution to development of soft magnetic cultivation cone for trapping of magnetic algal cells using rapid thermomagnetic processing of steel cone surface.
- Development of a magnetic scraper system for harvesting magnetic algae for biomass processing and nanoparticle recycling.
- Contribution to development of the process of separation of high volume of magnetic and non-magnetic algal cells.

Results: optimized process with 25% success of uptake and long-term viability and cell reproduction over 70%.

- Invited lecture at Microscopy Conference MC 2021, P. Švec, M. Mihalkovič, B. Rusanov, D. Janičkovič, V. Sidorov, P. Švec Sr, **Phase evolution clarification in Al-Ni-Co-RE amorphous alloys with varying Ni/Co ratio.** Microscopy Conference MC 2021, Joint Meeting of Dreiländertagung & Multinational Congress on Microscopy, 22-26 August, 2021. Vienna, Austria, Book of Abstracts, p. 113. Peculiarities in the transformation process from amorphous state were studied in detail by combination of x-ray diffraction, electron scanning diffraction and STEM (EDS/EELS). Formed intergranular phase transforms further into complex phases $Al_{19}Ni_5Gd_3$ **and newly identified $Al_{20}Ni_6Gd_4$**



- Development of a unique **spectrometer TATRA** that has been transferred and used in studies of ^{181,183}Au performed at **CERN-ISOLDE facility**. Due to excellent energy resolution of this spectrometer both for gamma rays and conversion electrons, extensive level schemes could be established.



- In 2019, IPSAS opened a quantum link between Bratislava and Vienna — **the first quantum communication optical fibre link between capitals of two countries**. A research group led by Rupert Ursin installed a quantum receiver station in Bratislava's institute of physics facilities. In 2021, the quantum communication experts from IP SAS were invited to a round table discussion about the future of Quantum Technologies at the ITAPA2021 international congress (Nov 8-10). In Dec 2021, the link with Vienna was extended to St. Polten and demonstrated a QKD exchange actively stabilised for 110h over 248km link of fibre (see Fig. below). Also the quantum receiver in Bratislava was replaced and updated by our newly formed research team led by Djeylan Aktas. Unfortunately, the corona situation and changes on the Austrian side (the whole group moved to private sector) does not allow us to make sufficient popularisation event including state representatives.

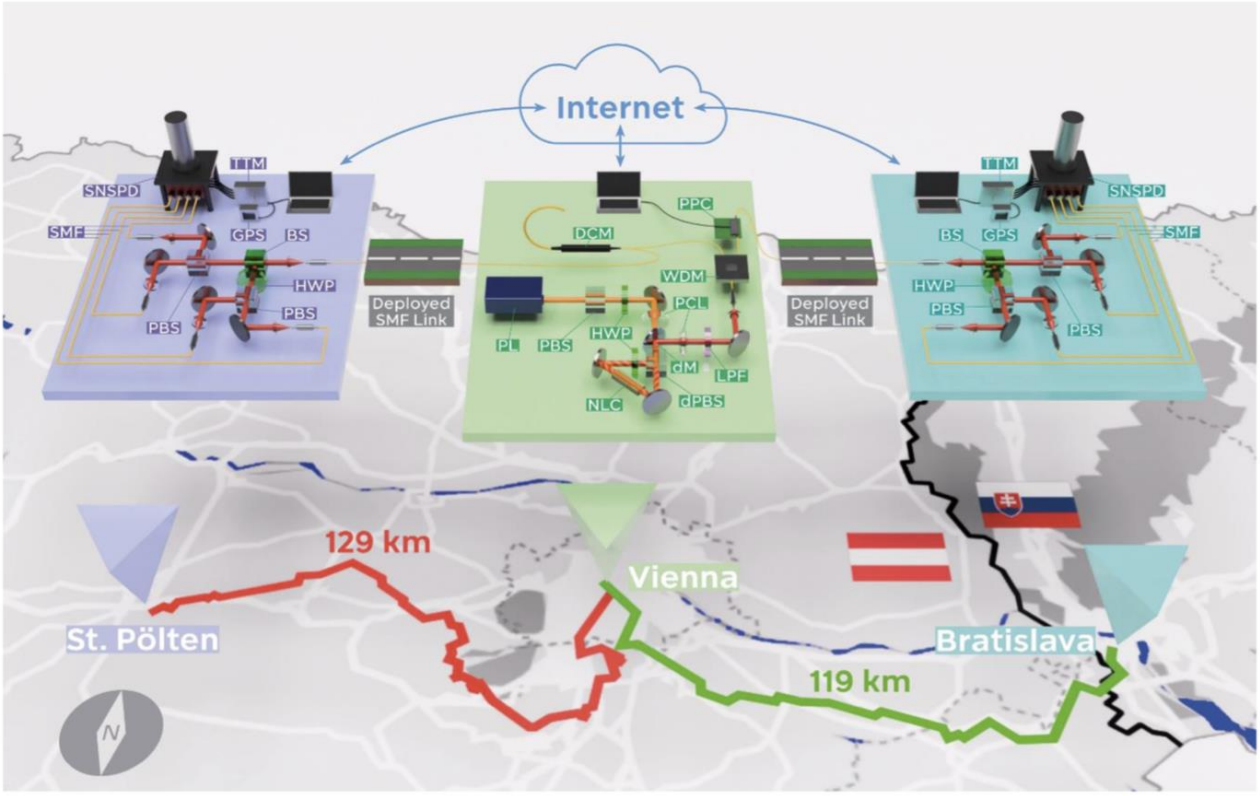


Figure 1. Sketch of the Setup. The source of entangled photon pairs is situated in Vienna. We create polarization-entangled photon pairs at two distinct telecommunication wavelengths by pumping a non-linear crystal (NLC) in a Sagnac configuration with a 775 nm laser (PL) and collecting the down-converted photons with single-mode fibres (SMF) connected to a wavelength division (de-)multiplexer (WDM). The idler photon passes a dispersion compensation module (DCM) which nonlocally recovers the entangled state's tight temporal correlations broadened by chromatic dispersion along the link. The idler is then directed along 129 km of fibre to a polarization measurement module (PMM) in St. Pölten in Lower Austria. The signal photon passes an automatized in-fibre piezo-based polarization controller (PPC) which nonlocally realigns the phase of the entangled state, should its quality decrease. Afterwards, it travels to a PMM in Bratislava of the same design as the one in Austria. In these PMMs, the photons are randomly directed to orthogonal measurements in two mutually unbiased linear polarization bases. They photons impinge on superconducting nanowire single-photon detectors (SNSPD), and a GPS-clock-disciplined time-tagging module (TTM) records detection time, measurement basis and outcome. Via classical internet connections, the two measurement stations' detection events are compared and coincidences calculated. If their quantum bit error rate increases, Vienna starts the polarization alignment. PBS: polarizing beamsplitter, HWP: half-wave plate, PL: planoconvex lens, dPBS: dichroic PBS, DM: dichroic mirror, LPF: longpass filter, BS: 50:50 beamsplitter

2.1.6 List of patents, patent applications, and other intellectual property rights registered abroad

None.

2.1.7 List of patents, patent applications, and other intellectual property rights registered in Slovakia

1. **Patent Number: 288901**

   Title: Chamber for the study of photopolymerization by the positron annihilation method. Patent no. 288901

   Applicant(s) or Proprietor(s): Polymer InstituteSAS, Institute of Physics SAS (50%)

   Inventor(s): Švajdlenková Helena, Ing., PhD.; Šauša Ondrej, RNDr., CSc.

   Industrial Property Office of the Slovak Republic: P 288901

   https://wbr.indprop.gov.sk/WebRegistre/Patent/Detail/117-2017

2. **Patent Number: 288762**

Title: Viacvrstvové pásy na báze zliatin kovov a spôsob ich výroby/ Multi-layer sheets of metal-based alloy and the method of their production

Applicant(s) or Proprietor(s): Institute of Physics SAS (90%), Slovak Centre of Scientific and Technical Information - CVTI SR

Inventor(s): Švec Peter, Ing., DrSc.; Janičkovič Dušan, RNDr.; Halász Michal;Švec Peter, Ing.; Hoško Jozef, Ing.

Industrial Property Office of the Slovak Republic: P 288762

https://wbr.indprop.gov.sk/WebRegistre/Patent/Detail/50045-2014

3. **Patent Number: 288586**

Title: Spôsob tvarovania konštrukčného prvku/ Hot shaping of metallic glasses

Applicant(s) or Proprietor(s): Institute of Physics SAS (90%), Slovak Centre of Scientific and Technical Information - CVTI SR

Inventor(s): Švec Peter, Ing., DrSc.; Janičkovič Dušan, RNDr.; Halász Michal;Švec Peter, Ing.; Hoško Jozef, Ing.

Industrial Property Office of the Slovak Republic: P 288586

https://wbr.indprop.gov.sk/WebRegistre/Patent/Detail/44-2013

4. **Patent Number:** 288234

Title: Spôsob výroby nanočasticových monovrstiev a multivrstiev/ A method for producing nanoparticle monolayers and multilayers

Applicant(s) or Proprietor(s): Institute of Physics SAS (100%)

Inventor(s): Chitu Lívia, Mgr.;Šiffalovič Peter, Dr. Ret. Nat., PhD.; Majková Eva, RNDr., DrSc.;Jergel Matej, Ing., DrSc.;Luby Štefan, prof. Ing., DrSc.

Industrial Property Office of the Slovak Republic: P 288234

https://wbr.indprop.gov.sk/WebRegistre/Patent/Detail/5006-2010

5. **Patent Number:** 286132

Title: Snímač pomerných pretvorení/ Magnetoelastic strain sensor

Applicant(s) or Proprietor(s): Institute of Physics SAS (100%)

Inventor(s): Baláž Pavol, Ing., CSc.;Bydžovský Ján, doc. Ing., CSc.; Kraus Luděk, Ing., CSc.; Pasquale Massimo, Dr.; Švec Peter, Ing., DrSc.

Industrial Property Office of the Slovak Republic: P 286132

https://wbr.indprop.gov.sk/WebRegistre/Patent/Detail/142-2004

6. **Utility Model Number:** 9351

Title: Štvorodrazový rtg. monochromátor na vysokorozlišovaciu rtg. difrakciu/ Four-bounce X-ray monochromator for high-resolution X-ray diffraction

Applicant(s) or Proprietor(s): Institute of Physics SAS (100%)

Inventor(s): Jergel Matej, Ing., DrSc.; Nádaždy Peter, Mgr., PhD.; Šiffalovič Peter, Dr. Rer. Nat. , DrSc.;

Industrial Property Office of the Slovak Republic: UV 9351

https://wbr.indprop.gov.sk/WebRegistre/UzitkovyVzor/Detail/50014-2021

7. **Utility Model Number:** 8774

Title: Method and prototype for hermetic bonding of ultrathin metallic alloys with vacuum flange

Applicant(s) or Proprietor(s): Institute of Physics SAS (66%), ILC - International Laser Center

Inventor(s): Prajapati Pareshkumar Manharbhai, Dr.; Venhart Martin, Mgr., PhD.; Bruncko Jaroslav, Ing., PhD.

Industrial Property Office of the Slovak Republic: UV 8774

https://wbr.indprop.gov.sk/WebRegistre/UzitkovyVzor/Detail/50033-2019

8. **Utility Model Number:** 288589

   Title: Spôsob uskutočňovania lokálnej nábojovej tranzientnej analýzy/ Method for performing the local charge transient analysis

   Applicant(s) or Proprietor(s): Institute of Physics SAS

   Inventor(s): Lányi Štefan, Ing., DrSc.; Nádaždy Vojtech, Ing., CSc.

   Industrial Property Office of the Slovak Republic: P 288589

   https://wbr.indprop.gov.sk/WebRegistre/Patent/Detail/78-2012

2.1.8 Narrative on the most important research outputs of the institute – especially focused on their importance for society (3-5 pages)

Development of any new technology crucially depends on the discoveries in physics, and technologies themselves are then enabling us to design new experiments in all research areas. The researchers at the institute are trained to be open-minded, critical and they are encouraged to cross the borders between the sciences. Our laboratories are completely open and freely accessible for colleagues from other institutes and their use is best illustrated by joint research papers and projects.

In the past new materials and their properties were discovered by coincidence, later by a systematic scientific analysis and measurements. With the increasing understanding of the nature, the birth of physics and science enables us to design new materials of desired properties. In the last century the development of material science employed computers and sophisticated screening instruments (microscopy, spectroscopy, etc.) provided us with limited possibilities to fabricate materials with given physical properties. Researchers at the institute are using all these tools to study new materials, but also to find out their potential applications.

Organic–inorganic halide **perovskite** solar cells (PSCs) have achieved amazing progress in terms of power conversion efficiency (PCE), rising from 3.8% to over 23.3%. Owing to perovskites' low nucleation and crystallization activation energy (56.6–97.3 kJ mol−1), a range of low temperature and large-scale solution fabrication processes have been actively investigated for potential commercialization. Although many excellent research institutes and enterprises have emerged to advance commercialization of PSCs, the performance of devices which have large areas still lag much farther behind those of smaller lab scales. The performances of PSCs are predominantly determined by the quality of the perovskite film, which in turn, is controlled by the fabrication process. A comprehensive and in-depth understanding of the nucleation and growth process during perovskite crystallization is imperative for the further advancement of large-scale manufacturing of high quality perovskite films.

In particular, searching for a simple method to replace the conventional antisolvent process with the objective of achieving a **high-quality perovskite film** is indispensable for the practical manufacture of solar cells. We explored antisolvent-free additive engineering to fabricate compact CH3NH3PbI3 (MAPbI3) perovskite films combining the coordination effect of methylammonium chloride (MACl) and methylammonium acetate (MAAc). We succeeded in fabricating high-quality monolayer-like perovskite films with a micro-scale grain size (~2 μm), a smooth surface and enhanced crystallinity. The time-resolved photoluminescence (PL) spectra and space-charge

limited current (SCLC) measurements have confirmed that there was a significantly reduced density of trap states, which has an imminent impact on the perovskite film quality. As a result, the **power conversion efficiency** (PCE) of the perovskite solar cells (PSCs) using the mixed additive **increases to 19.64%**, which is much larger than those of devices using a single MACl additive (15.61%). Accordingly, this provides a new one-step fabrication method of high-quality perovskite films for the coming generation of PSCs.

Besides contributing to the investigation of these structures we reviewed recent advances in the commercializations of the PSCs market, identified hurdles and challenges of perovskite materials for **applications in energetics**.

Significant research efforts have been focused on the fabrication and characterisation of **metallic High Entropy Alloys** (HEAs) with superior physical and mechanical properties, including high strength/hardness, outstanding wear resistance, exceptional high-temperature strength, good structural stability and good corrosion and oxidation resistance. HEAs typically consist of five or more elements that are mixed in equimolar concentrations to produce a maximum molar configurational entropy of $\Delta S_{mix} = R \ln N$, where N is the number of equimolar components and R is the gas constant. This entropic term has the effect of stabilising single phase multicomponent solid solutions. The large body of research undertaken in the field of HEAs has significantly improved the understanding of these new materials and intensive research is underway to develop HEAs as structural materials for e.g. **high-temperature applications**, hydrogen storage materials, radiation resistant materials, diffusion barriers for electronics, precision resistors, electromagnetic shielding materials, soft magnetic materials, **thermoelectric materials**, functional coatings, anti-bacterial materials, etc. In our laboratories we obtained unique insight into the microstructure of recently developed Ultra-High Temperature Ceramic material, a high entropy (Hf-Ta-Zr-Nb)C. The determined characteristics of this material are crucial for follow-up applications.

Use of **intermetallic compounds** composed of simple and transition metals as **catalysts** leads to improved activity and selectivity for a number of industrially important processes. For example, for semihydrogenation of alkynes to alkenes. The semihydrogenation of acetylene is an important step in the industrial **production of polyethylene** because the ethylene feedstock has to be cleaned of traces of acetylene to avoid poisoning of the polymerization catalyst, but further hydrogenation of the ethylene would reduce the polyethylene yield and must be avoided. Using density functional theory (DFT) calculations we simulated the semihydrogenation of acetylene to ethylene catalyzed by compounds of Pd with Ga or Al and of Co or Fe with Al. It turned out that acetylene is strongly bound to simple-metal atoms, whereas ethylene is weakly bonded on top of a transition-metal atom. The change from strong to weak bonding is of great importance for the selectivity of the process. The novel point elucidated by the DFT calculations is the **strong reactivity** of the non-transition-metal atoms arising from the strong metallocovalent bonding in the compounds, which also contributes to their stability.

Iron oxide nanoparticles have application in biomedical applications, medical diagnosis and therapeutics (e.g. in Magnetic Resonance Imaging (MRI) as contrast agents), or in bio-conjugated magnetic iron oxides NPs which involves targeting of MRI probes towards the brain tumor along with tumor real-time monitoring; although Co and Ni are also highly magnetic materials, they are toxic and easily oxidized. Applications of iron oxide NPs include also catalysis, terabit magnetic storage devices, magneto-optical devices, waste-water treatment, pigments, coatings, lubrications, sorbents. A last but not less important application of iron oxides is in **chemiresistive gas sensors**, i.e. sensors based on resistance modulation of semiconducting oxides by chemical adsorbed gas species, as gas sensing elements. We studied the Pd-doping of Fe_3O_4/γ-Fe_2O_3 nanoparticles (NPs) multilayers and we tested their gas sensing properties towards two reference species, i.e. nitrogen dioxide (NO_2, oxidizing gas) and acetone (C_3H_6O, a reducing volatile organic compound).

New material properties and processes can be discovered also today, especially in the area of nuclear and subnuclear experimental physics. Such discoveries are not aiming directly to everyday

technologies, however, they are definitely expanding our **knowledge and understanding** of the nature. We know the equations we have to solve to understand properties of any atom, or molecule, however, its complexity is extremal, and experiments must provide data in order to learn the properties. The research team at our institute focuses on the properties of atomic nuclei, especially the gold and its shape. The key characteristics to understand the shapes of the nuclei is the experimental characterisation of the associated spectra. There were two problems to address these questions. First one was to find conditions where inner structure of atomic nuclei may be revealed. It turned out CERN is the place meeting the conditions and our application for experiment there was accepted. However, the detectors there were not designed for this purpose, so our experimentalist have to design a suitable measurement instrument and transfer it to CERN. It was named **HIGH TATRA** and has on-line capability for γ-ray and conversion-electron spectroscopy. Using this device, we studied the alchemyst dream of changing the mercury 183Hg into gold 183Au at ISOLDE in CERN. Key details of the low-energy level scheme of the neutron-deficient nuclide 183Au populated in this decay were discovered. A broad energy germanium detector is employed to achieve this (the first-ever use of such a device in decay-scheme spectroscopy), by way of a combination of high-gain γ-ray singles spectroscopy and γ–γ coincidence spectroscopy. The observed data lead to the determination of a specific transition in the 183Au decay scheme, suggesting a **new possible shape** coexisting structure in this nucleus.

The task of machine learning is to apply what was learned by many observations in new situations that might not be observed before. It enables systems to learn and improve from experience without being explicitly programmed. The quantisation of this problem is not unique, however, in fully quantum version it is called **quantum learning** and is composed of the storage of the process to learn in quantum memory and retrieval phase where quantum programmable processor is used to implement the stored process on arbitrary input. Our researchers have strong experience in optimization and limitations of quantum devices. They designed **an optimal quantum device successfully learning** the performance of arbitrary unknown quantum computation. Imagine someone would find new quantum algorithm without sharing details. Quantum learning allows us to share the algorithm without revealing the details. The weak part, that may be seen also as a benefit, is coming from no-cloning principle that restricts the number of uses of the stored action to one. The result itself is based on nontrivial extension of the results from algebraic combinatorics.

2.1.9. Table of research outputs

Papers from international collaborations in large-scale scientific projects (Dwarf team, ALICE Collaboration, ATLAS collaboration, CD Collaboration, H1 Collaboration, HADES Collaboration, and STAR Collaboration) have to be listed separately

Scientific publications	2016			2017			2018			2019			2020			2021			total			
	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. / one million total salary budget	number	No. / FTE researches	No. /1 million total salary budget	number	averaged number per year	av. No. / FTE researches	av. No. / one million total salary budget
Scientific monographs and monographic studies in journals and proceedings published abroad (AAA, ABA)	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0.000
Scientific monographs and monographic studies in journals and proceedings published in Slovakia (AAB, ABB)	1	0.016	0.557	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.167	0.003	0.082
Chapters in scientific monographs published abroad (ABC)	1	0.016	0.557	0	0.000	0.000	0	0.000	0.000	1	0.017	0.494	0	0.000	0.000	0	0.000	0.000	2	0.333	0.005	0.163
Chapters in scientific monographs published in Slovakia (ABD)	1	0.016	0.557	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.167	0.003	0.082
Scientific papers published in journals registered in Current Contents Connect (ADCA, ADCB, ADDA, ADDB)	80	1.271	44.598	79	1.198	40.771	92	1.428	44.850	100	1.695	49.360	92	1.479	41.026	99	1.636	44.990	542	90.333	1.445	44.239
Scientific papers published in journals registered in Web of Science Core Collection and SCOPUS not listed above (ADMA, ADMB, ADNA, ADNB)	16	0.254	8.920	22	0.334	11.354	28	0.435	13.650	25	0.424	12.340	18	0.289	8.027	19	0.314	8.634	128	21.333	0.341	10.448
Scientific papers published in other foreign journals (not listed above) (ADEA, ADEB)	3	0.048	1.672	4	0.061	2.064	4	0.062	1.950	2	0.034	0.987	2	0.032	0.892	1	0.017	0.454	16	2.667	0.043	1.306
Scientific papers published in other domestic journals (not listed above) (ADFA, ADFB)	0	0.000	0.000	2	0.030	1.032	0	0.000	0.000	2	0.034	0.987	0	0.000	0.000	0	0.000	0.000	4	0.667	0.011	0.326
Scientific papers published in foreign peer-reviewed proceedings (AECA)	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	1	0.017	0.494	0	0.000	0.000	0	0.000	0.000	1	0.167	0.003	0.082

Scientific papers published in domestic peer-reviewed proceedings (AEDA)	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0.000
Published papers (full text) from foreign scientific conferences (AFA, AFC)	1	0.016	0.557	3	0.046	1.548	0	0.000	0.000	0	0.000	0.000	1	0.016	0.446	0	0.000	0.000	5	0.833	0.013	0.408
Published papers (full text) from domestic scientific conferences (AFB, AFD)	7	0.111	3.902	6	0.091	3.097	2	0.031	0.975	1	0.017	0.494	1	0.016	0.446	1	0.017	0.454	18	3	0.048	1.469

2.2. Measures of research outputs (citations, etc.)

2.2.1. Table with citations per annum (without self-citations)

Citations of papers from international collaborations in large-scale scientific projects (Dwarf team, ALICE Collaboration, ATLAS collaboration, CD Collaboration, H1 Collaboration, HADES Collaboration, and STAR Collaboration) are listed separately

Citations, reviews	2015		2016		2017		2018		2019		2020		total		
	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	No. / FTE researchers	number	averaged number per year	av. No. / FTE researchers
Citations in Web of Science Core Collection (1.1, 2.1)	1,611	25.60	1,782	27.03	1,602	24.86	1,736	29.42	2,246	36.11	2,605	43.04	**11,582**	**1,930.33**	**30.68**
Citations in SCOPUS (1.2, 2.2) if not listed above	21	0.33	17	0.26	93	1.44	21	0.37	18	0.29	37	0.62	**207**	**34.50**	**0.55**
Citations in other citation indexes and databases (not listed above) (3.2,4.2)	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	**0**	**0.00**	**0.00**
Other citations (not listed above) (3.1, 4.1)	34	0.54	16	0.24	3	0.05	5	0.09	3	0.05	16	0.27	**77**	**12.83**	**0.20**
Reviews (5,6)	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	2	0.03	**2**	**0.33**	**0.01**

2.2.2. List of 10 most-cited publications published any time with the address of the institute, with number of citations in the assessment period (2015 – 2020)

1. Mark Hillery, Vladimír Bužek and André Berthiaume, Quantum secret sharing, Phys. Rev. A 59, 1829 (1999), https://doi.org/10.1103/PhysRevA.59.1829 (850 citations)
2. D. R. Smith, S. Schultz, Peter Markoš, and C. M. Soukoulis, Determination of effective permittivity and permeability of metamaterials from reflection and transmission coefficients, Phys. Rev. B 65, 195104 (2002), https://doi.org/10.1103/PhysRevB.65.195104 (723 citations)
3. J. Adams, M.M. Aggarwal, Z. Ahammed, J. Amonett, B.D. Anderson, Peter Filip, at al., Experimental and Theoretical Challenges in the search for the quark-gluon plasma: The STAR Collaboration´s critical assessment of the evidence from RHIC collisions. Nuclear Physics A 757, p. 102-183 (2005), https://doi.org/10.1016/j.nuclphysa.2005.03.085 (552 citations)
4. N. Otuka, E. Dupont, E., V. Semkova, B. Pritychenko, A.I. Blokhin, M. Aikawa, S. Babykina, M. Bossant, G. Chen, S. Dunaeva, R.A. Forrest, T. Fukahori, N. Furutachi, S. Ganesan, Z. Ge, O.O. Gritzay, M. Herman, S. Hlaváč, K. Kato, B. Lalremruata, Y.O. Lee, A. Makinaga, K. Matsumoto, M. Mikhaylyukova, G. Pikulina, V.G. Pronyaev, A. Saxena, O. Schwerer, S.P Simakov, N. Soppera, R. Suzuki, S. Takács, X. Tao, S. Taova, F. Tárkányi, V.V. Varlamov, J. Wang, S.C. Yang, V. Zerkin, Y. Zhuang, Towards a more complete and accurate experimental nuclear reaction data library (EXFOR): International collaboration between nuclear reaction data centres (NRDC), Nuclear Data Sheets 120, p. 272-276 (2014), https://doi.org/10.1016/j.nds.2014.07.065 (235 citations)
5. J. Klinovaja, Peter Staňo, A. Yazdani, D. Loss, Topological superconductivity and majorana fermions in RKKY systems, Physical Review Letters 111, 186805 (2013) https://doi.org/10.1103/PhysRevLett.111.186805 (174 citations)
6. P. Rungta, V. Bužek, C.M. Caves, M. Hillery, G.J. Milburn, Universal state inversion and concurrence in arbitrary dimensions, Physical Review A 64, p. 042315 (2001) https://doi.org/10.1103/PhysRevA.64.042315 (158 citations)
7. M.S. Kim, W. Son, V. Bužek, P.L. Knight, Entanglement by a beam splitter: Nonclassicality as a prerequisite for entanglement, Physical Review A 65, 032323 (2002) https://doi.org/10.1103/PhysRevA.65.032323 (157 citations)
8. V. Bužek, M. Hillery, Quantum copying: Beyond the no-cloning theorem, Physical Review A 54, p. 1844-1852 (1996), https://doi.org/10.1103/PhysRevA.54.1844 (132 citations)
9. T. Koschny, P. Markoš, D.R. Smith, C.M. Soukoulis, Resonant and antiresonant frequency dependence of the effective parameters of metamaterials, Physical Review E 68, 065603 (2003) https://doi.org/10.1103/PhysRevE.68.065602 (101 citations)
10. J. Fabian, A. Matos-Abiague, C. Ertler, P.Staňo, I. Zitic, Semiconductor spintronics, Acta Physica Slovaca 57, p. 565-907. (2007),

    http://www.physics.sk/aps/pub.php?y=2007&pub=aps-07-04 (92 citations)

2.2.3. List of 10 most-cited publications published any time with the address of the institute, with number of citations obtained until 2020

1. Mark Hillery, Vladimír Bužek and André Berthiaume, Quantum secret sharing, Phys. Rev. A 59, 1829 – Published 1 March 1999 (2050 WOK citations), https://doi.org/10.1103/PhysRevA.59.1829
2. D. R. Smith, S. Schultz, Peter Markoš, and C. M. Soukoulis Determination of effective permittivity and permeability of metamaterials from reflection and transmission coefficients, Phys. Rev. B 65, 195104 – Published 19 April 2002 (2024 WOK citations) https://doi.org/10.1103/PhysRevB.65.195104
3. Vladimír Bužek and Mark Hillery, Quantum copying: Beyond the no-cloning theore, Phys. Rev. A 54, 1844 – Published 1 September 1996 (811 WOK citations) https://doi.org/10.1103/PhysRevA.54.1844
4. Pranaw Rungta, Vladimír Bužek, Carlton M. Caves, Mark Hillery, and Gerard J. Milburn, Universal state inversion and concurrence in arbitrary dimensions, Phys. Rev. A 64, 042315 – Published 18 September 2001 (494 WOK citations) doi.org/10.1103/PhysRevA.64.042315

5. M. S. Kim, W. Son, Vladimír Bužek, and Peter L. Knight Entanglement by a beam splitter: Nonclassicality as a prerequisite for entanglement, Phys. Rev. A 65, 032323 – Published 27 February 2002 (396 WOK citations) doi.org/10.1103/PhysRevA.65.032323
6. Vladimír Bužek, A. Vidiella-Barranco, and Peter L. Knight, Superpositions of coherent states: Squeezing and dissipation, Phys. Rev. A 45, 6570 – Published 1 May 1992 (395 WOK citations) doi.org/10.1103/PhysRevA.45.6570
7. T. Koschny, Peter Markoš, D. R. Smith, and C. M. Soukoulis, Resonant and antiresonant frequency dependence of the effective parameters of metamaterials, Phys. Rev. E 68, 065602(R) – Published 15 December 2003 (361 WOK citations) doi.org/10.1103/PhysRevE.68.065602
8. Jelena Klinovaja, Peter Stano, Ali Yazdani, and Daniel Loss, Topological Superconductivity and Majorana Fermions in RKKY Systems, Phys. Rev. Lett. 111, 186805 – Published 1 November 2013 (303 WOK citations) https://doi.org/10.1103/PhysRevLett.111.186805
9. Vladimír Bužek, H. Moya-Cessa, Peter L. Knight, and S. J. D. Phoenix, Schrödinger-cat states in the resonant Jaynes-Cummings model: Collapse and revival of oscillations of the photon-number distribution, Phys. Rev. A 45, 8190 – Published 1 June 1992 (276 WOK citations) https://doi.org/10.1103/PhysRevA.45.8190
10. F. A. M. de Oliveira, M. S. Kim, Peter L. Knight, and Vladimír Bužek, Properties of displaced number states, Phys. Rev. A 41, 2645 – Published 1 March 1990 (249 WOK citations) doi.org/10.1103/PhysRevA.41.2645

2.2.4. List of 10 most-cited publications published during the evaluation period (2016-2021) with the address of the Institute, with number of citations obtained until 2021

1. Huang, Fei* - Li, Mengjie* - Šiffalovič, Peter - Cao, Guozhong - Tian, Jianjun**. From scalable solution fabrication of perovskite films towards commercialization of solar cells. In Energy and Environmental Science, 2019, vol. 12, no. 2, p. 518-549. (2018: 33.250 - IF, Q1 - JCR, 13.103 - SJR, Q1 - SJR, karentované - CCC). (2019 - Current Contents). ISSN 1754-5692. Dostupné na: https://doi.org/10.1039/c8ee03025a (145 citations)
2. Howon, Kim** - Palacio-Morales, Alexandra - Posske, Thore - Rózsa, Levente - Palotás, Krisztián - Szunyogh, László - Thorwart, Michael - Wiesendanger, Roland**. Toward tailoring Majorana bound states in artificially constructed magnetic atom chains on elemental superconductors. In Science Advances, 2018, vol. 4, no. 5, eaar 5251. (2017: 11.511 - IF, Q1 - JCR, 5.817 - SJR, Q1 - SJR, karentované - CCC). (2018 - Current Contents). ISSN 2375-2548. Dostupné na: https://doi.org/10.1126/sciadv.aar5251 (121 citations)
3. Russotto, P. - Gannon, S. - Kupny, S. - Lasko, P. - Acosta, L. - Adamczyk, M. - Al-Ajlan, A. - Al-Garawi, M. - Al-Homaidhi, S. - Amorini, F. - Auditore, L. - Aumann, T. - Ayyad, Y. - Basrak, Z. - Benlliure, J. - Boisjoli, M. - Boretzky, K. - Brzychczyk, J. - Budzanowski, A. - Caesar, C. - Cardella, G. - Cammarata, P. - Chajecki, Z. - Chartier, M. - Chbihi, A. - Colonna, M. - Cozma, M.D. - Czech, B. - De Filippo, E. - Di Toro, M. - Famiano, M. - Gašparić, I. - Grassi, L. - Guazzoni, C. - Guazzoni, P. - Heil, M. - Heilborn, L. - Introzzi, R. - Isobe, T. - Kezzar, K. - Kiš, M. - Krasznahorkay, A. - Kurz, N. - La Guidara, E. - Lanzalone, G. - Le Févre, A. - Leifels, Y. - Lemmon, R.C. - Li, Q.F. - Lombardo, I. - Lukasik, J. - Lynch, W.G. - Marini, P. - Matthews, Z. - May, L. - Minniti, T. - Mostazo, M. - Pagano, A. - Pagano, E.V. - Papa, M. - Pawlowski, P. - Pirrone, S. - Politi, G. - Porto, F. - Reviol, W. - Riccio, F. - Rizzo, F. - Rosato, E. - Rossi, D. - Santoro, S. - Sarantites, D.G. - Simon, H. - Skwirczynska, I. - Sosin, Z. - Stuhl, L. - Trautmann, W. - Trifiro, A. - Trimarchi, M. - Tsang, M.B. - Verde, G. - Veselský, Martin - Vigilante, M. - Wang, Y. - Wieloch, A. - Wigg, P. - Winkelbauer, J. - Wolter, H.H. - Wu, P. - Yennello, S. - Zambon, P. - Zetta, L. - Zoric, M. Results of the ASY-EOS experiment at GSI: The symmetry energy at suprasaturation density. In Physical Review C, 2016, vol. 94, no. 3, 034608. (2015: 3.146 - IF, Q2 - JCR, 1.993 - SJR, Q1 - SJR, karentované - CCC). (2016 - Current Contents, WOS, SCOPUS). ISSN 2469-9985. Dostupné na: https://doi.org/10.1103/PhysRevC.94.034608 (88 citations)
4. Hsu, Chen-Hsuan - Staňo, Peter - Klinovaja, Jelena - Loss, Daniel. Majorana Kramers pairs in higher-order topological insulators. In Physical Review Letters, 2018, vol. 121, no. 19, art. no. 196801. (2017: 8.839 - IF, Q1 - JCR, 3.622 - SJR, Q1 - SJR, karentované - CCC). (2018 - Current Contents, WOS, SCOPUS). ISSN 0031-9007. Dostupné na: https://doi.org/10.1103/PhysRevLett.121.196801 (88 citations)
5. Dusza, Ján - Švec, Peter Jr. - Girman, Vladimír - Sedlák, Richard** - Castle, Elinor - Csanádi, Tamás - Kovalčíková, Alexandra - Reece, Michael J. Microstructure of (Hf-Ta-Zr-Nb)C high-entropy carbide at micro and nano/atomic level. In Journal of the European

Ceramic Society, 2018, vol. 38, no. 12, p. 4303-4307. (2017: 3.794 - IF, Q1 - JCR, 1.068 - SJR, Q1 - SJR, karentované - CCC). (2018 - Current Contents). ISSN 0955-2219. Dostupné na: https://doi.org/10.1016/j.jeurceramsoc.2018.05.006 (81 citations)

6. Liu, Y. - Palotás, Krisztián - Yuan, X. - Hou, T. - Lin, H.** - Li, Y.** - Lee, S.-T. Atomistic origins of surface defects in CH3NH3PbBr3 Perovskite and their electronic structures. In ACS Nano, 2017, vol. 11, no. 2, p. 2060-2065. (2016: 13.942 - IF, Q1 - JCR, 6.948 - SJR, Q1 - SJR, karentované - CCC). (2017 - Current Contents). ISSN 1936-0851. Dostupné na: https://doi.org/10.1021/acsnano.6b08260 (80 citations)
7. Klinovaja, J. - Staňo, Peter - Loss, D. Topological floquet phases in driven coupled Rashba nanowires. In Physical Review Letters, 2016, vol. 116, no. 17, 176401. (2015: 7.645 - IF, Q1 - JCR, 4.656 - SJR, Q1 - SJR, karentované - CCC). (2016 - Current Contents, WOS, SCOPUS). ISSN 0031-9007. Dostupné na: https://doi.org/10.1103/PhysRevLett.116.176401 (79 citations)
8. Heinosaari, T. - Miyadera, T. - Ziman, Mário. An invitation to quantum incompatibility. In Journal of Physics A: Mathematical and Theoretical, 2016, vol. 49, no. 12, 123001. (2015: 1.933 - IF, Q1 - JCR, 1.028 - SJR, Q1 - SJR, karentované - CCC). (2016 - Current Contents). ISSN 1751-8113. Dostupné na: https://doi.org/10.1088/1751-8113/49/12/123001 (62 citations)
9. Khodabakhshi, F.** - Arab, S.M. - Švec, Peter - Gerlich, A.P. Fabrication of a new Al-Mg/graphene nanocomposite by multi-pass friction-stir processing: Dispersion, microstructure, stability, and strengthening. In Materials Characterization, 2017, vol. 132, p. 92-107. (2016: 2.714 - IF, Q1 - JCR, 1.222 - SJR, Q1 - SJR, karentované - CCC). (2017 - Current Contents). ISSN 1044-5803. Dostupné na: https://doi.org/10.1016/j.matchar.2017.08.009 (54 citations)
10. Verma, Ankit - Thakur, Sourbh** - Mamba, Gcina - Prateek - Gupta, Raju Kumar - Thakur, Pankaj - Thakur, Vijay Kumar. Graphite modified sodium alginate hydrogel composite for efficient removal of malachite green dye. In International Journal of Biological Macromolecules, 2020, vol. 148, p. 1130-1139. (2019: 5.162 - IF, Q1 - JCR, 0.972 - SJR, Q1 - SJR, karentované - CCC). (2020 - Current Contents, WOS, SCOPUS). ISSN 0141-8130. Dostupné na: https://doi.org/10.1016/j.ijbiomac.2020.01.142 (51 citations)

2.2.5. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations in the assessment period (2015– 2020). The cited papers must bear the address of the institute

1. Vladimír Bužek, 2700 WOK
2. Peter Švec, 1483 WOK
3. Peter Staňo, 1159 WOK
4. Peter Markoš, 1134 WOK
5. Peter Šiffalovič, 687 WOK
6. Mário Ziman, 654 WOK
7. Eva Majková, 623 WOK
8. Matej Jergel, 617 WOK
9. Marián Krajči, 605 WOK
10. Martin Venhart, 440 WOK

2.2.6. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations obtained until 2020. The cited papers must bear the address of the Institute

1. Vladimír Bužek, 11256 WOK
2. Peter Markoš, 4039 WOK
3. Peter Švec, 3257 WOK
4. Marián Krajčí, 1971 WOK
5. Matej Jergel, 1769 WOK
6. Peter Staňo, 1652 WOK
7. Štefan Olejník, 1545 WOK
8. Marián Mihalkovič, 1437 WOK
9. Mário Ziman, 1399 WOK
10. Eva Majková, 1281 WOK

2.2.7. List of most-cited authors from the Institute (at most 10 % of average FTE researchers per year) and their number of citations obtained until 2021 of their papers published during the evaluation period (2016–2021). The cited papers must bear the address of the Institute

1. Peter Švec, 706 WOK
2. Peter Šiffalovič, 636 WOK
3. Peter Staňo, 588 WOK
4. Krisztián Palotás, 440 WOK
5. Eva Majková, 329 WOK
6. Matej Jergel, 272 WOK
7. Mário Ziman, 186 WOK
8. Ivan Štich, 178 WOK
9. Marek Mihalkovič 125 WOK
10. Martin Venhart, 91 WOK

2.3. Research status of the institute in international and national context

INTERNATIONAL/EUROPEAN POSITION OF THE INSTITUTE

2.3.1. List of the most important research activities demonstrating the international relevance of the research performed by the institute, incl. major projects (details of projects should be supplied under Indicator 2.4). Max. 10 items for institute with less than 50 average FTE researchers per year, max. 20 for institutes with 50 – 100 average FTE researchers per year and so on

1. **Project HELENIC-REF** - Hybrid Electric Energy Integrated Cluster concerning Renewable Fuels, H2020-FETOPEN-2014-2015-RIA, joint project of 6 partners supervised by NTUA Athens, Greece, duration 06/2015-05/2018. National coordinator SK: Peter Švec
2. **Project NEXMAG** - New Exchange-Coupled Manganese-Based Magnetic Materials M-ERA.NET project, duration 10/2015 – 09/2018. Hlavný riešiteľ za SK / project leader for Slovakia: Ing. Peter Švec, DrSc. Selected as M-ERA.Net Success story 2018, https://m-era.net/success-stories/new-exchange-coupled-manganese-based-magnetic-materials-nexmag).
3. **Project MAGSAT** – Novel soft magnetic cores tailored for use in space qualified magnetometers and satellite devices, joint bilateral project IEF SAS, IP SAS and TUBITAK-Institute of Metrology, duration 09/2018-12/2021, Principal investigator for IP SAS – Peter Svec.
4. **Project COSMAG** - From the Cosmos to the Lab: Development of the L10-FeNi Phase as a Disruptive Permanent Magnet Alternative, M-ERA.NET project, 10/2020-09/2023, partners IMDEA Nanociencia Madrid, IP SAS, IFW Dresden and IMA S.L. Barcelona (industrial partner). Principal investigator for SK – Peter Svec.
5. **Experiments at CERN and Jyväskylä.** Research group at Dpt. of Nuclear Physics is very active in the studies of exotic nuclei. Particularly study of odd-Au isotopes, where we have established a firm long-term collaboration with the University of Liverpool and University of Jyväskylä. Our group is a leading body. Within this collaboration proposals for experiments at CERN and Jyväskylä were submitted and experiments were subsequently performed.
6. **Cooperation China/SAS** 2018 – 2021, project APVV SK-CN-RD-18-000 P. Siffalovic, J. Tian, In situ growth process and controllable preparation of perovskite monolayer films
7. **Cooperation Malaysia/SAS** 2019-2021, Funding Scheme:Ministry of Higher Education, Malaysia, Grant Number:RGS/1/2019/STG05/UNIM/01/1, PI: Jan Ivančo, A high-precision Fullerene (C60) - tungsten oxide (WO_3) nanobiosensor for the non-invasive detection of acetone in human exhaled breath
8. **Project DOPE** - Dye-sensitized Solar Cell Based on Perovskite Solid-State electrolyte (DOPE), principal investigator: E. Majková. Project partners: Chung-Ang University Seoul, Middle East Technical University Ankara, Polymer Institute SAS Bratislava. FP7

Strengthening STI Cooperation between Korea and the EU, Promoting Innovation and the Enhancement of Communication for Technology-related Policy Dialogue (KONNECT)

9. **V4 — Korea Joint Research Programme** on Chemistry and Chemical Engineering, 2017–2020, Pb-free Perovskite Solar Cells with Long-term Stability (PPL), PI E. Majková. Project partners: Chung-Ang University Seoul, J. Heyrovsky Institute of Physical Chemistry Prague, Wigner Research Centre for Physics HAS Budapest, Military Institute of Engineer Technology Wroclaw, Polymer Institute SAS Bratislava.
10. **Project HiPhoP** - High dimensional quantum Photonic Platform, QuantERA project coordinated by Pascale Senellart (CNRS, France) QuantERA and including partners from Italy (Roberto Osellame, CNR and Fabio Sciarrino, University of Roma), Austria (Philip Walther, Vienna University), United Kingdom (Ian Walmsley, Oxford) and Slovakia (M. Ziman, IPSAS, Bratislava)
11. **Synchrotron beamtimes at European X-ray facilities** A large number of synchrotron beamtimes at European X-ray facilities were obtained in the competitive way, including ESRF (Grenoble, France), DESY (Hamburg, Germany), SOLEIL (Paris, France), ELLETRA (Trieste, Italy). M.Jergel is national delegate of Slovakia in the European Synchrotron and FEL Users Organization (ESUO).
12. **The Memorandum of Understanding** with iThemba Labs (Cape Town, South Africa) has been signed. The collaboration focuses on development of tape transportation systems for experiments with radioactive-ion beams and on applications of BEGe detectors.
13. **Cooperation CNR/SAS** 2016 – 2018, project Š. Luby, R. Rella, Advanced nanoparticle-based resistive-optoplasmonic solid-state chemical gas sensors with high sensitivity for environment protection, health improvement and explosive detection.
14. **Project QISS** JTF-61466 The Quantum Information Structure of Spacetime funded from Templeton Foundations (01/12/2019 - 31/08/2022), coordinated by Carlo Rovelli and Marios Chrisodoulou. Consortium includes more than 12 partners from all the continents.
15. **JINR collaboration** Investigation of relativistic nuclear interactions at the NUCLOTRON/NICA accelerator complex. JINR theme 02-1-1087-2009/2023, Collaboration led by Štefan Gmuca.

2.3.2. List of international conferences (co)organised by the institute

Researchers of the Institute of Physics are involved in the organisation of 30 scientific conferences. The following regular international workshops and conferences.

Applied Physics of Condensed Matter - APCOM conferences (http://kf.elf.stuba.sk/~apcom/)

The series started in 1995 with the workshop "Solid State Physics and Radioactive Irradiation". Next three years the name of this workshop was „Effect of NonStandard External Factors on Physical Properties of Solids“. Since 1999, its name has transformed to the current name "Applied Physics of Condensed Matter" (APCOM). APCOM provides an unique opportunity for experts in the field of applied physical research of condensed matter to come together and share their visions of future development and in the area of application of devices for example in electrical and nuclear power engineering, electronic and optical communication etc. The main focus of the conference is on presentation of both theoretical and experimental results, partly also of both computer simulation results and specific measurements techniques in the investigation of physical properties and structure of bulk solids and structures, thin solid films, ultrathin organic polymer films, micro- and nanostructures etc., exposed to the influence of a wide range of specific external factors. This international conference is co-orginazed by the Department of Metal Physics in collaboration with research teams at Slovak Technical University, University of Žilina and Slovak Physical Society that is hosted at our address.

- APCOM 2021, Štrbské Pleso, Slovakia, 23.06. – 25.06.2021
- APCOM 2019, Štrbské Pleso, Slovakia, 19.06. – 21.06.2019
- APCOM 2018, Štrbské Pleso, Slovakia, 20.06. – 22.06.2018
- APCOM 2017, Štrbské Pleso, Slovakia, 12.06. – 14.06.2017
- APCOM 2016, Štrbské Pleso, Slovakia, 22.06. – 24.06.2016

Central European Quantum Information Processing - CEQIP workshops (http://www.ceqip.eu)

CEQIP workshops are traditionally focused on current challenges and paradigms of mathematical and computational aspects of emerging quantum technologies. One of its strengths is the traditionally strong social program creating a very friendly and creative atmosphere. It has been organized since 2004 by researchers from the Research Center for Quantum Information jointly with Quantum Information Laboratory from Masaryk University in Brno. Because of uncertainties with covid implying certainties regarding travel uncertainties we skipped the organisations in 2020, 2021 and 2022.

- CEQIP 2019 Skalica, Slovakia, 03.06. – 06.06.2019, http://ceqip.eu/2019/
- CEQIP 2018 Smolenice, Slovakia, 13.06. – 16.06.2018, http://ceqip.eu/2018/
- CEQIP 2017 Smolenice, Slovakia, 31.05. – 03.06.2017, http://ceqip.eu/2017/
- CEQIP 2016 Valtice, Czech republic, 16.06. – 19.06.2016, http://ceqip.eu/2016/

Isospin, STructure, Reactions and energy Of Symmetry - ISTROS conferences

(https://www.fu.sav.sk/fileadmin/user_upload/oddelenia/ojf/nph/events/ISTROS/)

Istros is the ancient name of the river Danube, flowing through Bratislava, the capital of Slovakia and the seat of the medieval university Academia Istropolitana. The conference of the same name, taking place in the wine-producing area of Little Carpathian hills in Bratislava's hinterland, aims at providing a platform for meeting of international and Slovak scientists active in the field of nuclear physics, specifically dealing with experimental and theoretical aspects of physics of exotic nuclei and states of nuclear matter. It is organized every second year by researchers at the Department of Nuclear Physics.

- ISTROS 2019, Častá-Papiernička, Slovakia, 20.10. – 25.10. 2019
- ISTROS 2017, Častá-Papiernička, Slovakia, 14.05. – 19.05. 2017

Progress in Applied Surface, Interface and Thin Film Science - SURFINT-SREN conferences

- SURFINT-SREN 2021, Smolenice, Slovakia, 22.11. – 25.11. 2021
  https://lm.uniza.sk/~jurecka/SURFINT2021/
- SURFINT-SREN 2019, Florence, Italy,18.11. – 21.11. 2019
  https://lm.uniza.sk/~jurecka/konferencie/SURFINT-2019
- SURFINT-SREN 2017, Florence, Italy, 20.11. – 23.11. 2017
  https://lm.uniza.sk/~jurecka/konferencie/SURFINT-2017

Solid State Surfaces and Interfaces - SSSI conferences

- SSSI 2020, Smolenice, Slovakia, 23.11. – 26.11. 2020
  https://lm.uniza.sk/~jurecka/SSSI-2020/
- SSSI 2018, Smolenice Castle, Slovakia , 19.11. – 22.11. 2018
  https://lm.uniza.sk/~jurecka/konferencie/SSSI-2018/?str=8
- SSSI 2016, Hotel Signal, Piešťany, Slovakia, 21.11. – 24.11. 2016
  https://lm.uniza.sk/~jurecka/konferencie/SSSI-2016/?str=8

Events focused on material science co-organized by IPSAS

- IC-MSQUARE 2019 – 8th Int. Conference on Mathematical Modelling in Physical Sciences, Bratislava, Slovensko, 26.08. – 30.08. 2019
  https://www.icmsquare.net/index.php
- CUF-MAST 2019 – Central Europe Forum for Materials and Applications for Sensors and Transducers, 8th IC-MAST, Bratislava, Slovensko, 02.09. – 05.09. 2019
  http://www.icmast.net/
- IC-MAST 2018 – 7th International Conference on Materials and Applications for Sensors and Transducers, Bratislava, Slovensko, 24.09. – 27.09. 2018
  http://icmast.net/index.php
- New trends in solar cells, Bratislava, 19.04. – 22.04. 2016
  http://solarcells.sav.sk/

Events focused on nuclear research co-organized by IPSAS

- RNP 2019 – **Relativistic Nuclear Physics from Hundreds MeV to TeV**, Stará Lesná, Slovensko, 26.05. – 01.06. 2019 http://www.jinr.ru/posts/relativistic-nuclear-physics-from-hundreds-mev-to-tev/

Events focused on quantum technologies organized by IPAS

- IQUAS 2020 – **Informal quantum symposium**, Smolenice, Slovakia, 24.08. – 28.08. 2020 http://qute.sk/iquas/
- 2019 **QUAPITAL Summer School**, Bratislava, Slovensko, 30.09. – 04.10. 2019 https://quapital.eu/index.php?id=105
- **eduQUTE Quantum Technology School**, Bratislava, Slovensko, 19.02. – 22.02. 2018 http://www.qute.sk/
- MACROQUAS 2018 – **Optomechanical route to macroscopic quantum superpositions**, Bratislava, Slovensko, 22.03. – 23.03. 2018 http://quantum.physics.sk/conf/macroquas2018/index.php?page=home
- **Gravity in Qubits**, Smolenice, Slovensko, 21.11. – 24.11. 2018 http://www.qsimspacetime.com/
- MATHERMO 2016 – **FOCUS MEETING Mathematical foundations of quantum thermodynamics**, Smolenice, Slovensko, 06.12. – 09.12. 2016 http://quantum.physics.sk/conf/mathermo2016/index.php?page=home

General events

- SFS – **25th conference of Slovak physicists**, 06.09. – 09.09. 2021, Bratislava, Slovakia http://kf.elf.stuba.sk/~25konferencia/index.html
- **Physics in Fuzzy Spaces**, Stará Lesná, Slovensko, 26.09. – 01.10. 2016 http://sophia.dtp.fmph.uniba.sk/~tatry/index16.html
- **C-MAC Days 2016**, Bratislava, Slovensko, 21.11. – 24.11. 2016 http://www.eucmac.eu/index.php?option=com_mini&site=11&Itemid=93

2.3.3. List of edited proceedings from international scientific conferences

- Progress in applied surface, interface and thin film science – solar renewable energy news 2021. SURFINT – SREN VII: extended abstract book. Ed. B. Brunner. Bratislava, Comenius Univ., 2021. 79 s. ISBN 978-80-223-5296-3
- Proceedings of 11th Solid State Surfaces and Interfaces: (Extended Abstact Book). Bratislava, Slovak Republic, Comenius University Bratislava, 2020, p. 10-12. ISBN 978-80-223-5018-1
- SURFINT - SREN IV 2019: Extended Abstract Book. Slovak Republic, Comenius University Bratislava, 2019, p. 17. ISBN 978-80-223-4811-9
- Proceedings of 10th Solid State Surfaces and Interfaces 2018 : Extended Abstract Book. Bratislava, Slovakia, Comenius University, 2018. 102 p. ISBN 978-80-223-4606-1
- Progress in Applied Surface, Interface and Thin Film Science Solar Renewable Energy News 2017: Extended Abstract Book of 5th conference SURFINT-SREN V. Bratislava, Comenius University Bratislava, 2017. 182 s. ISBN 978-80-223-4411-1
- Proceedings of the ISTROS 2015 International Conference: 2nd International Conference of the Isospin, Structure, Reactions and Energy of Symmetry 2015, May 1-6, Častá-Papiernička, Slovakia. Bratislava: FÚ SAV, 2017. 111 s.. ISBN 978-80-971975-1-3
- Proceedings of 9th Solid State Surfaces and Interfaces: Extended Abstract Book. Bratislava, Comenius University, 2016. 110 s. ISBN 978-80-223-4203-2
- C-MAC Days 2016: Program and Abstracts. Bratislava: VEDA, 2016. 65 s. ISBN 978-80-224-1540-8

2.3.4. List of journals edited/published by the institute and information on their indexing in WOS, SCOPUS, other database or no database, incl. impact factor and other metrics of journals in each year of the assessment period

Institute was traditionally publishing an indexed research journal Acta Physica Slovaca. Changing the policy a few decades ago and publishing only review papers focused on students and early-stage researchers turned out to be successful and increased the impact factor a lot. Unfortunately, the policy turned out not to be sustainable, because of the lack of motivated authors and independent submissions (without invitation) can be counted with the fingers of one hand. Also the editorial policy of the Academy has changed more than 10 years ago and does not allow us anymore to fund at least symbolically the authors for their work. Since we do not see any reason to have a low-rank journal, we decided to offer the continuation to other institutes in Slovakia. This attempt was not successful so far and we decided to stop publishing Acta Physica Slovaca.

- 2021 Impact Factor 0.000
- 2020 Impact Factor 0.000
- 2019 Impact Factor 0.000
- 2018 Impact Factor 1.000
- 2017 Impact Factor 2.778
- 2016 Impact Factor 1.455

NATIONAL POSITION OF THE INSTITUTE

2.3.5 List of selected activities of national importance

1. **Slovak Quantum Technology platform** - established in March 2018 jointly with other institutes from SAS and universities with active quantum technology related research teams. This body is representing the academic community with respect to stakeholders and resulted in the establishment of **National center for quantum technologies** established by Ministry of edutation and Ministry of investments in November 2021 (qute.sk). Institute of Physics is playing the leading role as it has the largest research activity and experience in the area, also in European and international structures.

2.3.6. List of journals (published only in the Slovak language) edited/published by the institute and information on their indexing in WOS, SCOPUS, other database or no database, incl. impact factor and other metrics of journals in each year of the assessment period

NONE.

POSITION OF INDIVIDUAL RESEARCHERS IN THE INTERNATIONAL CONTEXT

2.3.7. List of invited/keynote presentations at international conferences, as documented by programme or invitation letter

Ing. Vlastimil Boháč, CSc.

22. — 24. 9. 2019, THERMAM 2019, Cesme, Turecko, „The models with accounted disturbance effects for the measurement of thermophysical properties of materials by Transient methods“

29. — 31. 5. 2017, Measurement, 11th International Conference, Smolenice, Slovensko, „Thermal Properties of Materials and their Characterization by Classic and Transient Methods“

1. – 3. 9. 2016, 3rd International Conference on Thermophysical and Mechanical Properties of Advanced Materials, THERMAM 2016, Izmir, Turecko, „The Use of Transient Methods for the Investigation of the Thermal Properties of Materials Correlated with the Changes of the Structure Caused by Effects of Different Origin“

Mgr. Ján Brndiar, PhD.

17. — 19. 1. 2017, 2nd international symposium on „Recent Trends in Analysis Techniques for Functional Materials and Devices“, Osaka, Japan, „Nanotribology and structural superlubricity on nanoscale“

RNDr. Beata Butvinová, CSc.

18. — 21. 11. 2019, SURFIN-SREN VI 2019, Progress in Applied Surface, Interface and Thin Film Science 2019, Solar Renewable Energy News VI, Florencia, Taliansko, „Impact of surfaces on the magnetic properties of Fe-based nanocrystalline ribbons“

RNDr. Stanislav Dubnička, DrSc.

8. 9. 2020, „Electromagnetic structure of mesons and baryons“, 20th Conference of Czech and Slovak Physicists (7. — 10. 9. 2020), https://indico.cern.ch/event/851173/

30. 1. — 3. 2. 2019, Excited QCD 2019, Schladming, Rakúsko, „Signs of universal vector-meson coupling constants f_rho, f_omega, f_phi with photons“

11. — 15. 3. 2018, Excited QCD 2018, Kopaonik, Srbsko, „Not all possible omega-phi mixing forms are physically acceptable“

17. — 22. 9. 2018, XXIV. International Baldin Seminar on High Energy Physics Problems, Dubna, Rusko, „Fully solvable mathematical scheme for finding out the right mass and width values of f_0(500) and rho^0(770) mesons“

22. — 25. 10. 2018, Electromagnetic Structure of Strange Baryons, GSI Darmstadt, Nemecko, „Prediction of octet hyperon EM FF's behavior by the unitary and analytic model“

Mgr. Andrej Gendiar, PhD.

7. — 8. 6. 2019, Workshop on Quantum Magnetism: Theoretical Challenges and Future Perspectives, UPJŠ Košice, Slovensko, „Majorana bound states affected by Coulomb interaction“

Ing. Štefan Gmuca, CSc.

23. — 29. 6. 2019, 38th Int. Workshop on Nuclear Theory, Borovets, Bulgaria, „Mapping of Dirac-Hartree-Fock approach onto the relativistic mean field model“

17. — 22. 9. 2018, XXIV International Seminar on High Energy Physics Problems "Relativistic Nuclear Physics and Quantum Chromodynamics", Dubna, RF, „Relativistic density functional for nuclear matter“

Ing. Matej Jergel, DrSc.

26. — 28. 3. 2018, BIT's 6th Annual Conference of AnalytiX, Miami, USA, „Pentacene Growth on Graphene by Insitu X-ray Scattering at Grazing Incidence“

24. — 26. 10. 2018, BIT's 8th Annual World Congress of NanoScience & Technology, Fukuoka, Japonsko, „Surface Engineering for Advanced X-ray Crystal Optics“

19. — 22. 11. 2018, Solid State Surfaces and Interfaces, Smolenice, „Surface Finishing of X-ray Crystal Optics After Nanomachining“

16. — 18. 3. 2017, BIT's 3rd Annual World Congress and EXPO of Smart Materials-2017, Bangkok, Thajsko, „Polymer-fullerene Phase Separation During Solvent Annealing Studied In-situ by Laboratory-based X-ray Scattering“

24. — 26. 10. 2017, BIT's 7th Annual World Congress of Nano Science & Technology, Fukuoka, Japonsko, „Tracking of Nanostructure Formation by Time-Resolved Laboratory Small-Angle X-ray Scattering“

4. 3. – 6. 3. 2016, BIT's 2nd Annual World Congress and EXPO of Smart Materials-2016, Singapur, „Real-Time Monitoring of Nanostructures and Processes at Nanoscale by Grazing-incidence Small-angle X-ray Scattering“

30. 6. – 3. 7. 2016, BIT's 6th Annual New Energy Forum, Goyang City, Korea, „Real-time X-ray Studies of the Bulk Heterojunction Formation for Active Layers of Polymer Solar Cells“

26. – 28. 10. 2016, BIT's 6th Annual World Congress of Nano Science & Technology, Singapur, „Copper Growth on Graphene Studied In-situ by Time-resolved Small-angle X-ray Scattering“

RNDr. Pavol Kalinay, CSc.

6. – 10. 6. 2016, SITGES XXV Conference, Barcelona, Španielsko, „Nonequilibrium Phenomena in Confined Systems“

prof. Ing. Štefan Luby, DrSc.

14. 9. 2020, „Graphene at the Crossroads“, VIII. Advances in Electronic and Photonic Technologies - ADEPT 2020 Conference (14. — 17. 9. 2020), Vysoké Tatry, Nový Smokovec, Slovensko, https://adept.fyzika.uniza.sk/program.php

15. 3. 2019, Int. Conf. All about People, Maribor, Alma Mater Europaea, „Participation and success rate of new EU member states in Horizon 2020 and their outlook in Horizon Europe“.

24. 4. 2019, Medz. konf. Muž Slnka, k 100. výročiu úmrtia M. R. Štefánika, Piešťany, „Návrat k Misii Štefánik“

10. — 12. 10. 2018, Danube Academies Conference, Stuttgart, Nemecko, „Participation and success rate of Danube region countries in H2020“

3. 3. 2017, Symposium Nanotechnology, European Academy of Sciences and Arts, Salzburg, Austria, „Brief history and foresight in nanoscience and nanotechnology“

14. — 18. 9. 2017, 9th Olympiad of the Mind, Kolympari, Crete, Greece, „Nanoethics – a way o humanization of technology for the common benefit“ 20. – 22. 4. 2016, Posolstvo Jána Pavla II. – Súčasné trendy a výzvy v ekonomike, vede, vzdelávaní, Poprad, SR, „The air which we are breathing“

25. 5. 2016, 14th Internat. Symposium MEMS, Bratislava, SR, „How to avoid pathological phenomena in science“

19. – 23. 6. 2016, Advances in Electronic and Photonic Technologies, Tatranská Lomnica, SR, „A brief history and foresight in nanoscience and nanotechnology“

RNDr. Eva Majková, DrSc.

25. — 27. 7. 2019, WCAM 2019 World Congress of Advanced Materials 2019, Osaka, Japonsko, E. Majkova et al., „Effect of carbon nanodots on the performance of perovskite solar cells“

13. — 15. 11. 2019, ANALYTIX2019 Europe, E. Majkova et al., „Kinetics of Nanostructure Formation by In-situ Grazing-Incidence X-ray Scattering – Three Topical Examples“

23. — 27. 10. 2018, Nano Science and Technology NANO S&T 2018, Potsdam, Nemecko, „Real time monitoring of Pentacene Growth on Graphene by In-situ X-ray Scattering at Grazing Incidence“

5. — 8. 3. 2018, 21st Sede Boker Symposium Sede for Solar Electricity Product, Ben Gurion University, Izrael, „Time-resolved GIWAXS studies of the organometallic perovskite layer structure annealed at various temperatures correlated with DOS mapping by ER EIS“

11. — 13. 5. 2018, 3rd Int. Conference on Nanomaterials: Synthesis, Characterization and Applications (ICN 2018), Kottayam, Kerala, India, „Uniform assemblies of 2D nanosheets: formation, properties and applications“

18. — 21. 9. 2017, EMRS Fall Meeting Varšava, Poľsko, „Time-resolved GIWAXS studies of the organometallic perovskite layer structure annealed at various temperatures correlated with DOS mapping by ER EIS“

13. — 17. 11. 2017, ICTF 17, International Conference on Thin Films 2017, New Delhi, India, „Kinetics of thin films growth studied by time-resolved small-angle x-ray scattering“

20. 11. 2017, 17 Energy Conversion Symposium, Chung Ang University, Seoul, Korea, „Nanofilms composed of 2D nanosheets“

21. — 24. 11. 2017, 4th International Conference on Advanced Electromaterials, ICEA 2017, Jeju, Korea, „Nanofilms composed of 2D nanosheets: formation, properties and applications“ 4th Korea – EU Bilateral Workshop on Advanced Materials processing, Jeju, Korea, „Time-resolved GIWAXS Studies of the CH3NH3PbI3 xClx Layer Structure Correlated with Photoluminescence and DOS Mapping“

RNDr. Ľubomír Martinovič, CSc.

18. — 12. 9. 2017, Light Cone 2017, Mumbai, India, „The Schwinger model: operator solutions and a genuine light-front treatment“

10. — 14. 7. 2017, Symmetry Methods in Physics, Jerevan, Armensko, „Massless light-front fields and conformal symmetry in two dimensions“

19. – 25. 6. 2016, Group31, 31st International Colloquium on Group Theoretical Methods In Physics, Rio de Janeiro, Brazília, „Two-dimensional massless light-front fields and conformal field theory“

5. – 8. 9. 2016, Light Cone 2016, IST Universidade de Lisboa, Portugalsko, „Quantum field theory in two dimensions: light-front versus space-like solutions“

RNDr. Marek Mihalkovič, CSc.

13. — 16. 12. 2021, Materials Research Meeting 2021, Pacifico Yokohama, Japonsko, „Coherent interface between clathrate and diamond structures“

3. – 5. 2018, ECMetAC Days 2018, Poznań, Poľsko, „Three dimensional local atomic configurations of decagonal AlNiCo quasicrystal studied by x-ray fluorescence holography“

RNDr. Naďa Mrkývková, PhD.

15. — 18. 10. 2019, SPICE 2019, Mainz, Nemecko, „pi-Conjugated Molecules on Few-Layered MoS substrate“

8. — 11. 7. 2019, 2nd International Conference on: Interface Properties in Organic and Hybrid Electronics: Perspectives & Key Challenges, Cergy Pontoise, Francúcsko, „Real-time study of diindenoperylene thin-film structure on MoS2 monolayer“

4. — 8. 3. 2019, NESY winter school 2019, Rakúsko, „Diindenoperylene Molecules on 2D MoS2 Substrates"

RNDr. Emil Pinčík, CSc.

15. — 17. 11. 2018, The 4th International Congress on Advanced Materials, Zhenjiang, Čína, „Black silicon and porous silicon - application in solar cells“

4. — 7. 12. 2017, 82nd IUVSTA Workshop, Okinawa, Japonsko, „About plasma anodic oxidation of high-doped GaAs“

15. – 18. 3. 2016, Fórum OPTONIKA – EOS LIGHTtalks, 24. veľtrh AMPER, Brno, Česká Republika, „Black silicon and porous silicon photoluminiscence“

5. – 9. 6. 2016, 2016 EMN Summer Meeting and Photodetector Meeting, Westin Resort and Spa, Cancun, Mexico, „Physical Properties and Light-Related Applications of Black Silicon Structures“

11. – 13. 11. 2016, Second International Conference on Advanced Materials for Power Engineering (ICAMPE – 2016), Kottayam, Kerala, India, „Optical Properties of Black Silicon and Porous Silicon – Application in Solar Cell Structures“

doc. RNDr. Martin Plesch, PhD.

26. 1. 2016, AMPSROC 2016, Kaohsiung, Taiwan, „Device independent random number generation“

27. 1. 2016, AMPSROC 2016, Kaohsiung, Taiwan, „International Young Physicists' Tournament“

RNDr. Daniel Reitzner, PhD.

7. 1. 2019, Trojkráľová konferencia, Praha, ČR, „Quantum Incompatibility“

15. 9. 2019, Cryocourse 2019, Zemplínska šírava, SK, „Introduction to Quantum Information“

30. 9. — 1. 10. 2019, Quapital summer school, Bratislava, SK, „Invitation to Quantum Information“

10. — 15. 9. 2018, MIPT (PhysTech) QUANT 2018, MIPT, Moskva, RF, „Decoherence in Quantum-Walk Searches“

28. 8. — 1. 9. 2017, Quantum Incompatibility 2017 Workshop, Maria Laach, Nemecko, „Incompatibility of unbiased qubit observables and Pauli channels“

Mgr. Michal Sedlák, PhD.

8. — 12. 1. 2018, Hong Kong workshop on quantum information and foundations, The Role of The Observer, Hong Kong, Čína, „Perfect Probabilistic Storing and Retrieving of Unitary channels“

10. — 15. 9. 2018, MIPT (PhysTech) QUANT 2018, MIPT, Moskva, RF, „Perfect probabilistic storing and retrieving of unitary channels“

18. – 22.1.2016 Toulouse, France, Linear Matrix Inequalities, Semidefinite Programming and Quantum Information Theory 2016, „Incompatibility of quantum testers“

Ing. Peter Švec, DrSc.

21. — 27. 10. 2021, 7th International Conference on Superconductivity and Magnetism (ICSM2021), Milas-Bodrum, Turecko, „Tailoring of GMI sensor characteristics of soft magnetic ribbons by layering and magnetic field annealing“

2. – 6. 7. 2018, 16th IUPAC Conference on High Temperature Materials Chemistry (HTMC-XVI), Ekaterinburg, RF, „Processing of New Soft and Hard Magnetic Systems Prepared by Rapid Quenching of the Melt“

25. – 28. 9. 2018, ICAMP-9, Shenyang, Čína, „Preparation and processing of new rapidly quenched soft and hard magnetic systems“

8. – 10. 10. 2018, XIII Symposium of Magnetic Measurements & Modeling, Cracow - Wieliczka, Poľsko, „New developments in rapidly quenched soft and hard magnetic alloys“

19. – 21. 5. 2016, SCIT 2016 – Systems, Control and Information Technology, Przemysłowy Instytut Automatyki i Pomiarów PIAP, Warsaw, Poľsko, „Selected trends in new rapidly quenched soft magnetic materials“

4. – 9. 9. 2016, LAM-16 – 16th International Conference on Liquid and Amorphous Metals, Bonn-Bad Godesberg, „Structure-property relationship in rapidly quenched alloys correlated with melt precursor processing“

Ing. Peter Švec Jr., PhD.

22. — 26. 8. 2021, MC 2021 Microscopy Conference, Viedeň, Rakúsko, www.mc2021.at, „Phase evolution clarification in Al-Ni-Co-RE amorphous alloys with varying Ni/Co ratio“

27. 8. — 1. 9. 2017, Intl. Conf. Rapidly Quenched and Metastable Materials (RQ16), Leoben, Rakúsko, „Advanced Structure Analysis of Hard Magnetic Al-Mn Alloys“

prof. Ing. Ivan Štich, DrSc.

19. – 24. 8. 2018, European Advanced Material Congress, Stokholm, Švédsko, „Many-body quantum Monte Carlo study of 2D materials: cohesion and band gap in single-layer phosphorene“

7. – 17. 9. 2018, 19th International Microscopy Congress, Sydney, Austrália, „Atomic Force Microscopy Study of Superlubricity and its Limitations“

9. v 23. 6. 2018, 3rd International Symposium on Recent Trends in the Elucidation and Function Discovery of Next Generation Functional Materials of Surface/Interface Properties, Osaka, Japonsko, „Subatomic-scale resolution with SPM: Co adatom on p(2-1)Cu(110):O“

17. — 19. 1. 2017, 2nd international symposium on „Recent Trends in Analysis Techniques for Functional Materials and Devices“, Osaka, Japonsko, „Atomic Force Microscopy Manipulation of Magnetic Atoms on a Surface“

3. 3. 2017, European Academy of Sciences and Arts(EASA), Symposium Nanotechnology, Salzburg, Rakúsko, „Atom by atom“

7. — 9. 12. 2017, The 25th International Colloquim on Surface Probe Microscopy, Atagawa Heights, Shizuoka, Japonsko, „SPM techniques for atomic- and subatomic-scale imaging and Manipulation“

RNDr. Kamil Tokár, PhD.

27. — 31. 8. 2017, International Symposium Dynamical Properties of Solids 36 (DyProSo 2017), Cracow, Poland, „Control of vibrational properties of multilayer phosphorene“

Mgr. Martin Venhart, PhD.

23. — 27. 10. 2017, CEA Saclay, Paris, Francúzsko, „TATRA decay station at ISOLDE and shape coexistence in odd-mass Au nuclei“

doc. Mgr. Mário Ziman, PhD.

14. —17.6.2021, 52 Symposium on Mathematical Physics "Channels, Maps and All That" ,Torun, Poľsko, „Probabilistic storing of quantum dynamics“

4. 12. 2020, „Optimal probabilistic storage and retrieval“, Quantum Foundations, Technology and Applications 2020, http://210.212.36.85/QFTA20/

24. 5. 2019, Quantum resources and their application, Sopot, Poľsko, „Quantum learning of quantum gates“

17. 10. 2019, Workshop on fundamentals of quantum information processing, Mohali, India, „Quantum Encryption“

18. 10. 2019, Quantum Foundations, Technologies and Applications QFTA-2019, Mohali, India, „Incompatibility and nonlocality of quantum process measurements“

2.3.8. List of researchers who served as members of the organising and/or programme committees

Year / No. of researchers in	Programme committees	Organising committee	Organising and Programme committees
2016	7	3	9
2017	5	7	4
2018	5	6	3
2019	9	4	14
2020	5	1	6
2021	2	0	3

2016: E. Pinčík, P. Rapčan, D.Reitzner, M. Sedlák, P. Švec, M. Ziman

2017: M. Balogh, V. Boháč, J. Klimo, E. Majková, Prajapati P. M., D. Reitzner, A. Repko, M. Sedlák, O. Šauša, P. Švec, R. Urban, M. Venhart, M. Veselský, M. Ziman;

2018: M. Balogh, S. Hlaváč, I. Janotová, M. Jergel, M. Mihalkovič, D. Reitzner, Matúš Sedlák, Michal Sedlák, P. Švec, M. Zemanová, M. Ziman;

2019: S. Bačová, M. Balogh, R. Brunner, Š. Gmuca, A. Herzáň, S. Hlaváč, M. Jergel, G. Kantay, J. Kliman, V. Matoušek, M. Mihalkovič, E. Pinčík, P. Rapčan, D. Reitzner, Matúš Sedlák, Michal Sedlák, P. Švec, M. Venhart, M. Ziman, P. Zitto;

2020: S. Bačová, V. Boháč, R. Brunner, Š. Gmuca, Š. Luby, E. Majková, D. Nagaj, E. Pinčík, D. Reitzner, M. Sedlák, O. Šauša, M. Ziman;

2021: V. Boháč, Š. Luby, P.Rapčan, O. Šauša, P. Švec; M. Ziman,

2.3.9. List of researchers who received an international scientific award

Luby Štefan

Honorary Senator of European Academy of Sciences and Arts 2021

Grantor: European Academy of Sciences and Arts

Description: After 15 years of membership in the Senate of the Academy, of which 10 years as Vice President awarded the honorary title of Honorary Senator of EAVU

Mihalkovič Marek

Jean Marie Dubois Award 2016

Grantor: International Conference on Quasicrystals

Description: Ocenenie "for theoretical work that has enabled and demonstrated the simulation of thermodynamic and dynamic properties of quasicrystals, based on realistic atomic-scale models and energetics".

Position of individual researchers in the national context

2.3.10. List of invited/keynote presentations at national conferences, as documented by programme or invitation letter

Mgr. Cyril Adamuščín, PhD.

26. 5. — 1. 6. 2019, RNP 2019, Stará Lesná, „Vector meson dominance model of hyperons and

issue of the F,D currents“

Ing. Ján Ivančo, DrSc.

8. 9. 2021, 25th SFS Conference, Bratislava, Slovakia, „Electronic Structure of Molecular Films and Associated Interfaces“

Ing. Štefan Gmuca, CSc.

2. — 5. 9. 2019, 24th Conference of Slovak Physicists, Žilina, "When the Universe Dies"

prof. Ing. Štefan Luby, DrSc.

6. 9. 2021, 25th SFS Conference, Bratislava, Slovakia, "Slovak physics in the information age - gains and losses"

9. 9. 2021, 38th Technology Days, UK, Bratislava, Slovakia, „Nanoscience, from manipulation of atoms to human needs“

29. 1. 2020, 30 years of SES NEZES, Bratislava, Slovakia, "Slovak science in international competition"

13. 11. 2019, Š. Luby, P. Kopčanský, J. Ivančo, XXIII. Congress of the Slovak Medical Society, Bratislava, "Nanotechnologies in Medicine"

23. — 26. 10. 2018, Nanoelectronics and Vacuum, School of Vacuum Technology, Vysoké Tatry, „Expansion of vacuum technology into microelectronics and nanoelectronics“

4. 12. 2018, Rectorate of STU for Alumni STU, “From the history of Czechoslovakia. microelectronics "

29. — 31. 5. 2017, Summer School of Vacuum Technology, Czech and Slovak Vacuum Society, Topoľčianky, SR, "Graphene - a member of the carbon materials family"

22. — 23. 6. 2017, XXX DidMatTech 2017, Trnava University in Trnava, „Humour in Science“

21. — 23. 9. 2017, Int. Conf. Physics, Technology and Ethics, University of Zilina, Zilina, SR, „Ethical challenges in nanometrology“

27. – 28. 9. 2017, conference: History, present and future of electrical engineering in Slovakia, Banská Štiavnica, SR, "Transistor - microelectronics - nanoelectronics - global context"

10. 10. 2017, National Conference on Ethical Issues in Science and Technology. Slovak Committee for Bioethics - UNESCO, MFA SR, Bratislava, SR, "Nanoethics"

8. – 12. 11. 2016, 19th School of Vacuum Technology Vacuum and new materials, Štrbské pleso, Slovak Republic, "Iron oxide nanoparticles, preparation, characterization, applications

RNDr. Eva Majková, DrSc.

2. — 3. 10. 2019, 21. School of Vacuum Technology, Štrbské Pleso, "Nanolayers prepared by physical vapor deposition"

doc. RNDr. Martin Plesch, PhD.

18. — 19. 10. 2018, Technology Forum (AtoS), Jasná, Low Tatras, "Quantum Computers: Today's State and Perspective"

RNDr. Anton Repko, PhD.

26. 5. — 1. 6. 2019, RNP 2019, Stará Lesná, „Nuclear structure by inelastic electron scattering“

Ing. Peter Švec, DrSc.

13. – 16. 6. 2016, CSMAG'16, Košice, Slovakia, 2 lectures „Development of selected amorphous and nanocrystalline soft magnetic systems with enhanced functional properties "a" Stress Monitoring & Annihilation In Steels Based On Magnetic Techniques "

Mgr. Martin Venhart, PhD.

8. 9. 2021, 25th SFS Conference, Bratislava, Slovakia, „Nuclear structure of light Au isotopes“

4. — 7. 9. 2017, 19th Conference of Czech and Slovak Physicists, Prešov, Slovakia, "TATRA Spectrometer at CERN: Study of the Structure of Gold Atomic Nuclei"

2.3.11. List of researchers who served as members of organising and programme committees of national conferences

Year / No. of researchers in	Programme committees	Organising committee	Organising and Programme committees
2016	0	0	0
2017	1	0	0
2018	0	1	0
2019	0	0	0
2020	0	0	0
2021	1	4	0

2016: –

2017: Š. Gmuca;

2018: M. Balogh;

2019: –

2020: –

2021: E. Bartoš, A. Gendiar, Š. Gmuca, M. Jergel, P. Šiffalovič;

2.3.12. List of researchers who received a national scientific award

Scientists of the year (Grantor: CVTI SR, ZSVTS, SAS)

2017 **Reitzner Daniel,** Young scientist of the year 2017

SAS Award (grantor: Presidium SAS)

2021 **Matoušek Vladislav, Venhart Martin**

category **Development of Scientific Infrastructure**

Description: The award was given for the development of the TATRA spectrometer and the implementation of the IS521 experiment at CERN

Presidium SAS publication award

2021 **Naďa Mrkývková, Vladimír Held, Peter Nádaždy, Riyas Subair, Eva Majková, Matej Jergel, Peter Šiffalovič,** For the publication: “Combined in situ photoluminescence and X-ray scattering reveals defect formation in Lead-Halide Perovskite films.”

2020 **Bodík Michal, Hagara Jakub, Halahovets Yuriy. Jergel Matej, Majková Eva, Mrkývková Naďa, Nádaždy Peter, Šiffalovič Peter, Tokár Kamil,** For the publication: "Diindenoperylene thin-film structure on MoS2 monolayer"

Sedlák Michal, Ziman Mário, For the publication: „Optimal probabilistic storage and retrieval of unitary channels“

2017 **Brndiar Ján, Štich Ivan, Turanský Robert,** For publication “Subatomic-scale force vector mapping above a Ge(001) dimer using bimodal atomic force microscopy”

Price for science (Grantor: Slovak Physical Society)

2021 **Gmuca Štefan**

Luby Štefan

2018 **Kliman Ján**

SFS Medal (Grantor: Slovak Physical Society)

2020 **Gmucová Katarína**

Presidium SAS medals (Grantor: Presidium SAS)

2018 **Bužek Vladimír,** SAS Gold Medal

2017 **Bužek Vladimír,** Most cited publications

2016 **Marián Krajčí**, Honorary plaque of SAS Dionýz Ilkovič for merits in physico-chemical sciences

OTHER MEDALS AND AWARDS

Luby Štefan

2021 FEI STU - 80 years of teaching electrical engineering. engineers in Slovakia

2020 M.R.Štefánik society - Silver medal

Slovak Writers 'Association, Non-Fiction Writers' Club - V. Zamarovsky National Award for contribution to non-fiction

2019 Ministry of Defence of the Slovak Republic - Plaque on the 25th anniversary of the Forces of the Slovak Republic

2018 S. Kassay Foundation - Excellence Prize

Slovak Vacuum Society - Medal on the 25th anniversary of the Slovak Vacuum Society

CVTI SR - Medal on the 80th anniversary of CVTI SR

2016 Rector of STU - STU medal

Supervisory Board of IDC Holding - IDC Holding Gold Medal

Slovak Medical Society - Gold medal of the Slovak Medical Society

2.4. Research grants and other funding resources

(List type of project, title, grant number, duration, total funding and funding for the institute, responsible person in the institute and his/her status in the project, e.g. coordinator "C", work package leader "W", investigator "I". Add information on the projects which are interdisciplinary, and also on the joint projects with several participating SAS institutes)

International projects

2.4.1. List of major projects of Framework Programmes of the EU (which pilar), NATO, COST, etc.

TYPE	PROJECT TITLE	DURATION	ACRONYM GRANT NUMBER	TOTAL BUDGET (IPSAS)	NAME (ROLE)
ERASMUS+	Development of Inquiry Based Learning via IYPT	01.11.2019 30.06.2022	DIBALI 2019-1-SK01-KA201-060798		Martin Plesch (coordinator)
H2020 EXCELLENT SCIENCE	Targeting Real chemical accuracy at the EXascale	01.06.2021 30.9.2023	TREX 952165	4 998 847,50 (125 988,10)	Ivan Štich (principal investigator)
H2020 FET OPEN	Hybrid Electric Energy Integrated Cluster concerning Renewable Fuels	01.06.2015 31.08.2018	HELENIC-REF 665318	2 578 386 (444 000)	Peter Švec (principal investigator)
H2020 RIA BBI-JTI	Valuable Products from Algae Using New Magnetic Cultivation and Extraction Techniques	01.04.2017 31.03.2020	VALUEMAG 745695	4 789 000 (417 000)	Peter Švec (principal investigator)
COST	High-performance Carbon-based composites with Smart properties for Advanced Sensing Applications	10/2020 10/2024	COST CA19118	(3 588)	Peter Šiffalovič (principal investigator)
COST	Trapped Ions: Progress in classical and quantum applications	12/2019 09/2022	TIPICQA CA17113	(6 597)	Vladimír Bužek (principal investigator)
COST	Quantum Technologies in Space	10/2016 10/2020	COST CA15220	(13 000)	Ziman, M. (principal investigator)
COST	Multi-Functional Nano-Carbon Composite Materials Network	04/2016 04/2020	COST CA15107	(12 000)	Šiffalovič, P. (principal investigator)

COST	Stable Next-Generation Photovoltaics: Unravelling Degradation Mechanisms of Organic Solar Cells by Complementary Characterization	02/2015 03/2018	COST MP 1307	(6 800)	Eva Majková (principal investigator)
COST	Thermodynamics in Quantum Regime	12/2014 12/2018	COST MP1403	(11 150)	Vladimír Bužek (principal investigator)
COST	Advanced phase contrast X-ray imaging and tomographic technics	01/2014 05/2017	COST MP1207	(4800)	Šiffalovič, P. (principal investigator)

National projects, incl. international projects with only national funding

2.4.2. List of ERA-NET projects funded from SAS budget

TYPE	PROJECT TITLE	DURATION	ACRONYM GRANT NUMBER	TOTAL BUDGET (IPSAS)	NAME (ROLE)
M.ERA NET	Surface engineering and advanced coatings for the next generation of X-ray diffractive optics	01.09.2013 31.08.2016	XOPTICS	75 000	Peter Šiffalovič (principal investigator)
V4-japan/JRP/	Perovskites Quantum Dots based Broadband Detectors – from a quantum dot to a functional detector	11/2021 10/2024	2021/96/PeDET	4 133	Peter Šiffalovič (principal investigator)
M-ERA.NET 2	From the Cosmos to the Lab: Development of the L10-FeNi Phase as a Disruptive Permanent Magnet Alternative	10/2020 09/2023	COSMAG	25 000	Peter Svec
Taiwan SAS_MOST	Tensor Network States Algorithms and Applications	01/2021 12/2022	TNSAA JRP/2020/1122/	25 000	Andrej Gendiar
QuantERA	Superinductor-based Quantum Technologies with Ultrastrong Couplings	01/2020 05/2024	SiUCs QuantERA/2019/888	50 000	Miroslav Grajcar
JRP - TÜBITAK	Novel soft magnetic cores tailored for use in space qualified magnetometers and satillite devices	09/2018 12/2021	MAGSAT	37 500	Peter Svec
QuantERA	High dimensional quantum Photonic Platform	04/2018 03/2021	HipHop	75 000	Mario Ziman
JRP V4-Kórea	Pb-free Perovskite solar cells with Long-term stability	01/2017 10/2020		37 500	Eva Majkova
SAS - TUBITAK JR	Towards low-cost and highly efficient polymer-based organic photovoltaics via Incorporation of graphene and noble metal nanoparticles	9/2013 8/2016		20 833	Eva Majkova
SAS- TUBITAK JRP	Physically processed rapidly quenched alloys for detection of low magnetic fields	11/2013 10/2016	FX-GATEX	20 833	Peter Svec

2.4.3. List of projects of the Slovak Research and Development Agency, APVV

Project title	Project ID	Project start	Project end	Budget	Coordinator	IPSAS PI
Quantum Information of ManyBody Systems	APVV-0808-12	01/10/13	30/09/2017	180000	Bužek	
Progressive nanocrystalline and amorphous materials for application in selected high-power electronic devices	APVV-0460-12	01/10/13	30/09/2016	250000	EVPU a.s., Nova Dubnica,	FU SAV - Švec
Study of hadron structure and the test of Standard Model with the more precise evaluation of QED running coupling constant at M_Z and the muon g-2 anomaly	APVV-0463-12	01/10/13	30/09/2017	115040	I - Dubnička	FMFI UK – Dubničková
Nanoparticles-based sensors of gaseous biomarkers of diseases/	APVV-14-0891	01/07/15	30/06/2019	235275	FU SAV - Ivančo	UPOL SAV
Quantum theory on graphs and networks	APVV-14-0878	01/07/15	30/06/2019	152536	Ziman	
Efficent preparation of powdered magnesium hydrid directly from the magnesium melt/	APVV-14-0934	01/07/15	30/06/2018	249999	UMMS SAV, F. Simancik	FU SAV - Švec
Research of the nanomachining technology for active surfaces of the new generation of the X-ray optics	APVV-14-0745	01/07/15	30/06/2018	250000	FU SAV - Majková	ElU SAV
Graphene-based nanoplatform for detection of cancer	APVV-14-0120	01/07/15	30/06/2018	246332	UPOL SAV-dr. Omastova	FU SAV-Siffalovic, Centrum biovied SAV, UEF SAV
Štruktúra jadrovej hmoty	APVV-15-0225	01/07/16	30/06/2020	250000	FU SAV - Venhart	
Inovatívna MoS2 platforma pre diagnózu a cielenú liečbu rakoviny	APVV-15-0641	01/07/16	30/06/2020	249717	FU SAV - Šiffalovič	UPOL SAV, Centrum biovied SAV, FChPT STU, FMFI UK
Výskum fyzikálnych vlastností a kinetiky formovania vrstiev čierneho kremíka	APVV-15-0152	01/07/16	30/06/2019	279481	FU SAV - Pinčík	FEI STU, UNIZA, UK
Atomic structure and exceptional properties of	APVV-15-0621	01/07/16	31/12/2019	249510	Švec	UExF SAV - I.

intermetallics, amorphous, nanocrystalline and complex metallic alloys						Skorvanek
2D-materials and their functionalization	APVV-15-0759	01/07/16	30/06/2019	170721	FU SAV - Štich/ Brndiar	
2D materials beyond graphene: monolayers, heterostructures and hybrids	APVV-15-0693	01/07/16	30/06/2019	249300	ELU SAV	FU SAV - Šiffalovič, Danubia NanoTech, s.r.o.
Advancement of knowledge in area of advanced metallic materials by use of up-to-date theoretical, experimental, and technological procedures	APVV-15-0049	01/07/16	30/06/2020	249525	MTF STU, J. Janovec	FU SAV - Švec
The behaviour of new progressive construction materials in aggressive environment of molten salts	APVV-15-0738	01/07/16	30/06/2020	249690	UACH SAV, F. Simko	FU SAV - Švec
Exotic quantum states of low-dimensional spin and electron systems	APVV-16-0186	01/07/17	30/06/2021	218179	UPJŠ KE - doc. Strečka	FUS AV - Gendiar
Properties of the graphene-diamond interface: study on the atomic level	APVV-16-0319	01/07/17	31/12/2020	210000	FEI STU - doc. Skákalová	FU SAV - Vretenár
Physical properties of organic compounds and water confined in mesopores of inorganic matrices	APVV-16-0369	01/07/17	30/06/2021	230000	FU SAV - Šauša	UPOL SAV - Bartoš
Real-time grow studies of hybrid van der Waals heterostructures	APVV-17-0352	01/07/18	30/06/2022	100000	FU SAV - Mrkývková	ELU SAV, UPOL SAV
Tribological properties of 2D materials and related nanocomposites	APVV-17-0560	01/07/18	30/06/2022	249599	CEMEA SAV - Ťapajna	ELU SAV, UMMS SAV, FU SAV - Šiffalovič
AFM: Imaging, manipulation, atomic-scale simulation	APVV-18-0211	01/07/19	31/12/2022	190320	FU SAV - Stich	STU
Rational design of hydrogel microcapsules for immunoprotection of transplanted pancreatic islets in diabetes treatment	APVV-18-0480	01/07/19	30/06/2023	210	UPOL SAV	MLC, FU SAV - Siffalovi
Optimisation methods for quantum technologies	APVV-18-0518	01/07/19	30/06/2023	180000	FU SAV - Ziman	
Hybrid Low Dimensional Layered Materials with new	APVV-19-0465	01/07/20	31/12/2023	220000	UPOL SAV-dr.	FU SAV - Jergel

Functionalities					Omastova	
Fabrication, physics and correlated states in metallic 2D transition metal dichalcogenides	APVV-19-0365	01/07/20	30/06/2023	249036	Hulman ELU SAV	FMFI UK, FU SAV - Siffalovic
Carbon-silicon based composite anodes for Li-ion batteries.	APVV-19-0461	01/07/20	30/06/2024	249989	CEMEA SAV - Hnatko	UACH SAV, UPOL SAV, UMMS SAV, FU SAV - Siffalovic
Novel nano / micro-structured metallic materials prepared by unconventional processing routes	APVV-19-0369	01/07/20	30/06/2024	249895	FUSAV-Švec	UExF SAV KE, I. Skorvanek
Perspective electronic spin systems for future quantum technologies	APVV-20-0150	01/07/21	30/06/2025	214959	UPJŠ	FU SAV - Gendiar
Towards lithium based batteries with improved lifetime	APVV-20-0111	01/07/21	30/06/2025	249882	CEMEA SAV-Siffalovic	UPJŠ, STU, UK, FU SAV-V.Nadazdy
Nanomedical approach to fight pancreatic cancer via targeting tumorassociated carbonic anhydrase IX	APVV-20-0485	01/07/21	30/06/2025	226000	Centrum biovied SAV-dr. Švastová	CEMEA, FU SAV - Annušová
Novel multi-principal element alloys – design, characterization and properties	APVV-20-0124	01/07/21	30/06/2025	249880	STU	FU SAV - Švec
Experimental investigation of deformation and electromagnetic properties of atomic nuclei	APVV-20-0532	01/07/21	30/06/2025	180000	FU SAV-Venhart	
Surface and Bulk Defect States Analysis Using Capacitance Microscopy-Based Methods	SK-HU-2013-0031	01/01/15	31/12/2016	1950	FU SAV - Lányi	
Probing quantum networks with quantum walks	SK-PT-2015-0029	01/01/16	31/12/2017	5400	FU SAV - Reitzner	
In situ growth process and controllable preparation of perovskite monolayer films	SK-CN-18-0006	01/10/18	30/09/2021	227568	FU SAV - Šiffalovič	University of Science and Technology Beijing, China
Molecular nanostructures on two-dimensional substrates	SK-AT-20-0006	01/04/21	30/12/2022	5000	FU SAV - Mrkývková	Montanuniversität Leoben, Rakusko

2.4.4. List of projects of the Scientific Grant Agency of the Slovak Academy of Sciences and the Ministry of Education, VEGA (for funding specify only total sum obtained from all VEGA grants in particular year)

ID	Supervisor	Title	Budget 2021	Budget 2020	Budget 2019	Budget 2018	Budget 2017	Budget 2016
2/0044/21	Kalinay Pavol, RNDr., CSc.	Efekty v priestorovo ohraničených difúznych systémoch	1,990.00					
2/0067/21	Herzáň Andrej, Mgr., PhD.	Jadrová štruktúra v okolí uzavretých protónových vrstiev	27,656.00					
2/0070/21	Stich Ivan, Prof., Ing., DrSc.	Nízko-dimenzionálne materiály-manipulácia, funkcionalizácia a bioaplikácie: LOW-D-MATTER	9,578.00					
2/0092/21	Šamaj Ladislav, RNDr., DrSc.	Štatistická mechanika klasických coulombovských systémov	4,976.00					
2/0105/21	Bartoš Erik, Mgr., PhD.	Využitie SU(3) symetrie a analytičnosti na nové teoretické vyhodnotenie g-2 anomálie, predpovedanie správania sa hyperónových elektromagnetických formfaktorov a vyhodnotenie vybraných rozpadov hadrónov	6,468.00					
2/0134/21	Šauša Ondrej, RNDr., CSc.	Fyzikálne vlastnosti uväznenej vody v prostredí lipidových dvojvrstiev a vplyv kryoprotektív	4,677.00					

2/0144/21	Švec Peter, Ing., DrSc.	Riadenie vlastností kovových systémov modifikáciou štruktúry na atomárnej škále pomocou vnútorných a vonkajších faktorov	23,635.00					
2/0181/21	Kliman Ján, Ing., DrSc.	Metóda prípravy vzoriek pre IBA a XRF aplikácie	4,229.00					
2/0183/21	Ziman Mário, doc. Mgr., PhD.	Dizajn zložitých kvantových meraní (DESCOM)	23,013.00					
2/0055/21	Tokár Kamil, RNDr., PhD.	Štúdium nízkomolekulových \pi-konjugovaných derivátov tiofénu vhodných ako organické polovodiče	661.00					
2/0046/21	Majková Eva, RNDr., DrSc.	Vplyv zabudovania MXénov do perovskitových solárnych článkov. Effect of incorporation of MXenes in the perovskite solar cells	12,824.00					
1/0714/21*	Vretenár Viliam Ing., PhD. / vedúci Němec Miroslav, doc. Mgr. PhD.	Výskum vybraných vlastností trvalo udržateľných izolačných materiálov s potenciálom využitia v drevostavbách	3,276.00					

2/0071/20	Brunner Róbert RNDr., CSc.	Výskum optických a morfologických vlastností nerovných a poréznych povrchov p-typu kryštalického kremíka s cieľom jednoznačne dokázať za akých podmienok pozorujeme jav kvantového uväznenia v kremíkových nanokryštáloch	3,551.00	1,832.00				
2/0156/20	Ivančo Ján Ing., DrSc.	Vrstvy trioxidu volfrámu pre chemirezistívne senzory stopových koncentrácií acetónu vo vzduchu	3,562.00	6,414.00				
2/0123/19	Krčmár Roman Mgr., PhD.	Kritické vlastnosti neštandardných tenzorových sietí	2,985.00	7,460.00	5,219.00			
2/0136/19	Plesch Martin doc. RNDr., PhD.	Benchmark Kvantových počítačov prístupných cez Klaud (BeKvaK)	5,772.00	6,927.00	6,263.00			
2/0161/19	Sedlák Michal Mgr., PhD.	Kvantové spracovanie informácie štruktúrami vyššieho rádu (HOQIP)	3,682.00	22,807.00	5,219.00			
2/0059/19	Hofbaurerová (Benkovičová) Monika RNDr., PhD.	Kombinácia nanočastíc a esenciálnych olejov na zmiernenie biologického poškodenia rôznych typov stavebných materiálov	12,138.00	15,607.00	12,849.00			
2/0123/18	Štich Ivan prof. Ing., DrSc.	Povrchy a 2D materiály: 2D-SURF	9,578.00	12,522.00	10,047.00	14,636.00		

2/0149/18	Pinčík Emil RNDr., CSc.	Výskum pasivovaných štruktúr štandardného porézneho kremíka a čierneho kremíka	-	1,832.00	1,724.00	1,650.00		
2/0081/18	Nádaždy Vojtech Ing., CSc.	Modifikácia rozhraní pre zlepšenie parametrov perovskitových solárnych článkov	7,187.00	10,026.00	12,090.00	22,900.00		
2/0003/18	Šamaj Ladislav RNDr., DrSc.	Základný stav a nízkoteplotné vlastnosti klasických coulombovských systémov		5,329.00	7,829.00	5,004.00		
2/0008/18	Kalinay Pavol RNDr., CSC.	Difúzny transport v priestorovo ohraničených štruktúrach		2,132.00	2,088.00	2,002.00		
2/0092/18	Jergel Matej Ing., DrSc.	Pokročilé monochromátory s pridanou funkcionalitou úpravy zväzku pre röntgenovú metrológiu a röntgenové zobrazovanie.		20,427.00	20,576.00	19,012.00		
2/0157/17	Šauša Ondrej RNDr., CSc.	Fyzikálne vlastnosti vody uväznenej v mezopóroch a kryoprotektíva		2,441.00	4,131.00	3,961.00		
2/0082/17	Švec Peter Ing., DrSc.	Nanoštruktúra a vlastnosti komplexných kovových materiálov		26,199.00	23,481.00	17,509.00		
2/0127/17	Maťko Igor Mgr., PhD.	Mikroštruktúra a sorpčné vlastnosti uhlíkových vlákien pripravených karbonizáciou celulózových prekurzorov		2,129.00	3,827.00	3,669.00		

2/0153/17	Bartoš Erik Ing., PhD.	Teoretický výskum hyperónov a ťažkých exotických mezónov		8,659.00	8,481.00	9,382.00		
2/0163/17	Gmucová Katarína RNDr., CSc.	Vzťahy medzi elektrónovou štruktúrou a mikroštruktúrou tenkých kopolymérnych vrstiev		3,907.00	3,827.00	3,335.00		
1/0676/17	Pinčík E. (Jurečka S. - vedúci)	Výskum elektrických a optických vlastností nanoštrukturovaných polovodičových rozhraní			1,866.00	1,777.00		
2/0024/17	Rusnák J.	Výskum skreslenia DLTS signálov.			1,724.00	1,650.00		
2/0129/17	Venhart M.	Experimentálne štúdium jadrových reakcií a jadrovej štruktúry s využitím zväzkov z tandemového urýchľovača			25,308.00	31,524.00		
2/0173/17	Ziman M.	Pamäťové a kauzálne štruktúry a procesy pri kvantovom spracovaní informácie (MAXAP)			13,048.00	13,761.00		
2/0192/17	Boháč V.	Vývoj senzorov a metód pre prechodové metódy merania termofyzikálnych vlastností látok a ich aplikácia pre možnosti sezónneho uskladnenia tepelnej energie			4,838.00	2,507.00		
2/0176/16	Gmuca Š.	Jadrová astrofyzika pri nízkych energiách			5,637.00	6,905.00	7,143.00	6,037.00

1/0018/15	Švec, ml. P. (Janovec J. - vedúci)	Zákonitosti tvorby a termodynamická stabilita štruktúrne komplexných fáz v zliatinách na báze hliníka alebo zinku				4,267.00	4,174.00	4,131.00
1/0501/15	Nádaždy V. (Čík G. - vedúci)	Nové stabilizované a štruktúrne usporiadané opticky a fotoelektricky aktívne organické materiály				1,777.00	2,087.00	3,086.00
2/0043/15	Plesch	Slabá náhodnosť v kvantových protokoloch				3,002.00	2,896.00	2,830.00
2/0162/15	Štich I.	Prvoprincípové počítačové modelovanie v nanotechnológiách					13,996.00	14,149.00
2/0130/15	Gendiar A.	Optimalizácia silnokorelovaných kvantovomechanických systémov pomocou tenzorových súčinových stavov					6,033.00	9,433.00
2/0151/15	Reitzner D.	Kvantové kráčania a nekompatibilnosť (QWIN)					7,239.00	9,433.00
2/0037/15	Butvinová B.	Vnútorné makroskopické sily – z čoho pochádzajú a ako ovplyvňujú magnetické vlastnosti vysokoindukčných kovových pások					1,882.00	1,839.00
2/0076/15	Pinčík E.	Výskum štruktúr čierneho kremíka					2,319.00	4,560.00

2/0004/15	Jergel M.	Vysoko kvalitné aktívne povrchy pre novú generáciu prvkov kryštálovej röntgenovej optiky					20,941.00	21,124.00
2/0010/15	Šiffalovič P.	Vzťah elektrónového transportu a štruktúry, rozmerov a usporiadania v nanočasticových súboroch pre pokročilé senzory plynov					14,399.00	14,249.00
2/0015/15	Šamaj L.	Štatistická fyzika priestorovo ohraničených systémov					7,239.00	7,074.00
2/0110/14	Běták E.	Jadrové reakcie v aplikáciách a astrofyzike					2,317.00	3,207.00
2/0197/14	Filip	Kvantové zmiešavanie stavov častíc v externých magnetických poliach						3,537.00
2/0189/14	Švec P.	Nové kovové materiály s komplexnou štruktúrou a mimoriadnymi objemovými a povrchovými vlastnosťami						16,035.00
2/0164/14	Šauša O.	Uväznené molekulárne systémy a ich dynamika v čiastočne zaplnených nanometrových póroch						4,716.00
2/0155/14	Rusnák J.	Výskum vplyvu vodivostných prúdov polovodičových štruktúr na DLTS						977.00

2/0099/14	Lányi Š.	Rastrovací nábojový tranzientový mikroskop na zobrazovanie a analýzu mäkkých vzoriek						2,355.00
2/0121/14	Venhart M.	Tvarová koexistencia v ťažkých atómových jadrách						11,319.00
2/0072/13	Olejník Š.	Uväznenie a vlastnosti základného stavu v kvantovej chromodynamike a v riešiteľných modeloch						4,716.00
1/0158/13	Dubnička S.	Teoretický výskum ťažkých kvarkónií						8,312.00
2/0165/13	Gmucová	Nanokompozitné tenké vrstvy – vlastnosti a použitie v senzorike						4,322.00
			171,438	***156,650***	***180,072***	***170,230***	***92,665***	***157,441***

2.4.5. List of projects supported by EU Structural Funds

Project title: Building-up Centre of Excellence for advanced materials application, CEMEA/ Vybudovanie Centra pre využitie pokročilých materiálov Slovenskej akadémie vied
Call code: OPVaI-VA/DP/2018/2.1.1-04
Code ITMS: 313021T081
Beneficiary: Slovak Academy of Sciences
Partners: Biomedicine Center SAS, Centre for Advanced Materials Application SAS, Institute of Electrical Engineering SAS, Institute of Physics SAS, Institute of Inorganic Chemistry SAS, Institute of Materials and Machine Mechanics SAS, Polymer Institute SAS
Non-refundable financial contribution: 29 941 629,34 EUR
Contribution for IP SAS: 150 000,- EUR

Project title: Research of new materials by methods of advanced diagnostics
Call code: OPVaI-VA/DP/2018/1.1.3-07
Code ITMS: 313011U400
Beneficiary: Institute of Physics SAS
Period: 1/2016 - 12/2019
Non-refundable financial contribution: 258 241,64 EUR

2.4.6. List of other projects funded from national resources

Program SASPRO - Mobility Programme of Slovak Academy of Sciences: Supportive Fund for Excellent Scientists

- Grant no: 0098/01/01 **Monoenergetic fast neutrons: Powerful tool for nuclear and material studies**
  Beneficiary: Dr. Prajapati Pareshkumar Manharbhai
  Period: 04/2015 - 12/2018
  Financial contribution: 174 912,- EUR
- Grant no: 0055/01/01 **Quantum walks and quantum incompatibility**
  Beneficiary: RNDr. Daniel Reitzner,PhD.
  Period: 04/2015 - 12/2018
  Financial contribution: 169 326,- Eur
- Grant no: 1250/02/01 - **Local Hamiltonians in Quantum complexity**
  Beneficiary: Mgr. Daniel Nagaj, PhD.
  Period: 09/2015 - 08/2018
  Financial contribution: 190 242,- EUR
- Grant no: 1239/02/01 **Development of Scanning Tunneling Microscopy Simulation Tools for Spin Transport**
  Beneficiary: Dr. Krisztián Palotás
  Period: 01/2016 - 03/2018
  Financial contribution: 129 666 EUR

2.4.7. List of projects funded from private funds

- **The Quantum Information Structure of Spacetime** (QISS),
  https://www.templeton.org/grant/the-quantum-information-structure-of-spacetime-qiss
  Funding body: Templeton foundation (https://www.templeton.org/), Grant ID 61466
  Duration: 12/2019-08/2022
  Coordinator: Carlo Rovelli
  Beneficiary: Mario Ziman, Andrej Gendiar
  Financial contribution: 83 244 eur

2.4.8. List of projects funded from other competitive funds

NONE

2.5. PhD studies and educational activities

2.5.1. List of accredited programmes of doctoral studies, period of validity, source of funding

Until the year 2018, the Institute of Physics trained PhD students in 5 accredited programmes. After the amendment of the Act. 269/2018 in SEP/2018, accreditation competencies have passed directly to the Universities. Now IP SAS cooperates with three Faculties in 6 study programmes. Annually, the Institute of Physics funds 4 PhD students from central resources of SAS, and typically 1 PhD student from internal resources of the Institute.

from 2016 – AUG/2018

The study programs of the third stage being carried out in cooperation with next faculties:

Faculty of Mathematics, Physics and Informatics of Comenius University in Bratislava

- Theoretical and mathematical physics
- Physics of condensed matter and acoustics
- Quantum electronics and optics and optical spectroscopy
- Nuclear and subnuclear physics

Faculty of Electrical Engineering and Computer Science of the Slovak Technical University in Bratislava

- Physical engineering

from SEP/2018 – now

Faculty of Mathematics, Physics and Informatics of Comenius University in Bratislava

the section **Physics** for study programs

- Theoretical Physics and Mathematical Physics
- Condensed Matter Physics and Acoustics
- Quantum Electronics and Optics and Optical Spectroscopy
- Nuclear and Subnuclear Physics

Faculty of Electrical Engineering and Computer Science of the Slovak Technical University in Bratislava

the section **Electrotechnics**

- Physical Engineering

Faculty of Natural Sciences of Comenius University

the section **Chemistry**

- Nuclear chemistry

2.5.2. Summary table on doctoral studies (number of internal/external PhD students at the end of the year; number of foreign PhD students, number of students who successfully completed their theses during the year, number of PhD students who quit the programme during the year*)*

PhD study	2016	2017	2018	2019	2020	2021

Number of potential PhD supervisors	51			51			51			51			51			49		
PhD students	**number, end of year**	**defended thesis**	**students quitted**	**number, end of year**	**defended thesis**	**students quitted**	**number, end of year**	**defended thesis**	**students quitted**	**number, end of year**	**defended thesis**	**students quitted**	**number, end of year**	**defended thesis**	**students quitted**	**number, end of year**	**defended thesis**	**students quitted**
Internal total	15	5	0	19	2	0	20	1	1	22	3	0	24	6	2	23	4	3
from which foreign citizens	2	0	0	2	0	0	6	0	0	10	3	0	14	1	2	13	2	2
External	2	0	0	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Other supervised by the research employees of the institute	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

2.5.3. PhD carrier path – Information on the next career steps of the PhD graduates who received their degree from the institute

2021	**Rupali**	**Tiwari**	Physical Engineering	Ing. Vlastimil Boháč, CSc.	Postdoc SAS Technical University in Zvolen
2021	**Ashin**	**Shaji**	Quantum electronics and optics and optical spectroscopy	Dr. Peter Šiffalovič, PhD.	Postdoc SAS
2021	**Jakub**	**Hagara**	Quantum electronics and optics and optical spectroscopy	RNDr. Peter Šiffalovič, PhD.	Postdoc Institut für Angewandte Physik, Universität Tübingen
2021	**Matúš**	**Balogh**	Nuclear and subnuclear physics	Mgr. Martin Venhart, PhD.	Postdoc INFN Legnaro Italy
2020	**Libor**	**Caha**	General and mathematical physics	doc. Mgr. Mário Ziman, PhD.	Postdoc Germany
2020	**Anna**	**Kálosi**	Physical Engineering	RNDr. Eva Majková, DrSc.	postdoc SAS
2020	**Riyas**	**Subair**	Quantum electronics and	RNDr. Eva Majková, DrSc.	Henkel AG & Co. KGaA

			optics and optical spectroscopy		
2020	**Peter**	**Nádaždy**	Quantum electronis and optics and optical spectroscopy	RNDr. Peter Šiffalovič, PhD.	Postdoc SAS
2020	**Róbert**	**Urban**	Nuclear and subnuclear physics	Mgr. Martin Venhart, PhD.	
2020	**Michal**	**Bodík**	Quantum electronics and optics and optical spectroscopy	RNDr. Peter Šiffalovič, PhD.	Postdoc ETH Zürich
2020	**Jozef**	**Klimo**	Nuclear and subnuclear physics	Mgr. Martin Veselský, PhD.	Postdoc KU Leuven
2019	**Dušan**	**Kamas**	Nuclear and subnuclear physics	Ing. Ján Kliman, DrSc.	Slovenské elektrárne Mochovce
2019	**Katarína**	**Čechová**	Nuclear and subnuclear physics	RNDr. Ondrej Šauša, CSc.	Postdoc SAS FNS UK BA
2019	**Matúš**	**Sedlák**	Nuclear and subnuclear physics	Mgr. Martin Venhart, PhD.	Postdoc INFN Legnaro Italy
2018	**Jozef**	**Leja**	Nuclear and subnuclear physics	Ing. Štefan Gmuca, CSc.	Postdoc STU BA
2018	**Marco**	**Pelletta**	Quantum electronics and optics	Dr. Peter Šiffalovič, PhD.	R&D in Data Intelligence Engineer, Dell Technologies
2017	**Juraj**	**Zigo**	Condensed matter physics and acoustics	Ing. Peter Švec, DrSc.	
2017	**Michal**	**Daniška**	General and mathematical physics	Mgr. Andrej Gendiar, PhD.	Data Specialist in Insurance group
2016	**Andrej**	**Vojtko**	Condensed matter physics and acoustics	RNDr. Eva Majková, DrSc.	R&D Protherm
2016	**Michal**	**Kaiser**	Physical Engineering	Ing. Vojtech Nádaždy, CSc.	IT specialist
2016	**Ján**	**Hudec**	Physical Engineering	Ing. Ľudovít Kubičár, DrSc.	Postdoc SAS Electronic - skCube

2016	**Martin**	**Hodas**	Quantum electronics and optics and optical spectroscopy	Dr. Peter Šiffalovič, PhD.	Postdoc Institut für Angewandte Physik, Universität Tübingen,DE
2016	**Jozef**	**Genzor**	General and mathematical physics	Mgr. Andrej Gendiar, PhD.	Postdoc Kobe Japan, Postdoc NTU, Taiwan

2.5.4. Summary table on educational activities

Teaching	2016	2017	2018	2019	2020	2021
Lectures (hours/year)*	**158**	**146**	**139**	**252**	**112**	**156**
Practicum courses (hours/year)*	**13**	**60**	**76**	**52**	**156**	**82**
Supervised diploma and bachelor thesis (in total)	**5**	**11**	**16**	**12**	**20**	**14**
Members in PhD committees (in total)	**10**	**11**	**4**	**4**	**5**	**5**
Members in DrSc. committees (in total)	**3**	**1**	**0**	**1**	**0**	**0**
Members in university/faculty councils (in total)	**10**	**7**	**5**	**5**	**2**	**2**
Members in habilitation/inauguration committees (in total)	**2**	**1**	**2**	**2**	**1**	**1**

2.5.5. List of published university textbooks

NONE

2.5.6. Number of published academic course books

NONE

2.5.7. List of joint research laboratories/facilities with universities

- Laboratory of quantum measurements, common laboratory of Faculty of Mathematics, Physics and Informatics, Comenius university and IoP, located at IoP
- Laboratory of ultrafast laser photonics, common laboratory of International Laser Center (CVTI SR), located at Faculty of Natural Sciences, Comenius University

2.5.8. Supplementary information and/or comments on doctoral studies and educational activities – focused on what changes have occurred since the last evaluation in 2016

The main difference with the previous period is that the interest of the students to get PhD positions has increased by a factor of ten (around 100 applications each year), the number of studied students permanently grows (Tab. 2.5.2). The main limiting factor to accept more students is the strict limitation of the existing financial funds. We had to adapt the selection procedures.

The established policy of the Institute of Physics is to encourage our doctoral students to complete part of the studies in high ranking laboratories abroad. We are successful in the majority of cases and our students take part or perform experiments at European Large Scale Facilities. The students are encouraged to participate at internal PhD seminars with their own lectures and communication training. Moreover, the students are engaged in popularisation activities of the Institute and they attend students workshops or scientific conferences under the supervision of their supervisors. Each student participates in some research project.

After finishing PhD studies, many of our students got a postdoc position abroad and several of them found a job in the local industry.

The special benefits for PhD students include meal vouchers in the same way as for the employees.

2.6. Societal impact

2.6.1. The most important case studies of the research with direct societal impact, max. 4 for institute with up to 50 average FTE researchers per year, 8 for institutes with 50 – 100 average FTE researchers per year and so on. Structure: Summary of the impact; Underpinning research; References to the research; Details of the impact; Sources to corroborate the impact. One page per one case study.

Summary of the impact: Installation of measurements of thermophysical parameters

Underpinning research: Development of sensors and measurement methods for transient techniques for the measurement of thermophysical properties of materials and their application for seasonal storage of heat energy. In cooperation with the Institute of Materials and Machine Mechanics, SAS, laboratory measurements of thermophysical properties of aluminum foam were performed. The pulse transition method was used to measure thermal diffusivity and thermal conductivity as well as specific heat capacity. The use of this new material in various areas of industry requires knowledge of thermal properties in terms of product design at its use in many applications in (2017). Experimental and theoretical cooperation with the Department of Building Physics at Slovak Technical University in the field of measuring concrete with various fillers was established. The measured concretes were made with organic filler such as horse manure and various polymers like polyethylene or rubber. Investigation of the thermal properties of concrete materials where waste materials are used as filler is especially welcome from an economic and ecological point of view (2017-2020). In cooperation with the Faculty of Wood Sciences and Technology at the University of Technology in Zvolen, the thermophysical properties of wood materials and their composites were measured. These materials are designed for use in construction and their importance lies in reducing the energy consumption of buildings.

References:

1. R. TIWALI et al., The non-planar surface of carbonate rock sample affecting the behaviour of thermal response and the measurement of thermophysical parameters by Pulse Transient Technique. In Thermal Science and Engineering Progress, 2021, vol. 24, 100927. https://doi.org/10.1016/j.tsep.2021.100927
2. R. TIWARI et al, Thermophysical Parameters of Carbonate Rock estimated by Slab Model Developed for Pulse Transient Technique, Measurement Science Review, 2020, vol. 20, no. 5, p. 218-223. https://doi.org/10.2478/msr-2020-0027
3. V. BOHÁČ et al., The transient method measurements of thermophysical properties of non-solid clay loam. In AIP Conference Proceedings, 2018, vol. 1988, no. 2, art. no. 020006. https://doi.org/10.1063/1.5047600
4. V. BOHÁČ et al, Electronic unit RTA for measuring thermophysical properties by transient planar hot discs sensor. MEASUREMENT 2017, https://doi.org/10.23919/MEASUREMENT.2017.7983561

5. V. BOHÁČ, P. DIEŠKA, Measurement of liquid polymer composite with ATO particles by pulse and step-wise transient techniques. In THERMAM 2018 : 7th Rostocker International Conference on Thermophysical Properties for Technical Thermodynamics : Book of Abstracts. - Rostock, Germany : Institute of Technical Thermodynamics, University of Rostock, 2018, p. 29.

Details of impact: We have built a system for **monitoring the moisture content** in the **Museum of rock dwellings in Brhlovce**. The dependence of thermophysical parameters on the moisture content in porous materials were measured in the laboratory using the Hot-Ball method. The probes calibrated in this way were inserted into the tuff massive placed at various depths. The system enables monitoring of changes in moisture content in buildings protected as cultural heritage (2012 - 2018). A similar project to measure the effect of precipitation on the moisture content in sacral buildings was launched in the **St. Martin's Cathedral tower in Bratislava**. **Monitoring changes in the moisture** content in monuments and other buildings helps to optimize the maintenance of buildings and control of their physical conditions (2014 -2019).

For Fy. COLVER, the Thermophysical properties of a copolymer of vinyl acetate (containing vinyl acetate monomer units) with ethylene and carbon composite were measured. The composite material is applied to the window glass and, after polymerization, causes a trapping effect for thermal radiation. The result is a saving of thermal energy expenses for the heating of buildings (2017 - 2018).

In cooperation with ETOP Alternative Energy, s.r.o., that manufactures and installs systems for seasonal thermal energy storage. Heat is stored during periods of excess solar energy and reused at a later period when there is a shortage. The measured samples were obtained directly from the geological subsoil where specific repositories were built. These were samples of clayey clay and limestone rock. The use of polymer fiber mortar has been proposed for filling energy needles. The investigated thermophysical parameters of these materials served as input data for calculations of temperature fields around energy needles. It also helps to set optimal regime for storage and heating operation of storage circuits. (since 2016 until now)

Sources to corroborate the impact: None.

Summary of the impact: Determine the amount of radium in water.

Underpinning research: In addition to the contribution of the results to basic research (changed properties of materials in nanoscale pores compared to volume systems), the project also brought several practical results that will be used in further research. It is mainly the possibility of monitoring the filling of the matrix pores with other molecules using a positron probe. This means that it is possible to monitor the sorption and desorption processes in situ, the degree of nanopore filling in various technological processes of sorbent preparation etc. An example of a possible use of the investigated confined systems are composites based on standard inorganic SiO_2 matrices, such as silica gels with MnO_2 entrapment. Such a composite makes it possible to separate and determine the amount of radium ^{226}Ra in water samples. The capability of 226Ra separation and determination in water samples using the MnO2-SiO2 composite resin was demonstrated. The results of the waters analyzed using the MnO2-SiO2 composite resin were compared with the results obtained using separation by the standard Eichrom method with MnO2-PAN resin. The proposed method was applied to the 226Ra determination in various types of natural mineral, mountain spring, drinking and natural healing waters from Slovakia and Czech Republic. The obtained 226Ra activity in the analyzed samples was compared with the limit values set in Edict 528 of the Ministry of Health of the Slovak Republic in 2007 and no limit was exceeded.

References: S. Dulanská et al., Applied radiation and isotopes **140**, 96 (2018)

Details of impact: The proposed method of determining this one of the most toxic alpha-emitters in the environment could be a very cheap alternative to the extraction of ^{226}Ra by chromatographic methods that use expensive resins.

Sources to corroborate the impact: None.

2.6.2. List of the most important studies and/or other activities commissioned for the decision-making authorities, the government and NGOs, international and foreign institutes (title, name of institution, contract value, purpose (max 20 words))

- **Martin Venhart** serves as Vice-chair of the Committee for collaboration of Slovak Republic with CERN. The Committee directly influences funding of the CERN-related research in Slovakia.
- **Stanislav Dubnička** served as Chair of the Committee for collaboration of Slovak Republic with JINR in Dubna. The committee directly influenced the dedicated funding for Slovak researchers included in the collaboration. He resigned in 2021 and **Erik Bartoš** became the member of this committee.
- **Martin Venhart** is member of NuPECC - an Expert Committee of the European Science Foundation (since 2019). The objective of NuPECC is to: 1) develop the strategy for European Collaboration in nuclear science by supporting collaborative ventures between research groups within Europe, and 2) promote nuclear physics and its trans-disciplinary use in applications for societal benefit.
- **Martin Venhart** was a member of Presidium of Slovak Academy of Sciences.
- **Andrej Herzáň** is a Slovak representative in the European Commission for Future Accelerators – Early-Career Researchers (ECFA-ECR) Panel. The objective of the ECFA - ECR Panel is for its members to discuss all aspects that contribute in a broad sense to the future of the research field of particle physics. Members act as individuals, but should be able to represent the views of early-career researchers in particle physics in the country from which they were nominated.
- **Matej Jergel** is a national delegate in the European Synchrotron and FEL User Organisation (since 2014).
- **Matej Jergel** is member of the National Committee of IUPAP (since 2013).
- **Vladimír Bužek** was a member of strategic advisory board of Quantum Flagship formulating the framework of this initiative and defining the strategic documents. Until 2020 he also served as sherpa for quantum technologies.
- **Mário Ziman, Peter Staňo, Miroslav Grajcar**, Tomáš Samuely, Martin Gmitra: Action plan for quantum research in Slovakia, project plan for Ministry of Education (delivered in January 2019)
- **Mário Ziman** is a Slovak representative of Quantum Community Network being bottom-up advisory platform for the Strategic Advisory Board. It is very efficient in providing communication with researchers, thus, providing valuable inputs from individual countries including the direct political influence on the national representatives in the decision-making bodies at European Commission.
- **Peter Švec Sr.** was a member of IUPAP C10 Commission for Solid State Physics, 2017-2021 and since 11/2021 he was elected Vice Chair of this Commission for period 2021-2024.
- **Mário Ziman:** Possibilities of the development of quantum technologies in the Slovak Republic - study for the Ministry of Investments, Regional Development and Informatization of the Slovak Republic. (delivered on dec/2021)

- **Mário Ziman:** The Analysis of the Placement Possibilities of a Terrestrial Quantum Communication Infrastructure in Slovakia, short study for the Ministry of Investments, Regional Development and Informatization of the Slovak Republic. (delivered on dec/2021)

2.6.3. List of contracts and research projects with industrial and other commercial partners, incl. revenues (study title, name of institution, contract value, country of partner, purpose (max 20 words))

- **Project APVV-14-0745, 2015-2019.** Research of the nanomachining technology for active surfaces of the new generation of the X-ray optics. Company Integra TDS, Ltd. was a contractual beneficiary of the project results.
- Thermal conductivity measurement of dynamo sheets for **US Steel company in Košice**. A new unique experimental instrument for measuring the thermal conductivity of thin metallic sheets has been designed and constructed. Measured data of dynamo sheets as a function of temperature show positive dependence on temperature. Data help to design the operation mode of products made from this material. (since 2009).
- **HEES4T industrial research project**, 2018 - 2021, Research and development of highly efficient energy sources and technologies for transport systems using the principles of Industry 4.0
  Principal investigator: Electrotechnical Research and Projecting Co., Nova Dubnica, Slovakia
  Goal: Preparation of magnetic materials for prototypes of efficient magnetic circuits for power electronics and energy - transport system
  Contract: 206 500

2.6.4.1 List of intangible fixed assets (internally registered IP (confidential know-how), patent applications, patents granted, trademarks registered) denoting background IPR

Patent granted

- ŠVAJDLENKOVÁ, Helena - ŠAUŠA, Ondrej. **Chamber for the study of photopolymerization by the positron annihilation method**: Patent document. Document number: 288901. Document's type: B6. Int. Cl. (2021.01): G01N 23/00. G01N 1/00. Application number: 117-2017. Date of application: 16.11. 2017. Publication Date of Published Application: 4.6. 2019. Bulletin of the Industrial Property Office of the Slovak Republic No .: 06/2019. Date of notification of the grant of the patent: 13.10. 2021. Bulletin of the Industrial Property Office of the Slovak Republic no. : 19/2021. Date of making the patent available to the public: 2.9. 2021. Owner: Institute of Polymers SAS, Bratislava. Institute of Physics SAS, Bratislava. Representative: Count Martin, Ing. PhD., Bratislava. Banská Bystrica: Industrial Property Office, 2021. patent file number 288901, 7 p. Type: AGJ
- LÁNYI, Štefan - NÁDAŽDY, Vojtech. **Method for performing the local charge transient analysis**" Patent No. 288589. Patent owner: Institute of Physics of the Slovak Academy of Sciences, Bratislava, SK. Bratislava, SR : Industrial Property Office of the Slovak Republic, 21.06.2018
- JERGEL, Matej - NÁDAŽDY, Peter - ŠIFFALOVIČ, Peter. **Four-bounce X-ray monochromator for high-resolution X-ray diffraction**: Utility Model No. 9351. Patent owner: Institute of Physics of the Slovak Academy of Sciences, Bratislava, SK. Registered at: Industrial Property Office of the Slovak Republic, 20.10.2021

2.6.4.2 List of licences sold abroad and in Slovakia, incl. revenues (background IPR identification, name of institution, contract value, country of partner, purpose (max 20 words))

NONE

2.6.5. Summary of relevant activities, max. 300 words (describe the pipeline of valorization in terms of Number of disclosure, Number of registered IP internally, number of CCR/LIC contracts and their respective summary values, the support you are receiving in specific points internally at the institute, at SAS, externally – also the limitations and drawbacks.

NONE

2.7. Popularisation of Science (outreach activities)

2.7.1. List of the most important popularisation activities, max. 20 items

Most of the outreach activities are in Slovak. Here is the selection.

1. An annual Doors Open Days, presentations and excursions through our labs, https://fu.sav.sk/index.php?id=dod2020
2. IPSAS popular science lectures offer,

   https://www.fu.sav.sk/index.php?id=popular&L=1
3. Daniel Nagaj, World as the computation, European Researcher's Night 2017, keynote public lecture, https://www.youtube.com/watch?v=fFf-jnkr_cE
4. Vladimír Bužek, The art of quantum, ITAPA 2016 conference, lecture, https://www.youtube.com/watch?v=zEWCHMNNIL0
5. Martin Venhart, Periodic table of elements, Science in Theathre, moderated discussion, 2.7.2019, https://www.youtube.com/watch?v=_FLgVjkliVk
6. Daniel Nagaj, How quantum computing threatens internet security and what's being done about it, Slovak Radio International, interview, 7.10.2020,

   https://enrsi.rtvs.sk/articles/science-and-nature/236276/how-quantum-computing-threatens-internet-security-and-whats-being-done-about-it
7. Štefan Luby, Miraculous graphen, Quark 2/2021, popular science article, https://www.quark.sk/divotvorny-grafen/
8. Vladimír Bužek, Slovaks are testing unbreakable ciphersystem connecting Vienna and Bratislava, interview zive.sk, 5.10.2020,

   https://zive.aktuality.sk/clanok/148961/slovaci-testuju-neprelomitelny-sposob-sifrovania-idu-spojit-bratislavu-a-vieden/
9. Martin Venhart, Discoveries of new chemical elements, Scientific patisserie, 28.3.2017, https://vedanadosah.cvtisr.sk/priroda/objavy-novych-chemickych-prvkov/
10. Andrej Liptaj, It is expected the Hawking's work will be updated, interview, newspapers Pravda, 15.3.2018

    https://vat.pravda.sk/vesmir/clanok/462345-ocakava-sa-ze-hawkingove-prace-budu-pozmenene-alebo-doplnene/
11. Mario Ziman, Quantum cryptosystems, PC Revue 11/2017, popular science article, https://www.nextech.sk/a/Kvantove-sifrovanie
12. Martin Venhart, R. Balogh, RTVS (Slovak radio), Series Science.sk, interview, How to discover secrets of physics? https://www.rtvs.sk/radio/archiv/11373/895436
13. Martin Plesch, What is the future of Quantum computers?, internet journal INDEXMAG, popular science article, 2.1.2020,

    https://indexmag.sk/2020/01/02/aka-je-buducnost-kvantovych-pocitacov/
14. Mario Ziman, CESTA K POVOLANIU: No apple fell in the way of the quantum physicist, Eductech, interview, 6.11.2017, https://www.eductech.sk/novinky/cesta-k-povolaniu-ziadne-jablko-nepadlo-kvantovemu-fyzikovi-do-cesty/
15. Daniel Reitzner, Young Researcher Award 2017: It's a great feeling to know something as the only one in the world, Newspaper SME, interview, 11.8.2018

    https://tech.sme.sk/c/20902851/mlady-vedec-roka-je-skvely-pocit-ked-nieco-viete-ako-jediny-na-svete.html
16. Martin Venhart, Atomic nucleus, SAV Scientific Podcast, interview, 17.7.2021 https://www.youtube.com/watch?v=hnpvc4D9wb8
17. Martin Plesch, Quantum computer is as human, Eductech, interview, 9.2.2020, https://www.eductech.sk/novinky/martin-plesch-kvantovy-pocitac-je-ako-clovek-

nepocita-presne-casto-sa-myli-ale-dokaze-riesit-ulohy-na-ktore-su-bezne-pocitace-kratke/

18. Martin Venhart, On the history of Nobel Prize, TA3 television, interview, 19.7.2018, https://www.ta3.com/clanok/129605/m-venhart-o-historii-nobelovej-ceny
19. Mario Ziman, Quantum Age, Europeans Researchers Night 2020 (virtual), keynote public lecture, 27.11.2020, https://www.youtube.com/watch?v=2CiQqzBXKMA
20. Daniel Reitzner, Mario Ziman, Diana Cencer, European Researcher's Night 2019, DECIPHER - competition in discovering and breaking ciphers, http://sifrovacka.nocvyskumnikov.sk/2019/index09.php

2.7.2. Table of outreach activities according to institute annual reports

Outreach activities	2016	2017	2018	2019	2020	2021	total
Articles in press media/internet popularising results of science, in particular those achieved by the Organization	7	1	7	4	11	13	43
Appearances in telecommunication media popularising results of science, in particular those achieved by the Organization	5	0	4	2	7	4	22
Public popularisation lectures	29	13	25	32	7	13	119

2.8. Background and management. Infrastructure and human resources, incl. support and incentives for young researchers

The Library of IP SAS, including books, scientific journals and other documents, is available to its personal and wider academic audience through presence library services and also through the electronic catalogue in the form of the open source system PhpMyBibli. The catalogue is available at http://kniznica.fu.sav.sk.

2.8.1. Summary table of personnel

2.8.1.1. Professional qualification structure (as of 31 December 2021)

	Degree/rank	Research position

	DrSc./DSc	CSc./PhD.	professor	docent/ assoc. prof.	I.	II.a.	II.b.
Male	14	57	4	2	18	34	18
Female	1	11	0	0	1	4	6

I. – director of research with a degree of doctor of science/DrSc.

II.a – Senior researcher

II.b – PhD holder/Postdoc

2.8.1.2. Age and gender structure of researchers (as of 31 December 2021)

Age structure of researchers	< 31		31-35		36-40		41-45		46-50		51-55		56-60		61-65		> 65	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Male	8.0	1.4	10.0	6.7	9.0	7.7	12.0	10.7	6.0	3.6	2.0	1.2	4.0	4.0	11.0	11.0	12.0	8.8
Female	7.0	0.3	3.0	1.1	4.0	3.2	1.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	2.5

A – number

B – FTE

2.8.2. Postdoctoral fellowships (list of positions with holder name, starting date, duration. Add brief information about each fellow's career path before and after receiving PhD degree, etc.)

2.8.2.1. MoRePro and SASPRO fellowships

- **Hamed Mohamed Mohammady**: Operational quantum thermodynamics (01/04/2020 - 28/02/2021), MOREPRO fellow (M.Ziman). Before Marie Curie fellow at Lisbon (supervised by Yasser Omar), after QuiC fellow at University of Bruxelles in Belgium (supervised by Nicolas Cerf)
- **Daniel Reitzner:** Quantum walks and incompatibility (01/09/2015 - 31/12/2018), SASPRO fellow (M. Ziman). Before Fullbright stipendist at CUNY in New York (supervisor: Mark Hillery) and postdoctoral fellow at Garching in Germany (supervisor: Michael Wolf). After SASPRO researcher at IPSAS, Masaryk University in Brno, since 2021 researcher at VTT Espoo in Finland.
- **Daniel Nagaj** Local Hamiltonians in Quantum Complexity (07/04/2015 - 31/12/2018), SASPRO fellow (M. Ziman). Before postdoctoral fellow at Vienna university. After he remained a researcher at IPSAS.
- **Krisztián Palotás** Development of Scanning Tunneling Microscopy Simulation Tools for Spin Transport (01/01/2016 - 31/12/2018), SASPRO fellow (I. Štich). Before Hungarian State Eötvös Fellow at Vienna University of Technology in Austria and after researcher at Wigner Research Center for Physics in Budapest.
- **Pareshkumar Manharbhai Prajapati** Monoenergetic fast neutrons: Powerful tool for nuclear and material studies (16/03/2015 - 16/03/2018), SASPRO fellow (M. Venhart).

2.8.2.2. Stefan Schwarz fellowships

- **Sheikh Sazim** (M. Ziman)
- **Chiranjib Mukhopadhyay** (M. Ziman)
- **Matúš Sedlák** (M. Venhart)
- **Monika Hofbauerová** (E.Majková)
- **Matej Pivoluska** (M.Plesch)
- **Tomáš Rybár** (M. Ziman)
- **Kamil Tokár** (I. Štich)
- **Adriana Annušová** (E. Majková)
- **Andrej Herzáň** (M. Venhart)
- **Roman Krčmár** (A. Gendiar)
- **Anton Repko** (M. Venhart)
- **Peter Švec ml.** (P. Švec)
- **Thakur Shoubhr** (I. Štich)
- **Karol Végso** (P. Šiffalovič)

2.8.2.3. Postdoctoral positions from other resources (specify)

- **Natália S. Móller,** 01/03/2021-31/08/2022, QISS Templeton fellow (funded from QISS project)
- **Seyed Arash Ghoreishi,** 01/01/2021 - 12/12/2022, funded from APVV OPTIQUTE
- **David Davalos,** 01/09/2021-12/12/2023, funded from APVV OPTIQUTE, since 01/01/2022 Schwarz fellow
- **Leevi Leppajarvi,** 01/10/2021 - 12/12/2023, funded from APVV OPTIQUTE, since 01/01/2022 Schwarz fellow, since 01/09/2022 SASPRO2 fellow

2.8.3. Important research infrastructure introduced during the evaluation period with the information about the sources of funding *(max. 2 pages)*

- **Tandetron laboratory** in Piešťany, built as a part of the project funded by the European Regional Development Fund. The laboratory is equipped with the 2 MV electrostatic accelerator of the Tandetron type. Light ion beams are provided by the Duoplasmatron ion source model 358. Laboratory is further equipped with the array of four high-efficiency coaxial Germanium Pop-Top detectors, scintillation detectors and a neutron detector. Research in the laboratory focuses on the study of nuclear structure in the vicinity of the closed proton shells.
- **Making nuclear and XRF targets with the HIVIPP method**. The module that employs the high energy vibrational powder plating (HIVIPP) technique for preparation of thin targets from powder material was developed. In the testing phase of this apparatus the Mn target was deposited in-air onto the Al backing foil. The properties of the target prepared were studied using the XRF microscope. The previous observations concerning the applicability and suitability of the deposition method were confirmed. Currently a vacuum version of the deposition apparatus is being built. It will be used for the preparation of thin targets sensitive to oxygen contents.
- The infrastructure of the **positron annihilation laboratory** has been improved. Funds were obtained from running grants from APVV and VEGA. It is mainly a matter of building two more spectrometers for measuring the lifetimes of positrons, which enables faster realization of the research intentions of the positron annihilation group. In addition, other smaller ancillary equipment was built, specializing in illuminating the examined samples (one of which is also patented).
- In 2016, we installed a **small-angle X-ray scattering system** (SAXS) with funding from the European Regional Development Fund (Bruker AXS, Germany). The system is suitable for determining the size and dispersion of low-dimensional materials. The system is also routinely used for grazing-incidence wide-angle X-ray scattering (GIWAXS) to determine crystallographic phases and their spatial orientation in nanostructures. Complex structural characterization provided by this system is a prerequisite for understanding basic phenomena in low-dimensional materials at different length scales.

- In 2021 we open a new quantum photonics lab in IPSAS (personnel and equipment) was the first step towards building on the first significant results that came out of the collaboration with the Austrian Academy of Sciences team on quantum communication. The equipment was largely financed through a 0.5 mil. EUR direct funding from the Ministry of Education, Science, Research and Sport of the Slovak Republic. This provided the necessary environment to apply to several new sources of funding including the substantial European EuroQCI project, goals of which are to build a Europe-wide quantum communication infrastructure. Together with the national support from the Recovery and Resilience of Slovakia funds the institute expects up to 16M€ of grant money to be injected in the development of a quantum technologies ecosystem. Our plan is to develop an entanglement-based quantum layer communication infrastructure to create the backbone of a national quantum network. The network will facilitate an enhanced security for communication, but also allow transfer of quantum information – thus being able to serve as experimental quantum infrastructure, e.g., to test quantum communication tasks more complex than the quantum key expansion itself.
- **Quantum links**. Currently, there are two quantum links in place/being further developed in Slovakia: a long-distance one, between Bratislava (Institute of Physics of the Slovak Academy of Sciences – IPSAS) and a short-distance one, within Bratislava (between IPSAS and the International Laser Centre – ILC).

2.9. Supplementary information and/or comments on all items 2.1 – 2.8 (max. 2 pages in total for the whole section)

During the whole period the Institute of Physics has improved both the quality and the impact of its research outputs. As a result the number of highly impacted journals has increased, the number of citations started to increase, on average we reached almost two publication per researcher per year and in the SAS annual performance evaluations of institutes we kept the leading positions. Our effort has established new research partnerships and brought many new promising collaborations. We are in the process of undergoing organisational changes with the final goal of a positive atmosphere and motivating research spirit of all the employees.

We adopted a new proactive strategy in hiring early-stage researchers - PhD students and postdocs. Advertised open calls resulted in an increase of PhD applications by order of magnitude. We are actively using existing projects and programs to attract postdoctoral researchers. We were relatively successful in academic calls for Schwarz stipendists (on average 2 positions ever year), SASPRO stipendists (5 successful applications, but only 4 have started) and have regular visitors through national scholarship programs. All departments agreed on allocation of the joint budget to establish IPSAS PhD scholarship and IPSAS fellowship (program without experience restrictions, but fellows must not be employed at IPSAS before). All these activities have increased the fraction of foreign researchers and English has become the standard language at the institute.

Researchers at the institute were always involved in focused individually organised popularisation activities, especially, targeting high school students and it was not different during the evaluation period. We started to create a common outreach strategy. The pandemic has defined the form and our researchers very proactively joined initiatives for students coordinated by the Presidium.

Martin Plesch is individually involved in the organisation of **Young Physicists Tournament** - a very popular competition of teams of high school students in presentation and mutual defense of their solutions of given research problems. Slovak teams are often very successful also at the world final.

Martin Venhart as a member of SAS Presidium was responsible for outreach activities and started several popularisation projects. Our students actively participated in **Young Researcher's Roadshow** bringing researchers and experiments to classes.

Mario Ziman and Denisa Lampášová were participating in organisation of **School of Young Scientists** coordinated by Institute of Materials.

3. Implementation of the recommendations from the previous evaluation period

Recommendations from the previous evaluation period:

1. Unclear picture of governing structure
2. Prepare strategic plan
3. Stimulate outreach activities
4. Address gender issues (4 females, one below 60)
5. Address decreased teaching

All the recommendations were covered in the institutional strategic documents. The main objectives of the action plan includes the following:

1. **Increasing quality/impact of publications.** During the previous period the publications in highly impacted journals (IF larger than 8 - number set by the IF of Physical Review Letters) were not very common. This has changed dramatically in this period during which we recorded 37 publications of this type increasing from one **highly impacted paper** in 2016 to 14 such papers in 2019 (in details 2016 - 1, 2017 - 4, 2018 - 9, 2019 - 14, 2020 - 7, 2021 - 9). In order to motivate this objective we started in 2019 to reward these papers (2000 eur / paper) if one fifth of authors is affiliated with the Institute in order to separate publications that have originated at the institute (if not, each case is discussed). In 2021 we also started to **reward highly cited publications** (the same amount) that have received in total more than hundred citations (self-citations excluded) while keeping the average 7 citations per year (compatible with the concept of "long-term" impact factor). The number of rewarded publications is limited by the total budget allocated for rewarding highly impacted publications and so far we rewarded 5 such publications, but more will come to be rewarded this year. Also the increasing total number of citations per year is witnessing the impact and quality of the achieved research results. One of the papers appeared in WOK database as a "highly cited paper".
2. **Increasing the number of PhD students and internationalisation of PhD programs.** During this period we identified the brain drain as the reason for the lack of interest of students from Slovak universities to continue in PhD studies. We started to advertise positions globally (using universally the Euraxess platform, but also dedicated websites for particular areas of research) and had to introduce a **two-step selection procedure** (pre-selection at the departments and then final institutional round with selected candidates), because the total number of applications is typically reaching one hundred every year - vast majority (98%) from abroad. The guaranteed limit set by Presidium SAS is 4 fellowships every year. Given our restricted budget in 2020 we established one **IPSAS PhD fellowship** per year covering half of the PhD students and the remaining half has to be covered from the resources of the department. Departments were paying three more PhD students completely. On average we have 20 PhD students every year - 80% from abroad, thus, the **internationalisation** was definitely achieved and English became the dominant language at the institute not only for PhD students. The weak part of internationalisation is the stability and quality of PhD students. During the period we improved in the selection process, however, the better opportunities are draining a small percentage of the best PhD students to continue in their PhD abroad. PhD students are regularly meeting with a scientific secretary and presenting at training seminars although the whole activity was strongly affected by the covid, thus, the societal dimension of these meetings were essentially lost.
3. **Increasing activity in the applications for ERC and H2020 projects.** There were two applications for ERC during the period. The second application was awarded B and based on that received private support (ESET award) to prepare a new application. During the period we were involved in 3 H2020 projects and participated in more than 30 applications in various schemes.
4. **Outreach activities.** The outreach activities were happening to a large extent also in the previous period, however, it was based on individual activities and not properly reported. This has slightly changed during this period and becomes a bit more organized. In 2020 we allocated a budget to support popularisation activities, especially, the popular-science lectures, videos preparation and popular-science articles. The main popularisation activity

of the institute is the **IPSAS Open Science (Week) Days** in November that resulted in the offer of lectures during the whole year. Few short videos were produced to attract high schools to join the lectures. During the dedicate week we deliver approximatively 30 popularisation lectures at individual high schools all over Slovakia. During the whole period we participated at **Researcher's Night** with several stages and keynote lectures. We contributed significantly to an organisation in 2017 that was partially focused on quantum technologies. As part of Researcher's night we prepared public cipher games (Desifruj) in 2018 and 2019. Over the last two years we contributed to the organisation of Summer camp for children coordinated by the Institute of Materials. PhD students at the nuclear department have designed a "home-made" fog chamber for popularisation purposes within the SAS activity **Young researcher's Roadshow**. During the Covid our colleagues also participated at online popularisation and education activities. For details on all the mentioned activities see the part on popularisation.

5. **Teaching activities -** The reduction of teaching activities in the previous period was caused by the structural and legislation changes at Slovak universities and the fact that Institutes lost the independence in PhD training. During this period we open new courses at Slovak Technical University.
6. **Increasing the fraction of female researchers.** Altogether we ended the considered period with 19 female researchers (7 of them PhD), which means we increased the number almost five times, thus, reached that 15% of all researchers are females which follows the typical fraction of female students of physics and engineering at the universities. One third of them are from abroad. No positive discrimination was implemented. It is positive that female researchers returned back to research from their maternity leaves and also male researchers were taking the option for parental leaves.
7. **Governing structure** - In autumn 2019 the Institute has changed the director. The governance structure remains unchanged, but the communication becomes more organized, thus, increasing the transparency of the governance. During 2020 we started with regular monthly meetings (collegia) between the director and leaders of individual departments aiming to discuss organisational and strategic issues. Among other things we agreed on organisational rules. In particular, the departments were given complete freedom in their employment policy, the model of distribution of the institutional budget over the departments was introduced and in accordance with the action plan the research evaluation strategy was designed. In particular, the independence of departments was strengthened by fixing their yearly budget that is fully under the control of the department and can be used in accordance with their preferences. The quality of the performance is controlled by the management through evaluation of the performance of the departments in publications, citations, projects and PhD training following the performance evaluation of the institutes determined by the Presidium of SAS. This performance evaluation quantifies the relative contribution of departments to overall performance, thus defining the performance distribution. The budget distribution in year X is given as a weighted average of the budget distribution in the previous year (90%) and performance distribution from the previous year (10%). This update aims to motivate the departments to keep high standards of their performance.
8. **Internationalisation.** We were successful in attracting postdoctoral fellows from abroad mainly through the academic programs of MOREPRO, Schwarz stipend and National scholarships. In 2020 we established **IPSAS fellowship** programme offering one year temporary position for a researcher outside of the institute.
9. **International advisory board** was created in 2019
    - Prof. Dr. Jürgen Eckert, Montanuniversität Leoben
    - Prof. Jaroslav Fabian, Universität Regensburg
    - Prof. Robert Kamiński, Instytut Fizyki Jądrowej, Krakow

    In December 2019 they joined the annual institutional meeting in Bratislava and gave relatively positive feedback and valuable recommendations for the organisation matters and plans at the institute.

4. Research strategy and future development of the institute for the nextfive years

(Recommended 3 pages, max. 5 pages) **Research strategy of the institute in the national and**

international contexts, objectives, and methods (including the information on when the strategy was adopted)

The institute is facing two main non-scientific medium-term challenges: **budget and age structure**. Unfortunately, both of them have no simple short-term solution, but must be seriously addressed in the next five years.

The budget is affected not only by global situation, but also by the long-standing uncertainties around the direct state support of Slovak Academy of Sciences (lack of state research politics) and instability plus underfunding of the national grant systems. The **long-term stabilisation** of the budget is necessary for the definition of more serious research and development strategy of the institute. Unfortunately, this is beyond the scope of the institutional management and establishing different sources seem necessary. The preparation of the **financial development strategy plan** (strengthening collaboration with industry sector, commercialise research-based services, etc.) is one of the first tasks in front of the institutional management.

Although we managed to **decrease the average age**, the distribution of age is exhibiting gaps in the category of **experienced researches** (50-60 years) and **early-stage researchers** (25-35). The first gap is related to global political changes in the last century, but the new gap is caused by accelerating “exodus” of students from Slovakia. This process is still ongoing and at the Institute the gap below 25 is fixed, because we are able to attract graduate students from abroad. It helps in internationalisation of the institute. Currently almost one third of researchers (including PhDs) is of non-Slovak origin. In order to fill both gaps at least partially we established **IPSAS fellowship position** - temporary research position selected every year in order to increase the transfer of knowledge from outside of the institute, but also to identify potential long-term research leaders and new research directions. It turns out such a tool is not sufficient and attracting new research teams is one of our priority within next five years. In particular, we aim to open a call for **IPSAS starting research teams** to enable promising researchers at the early-stage of their carrier to establish their own research teams. Using the **ERA chair** and **IMPULZ programs** we plan also to attract experienced researchers and strengthen the existing research environment at the institute by exploring new research directions. First examples of this type are **recently established research teams** focused on superconducting spintronics and quantum photonics. Both directions are new at the institute, but with a reasonable overlap with the existing research activities.

RESEARCH

Major objectives:

- Low-energy transitions spectrometer
- Non-invasive detection of biomarkers
- Quantum communication network

Within our traditional area of **material research** we will continue in the design of metallic materials, phenomena and processing technologies for energy, high performance composites and functional materials. Special focus is planned on the implementation of solid-state physics and unconventional processing **techniques for green technologies**. In particular, we aim to investigate innovative surfaces, coatings and interfaces for **new-generation material systems** with emphasis on energy generation, energy management and recycling of strategic elements. Combining the development of experimental, computational and modeling techniques we plan to study **atomically resolved structures** in metastable, complex, multicomponent and catalytic systems.

In parallel with basic materials research a part of the effort will be devoted to design and implementation of **diverse hi-tech devices** (sensors, etc.) based on developed materials and phenomena and to cooperation in direct application of these materials, processes and measuring techniques by the industry sector. These include, a. o., **special thermophysical techniques** and methods of determination of thermal properties of real sample objects for civil engineering (thermal insulation and heat storage materials) based on decades-long experience in the field, and

cooperation in enhancement of performance of **nanocrystalline black-silicon based solar cells** jointly with Japanese partners.

In accord with EU initiatives, attention will be given also to the aspects of **lifetime of materials** and to implementation of acquired knowledge, developed materials and new phenomena in the process of increasing technology readiness level (TRL) for specific lines of production in electronics, magnetics, measurement, sensors, diagnostics and materials processing. Special emphasis, also with respect to the present political and economic situation, will be put on materials and processes leading to replacement of strategic materials, especially in **soft and hard magnetic materials**.

Future prospects in the area of **nuclear physics** are based on approved program at CERN (**beta-decay spectroscopy**), and at the Accelerator Laboratory of the University of Jyväskylä - JYFL (**isomer spectroscopy**). Recent analysis of the data from the previous experiments suggests **existence of high-spin isomeric states in odd-Au isotopes**. These isomers can be used as "feeders" of excited states that are not accessible through the beta decay. A pilot experiment has been approved, which requires a **new detection setup** at focal plane of the separator in Jyväskylä. It has been designed to be able to accept at least factor of 10 more beam than existing setup. If the method proves its relevance, it will open a new possibility for studies of odd-Au isotopes. At ISOLDE, systematic studies with high resolution and conversion electrons will be performed. A **new spectrometer** will be constructed with aim on **low-energy transitions**. This will have an impact not only to nuclear physics, but also for studies of isotopes **relevant for nuclear medicine** (possible therapy with low-energy electrons).

The above program, which has started already, needs to be complemented with systematic measurements of lifetimes of excited states. They will bring a new insight into the intrinsic structure of observed new configurations. This needs to be combined with the state-of-the-art nuclear theory. To accomplish this objective, the **theoretical description using the Skyrme QRPA** combined with the recently introduced corrections will be extended to odd-mass nuclei, which are currently in the focus of our experimental group. The above program will be subject of **ERC proposal resubmission**, which is in preparation.

Research program in the **Tandetron laboratory** in Piešťany will focus on topics related to **nuclear industry in Slovakia** (in close collaboration with Slovak University of Technology and Comenius University). For this program, the accelerator will be used as a source of fast neutrons. In fundamental nuclear structure research we will focus on measurements of transitions with low probabilities in light nuclei (induced either via neutrons or charged particles) and **nuclear astrophysics reactions**.

This year we started research project (in collaboration with Polymer Institute SAS) aiming to exploit the methods of positron annihilation to investigate the **processes of photopolymerization** and **photodegradation of polymers**. The regulation of photopolymerization by physicochemical influences has an impact on the quality of the crosslinking of the polymers and thus ultimately on the material properties. Targeted research will focus on a class of dimethacrylates and epoxides with wide use in practice (dental materials, retention matrices for biosensors, surface protective layers).

Regarding **particle physics program**, the focus will be set on the answering open questions in the field of Standard Model theory. With the more precise determination, e. g., the **value of hadronic contributions to muon anomaly**, the running QED constant, the description of decay processes of very heavy mesons, will advance our knowledge in the field of the phenomenology of particle physics and specify the possible contributions of **physics beyond the Standard Model** in more detail. In connection with the specified objectives, new mathematical and numerical methods of calculations of investigated quantities will be developed.

Application of low-dimensional materials: In the next period, based on our expertise, we will further **develop various types of low-dimensional nanomaterials**, such as

nanoparticles/nanosheets of MoO_x, MoS_2 and MXenes (collaboration with Polymer Institute SAS), and study their properties. In particular, large-area self-assembled monolayers of mono- and few-layer nanosheets of various MXenes ($Ti_3C_2T_x$, V_4CT_x, ...) fabricated by modified Langmuir-Schaeffer technique will be developed. The MXenes with various terminal groups provide a large number of active surface sites for more specific detection schemes compared to metal oxide nanoparticles, which opens the possibility to prepare **highly responsive sensors**. Current chemoresistive sensors based on metal oxides can already detect low concentrations of volatile organic compounds and have the potential to be used for the **non-invasive detection of biomarkers** of disease in a patient's exhaled air. By employing a new class of MXene-based sensors, we expect to further increase the selectivity of chemoresistive sensors.

Based on our recent results on functionalization of nanoparticles/nanosheets with specific biomolecules, we will focus on the application of MoO_x and MXenes nanoconjugates for **targeted treatment of pancreatic cancer cells**. The MoO_x and MXenes nanosheets exhibit a photothermal effect after being illuminated in the infrared region. In particular, the light is efficiently converted to heat and local ablation of cancer cells occurs. To achieve targeted delivery of the nanosheets to cancer cells, a previously verified scheme of the bioconjugation of the nanosheets with the M75 antibody will be employed. This antibody selectively binds to CAIX expressed on the surface of cancer cells. In this way, **highly spatially specific and minimally invasive cancer treatment** can be achieved. This research will be conducted in tight collaboration with the Biomedical Centre SAS.

Devices based on perovskites: In the current research of hybrid organic-inorganic perovskite solar cells, it is necessary to solve several challenges that limit their practical use. One of them we want to address is **temporal and temperature stability.** We have already begun research into 2D perovskites as active layer in the perovskite solar cell that exhibit higher stability compared to their 3D counterparts. The stability of perovskite layer also has an important environmental aspect as the lead-based perovskite solar cells have provided the best power conversion efficiency (PCE) so far. Therefore, as another challenge, we will focus on the research into **lead-free perovskite solar cells**, which has started recently and is also supported by a bilateral project with a Taiwanese partner. Simultaneously, we will work on improving PCE of the hybrid perovskite solar cells by **optimizing the morphology of the perovskite layer**. In particular, we will optimize the perovskite grain growth and reduce the grain boundary area to suppress the non-radiative recombination. In particular, we will optimize the perovskite grain growth and reduce the grain boundary area to suppress the non-radiative recombination (e.g. embedded LD nanomaterials, additives, modification of the growth conditions). Here, the in-situ GIWAXS and photoluminescence studies in real time will provide a key. Another important branch of our research includes **perovskite quantum dots** (0D perovskites). We plan to use them in solar cells as well as for advanced applications for broadband detection of electromagnetic radiation, starting from the visible range up to the X-rays. Versatile detectors on flexible substrates can be developed by this approach. This research will be performed within a project of the V4-Japan Joint Research Program on Advanced Materials, which has started recently.

Advanced defect analysis: In this rapidly developing field, we endeavor to combine three techniques that can be used to **detect defects in organic semiconductors** and also in perovskites. The **energy-resolved electrochemical impedance** (ER-EIS) is used to track the density of defect states in a static state, i.e. when the film is already formed. To understand the formation of defect states and their connection to structural defects, we plan to **combine the ex-situ ER-EIS with the in-situ time-resolved photoluminescence/GIWAXS method** recently developed at our institute. The combined analysis will provide deeper insight into the kinetics of defect formation and thus offers a potential solution for its mitigation. Finally, we will complete the picture using the **nanoscale infrared spectroscopy** (nano-FTIR), which allows spatial identification of chemical and/or orientational defects at the nanoscale. By combining the above three methods, we hope to design future semiconductor materials with low defect density as required for high-performance applications. We will focus primarily on photovoltaic hybrid

inorganic-organic and organic materials in order to improve their photoconversion efficiency and stability, which will bring them closer to practical use.

In the field of **innovative X-ray optics,** we will continue our collaboration with Integra TDS Ltd. Company in extending the method of SPDT nanomachining to the **curved X-ray optics** in Laue or Bragg geometry such as beam splitters or Johansson monochromators. These elements of X-ray optics can be used in several applications such as **biomedical imaging** and spectroscopic measurements at **synchrotron beamlines**, beam steering in **particle accelerators** with the energies above 100 keV and optics elements in X-ray free-electron lasers (XFEL). Enhanced quality of these elements due to the SPDT nanomachining will extend the utilization of these techniques. In addition to traditional Si and Ge, diamond elements will be tested, which are characterized by heat resistance. It is required for applications at synchrotron beamlines and FELs, which supply high intense beams of electromagnetic radiation.

The area of **quantum technologies** worldwide are witnessing investments both from the governmental and the industrial sectors. Institute of Physics is coordinating national activities in this area and represents the academic community in the **Slovak National Center for Quantum Technologies (QUTE.sk)** established in November 2021 by Ministry of Investments and Ministry of Education. Shortly, the goal of the QUTE.sk National Center is to create optimal conditions to increase Slovakia's competitiveness and excellence in research and **innovation in quantum technologies**, which will play a key role in future industrial and security applications. In addition to establishing Slovak research and innovation in quantum technologies, QUTE.sk's long-term strategic vision is to prepare Slovakia for the quantum industry.

One of the main quantum technology challenges we are going to address over the next five years is the installation of **quantum communication infrastructure** across Slovakia (skQCI) being the part of the European Initiative **euroQCI**. Half of the investments are planned in the national Recovery and Reconciliation Plan and the second half from European resources allocated for euroQCI. Within this project our responsibility is to design academic quantum communication backbone infrastructure connecting major research institutes in Slovakia. Altogether it consists of 12 quantum communication stations enabling the **quantum key distribution layer**, thus, securing the communication, but also serving as research **quantum network** infrastructure. Our solution is based on in-house development and the Research Center for Quantum Information has recently established an **experimental photonics quantum communication group** at the Institute led by Dr. Aktas previously experienced in the design of quantum communication networks in Bristol. Our major goal is to build up the expertise in the area of quantum photonics technologies and initiate research and innovations in this direction. One of the major research challenges is the design and demonstration of **multi-partite anonymous communication protocols** and **distributed quantum computation**. Existing experience in quantum measurement theory and quantum optimization methods will be beneficial for the development of **quantum certifications and verification methods**.

We aim to design **original quantum communication sources and detectors** which has an added value in the form of establishing a direct research know-how, hands-on education and training of experts and users, and technology/knowledge transfer to Slovakia. The focus within this project is on hardware (infrastructure); However, a simultaneous development of related software solutions (key management, interfaces, etc.) is necessary as well in order to achieve complete functionality in the existing **cyber-security systems**. Such functionality and integration are planned to be developed in cooperation with other national euroQCI initiatives (Austria and the Czech Republic). We are also applying for NATO funding with partners with expertise in post quantum cryptography (University of Alabama, VTT Finland, University of Juan Carlos and Slovak University of Technology) to tackle the task of handling hybrid solutions implementing PQC & QKD together in a standardised infrastructure. An **OpenQKD-project** funding (80k EUR) has already been secured for 2022. Also, one of the nodes of the planned terrestrial network is identified for potential future integration with space quantum communication infrastructures – hence, it will be exploited for testing the interface between the QCI's space and terrestrial systems.

Alongside with the experimental activities we will continue with the **development of quantum technology foundations** in the areas of quantum simulations, quantum measurements and quantum communication. Using the excellence program IMPULZ of Slovak Academy of Sciences we are opening a research **group of superconducting spintronics** (SUPERSPIN). It fits the research plans of the IPSAS department Research Centre for Quantum Information aiming to strengthen the performance in the area of **enabling technologies for quantum information processing**, namely within the research area of theoretical superconductivity. Let us stress that **superconducting qubits** represent currently the leading experimental/industrial platform for quantum simulations and computing. This group will extend and connect the existing research activities in **experimental superconducting qubits** (Miroslav Grajcár) and development of **quantum simulations methods** (Andrej Gendiar), thus, strengthening the competitiveness in all these research activities. Particular research goals cover investigation of spin relaxation phenomena in low-dimensional **unconventional superconductors** and **topological states** engineered through proximity effect.

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