Latvian Academy of Sciences

ACHIEVEMENTS IN SCIENCE 2024

FUNDAMENTAL SCIENCE

Theoretical Physics

Powering Tomorrow: Unlocking the Potential of Graphene, Batteries, Superconductivity and Photocatalysis.

Authors
LAS full member Roberts Eglītis, LAS full member Juris Purāns, LAS corresponding member Anatoli Popov, Professor Ran Jia.

Institute of Solid State Physics, University of Latvia,
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In 2023 and 2024, the research group has published 13 articles in prestigious scientific journals, offering innovations and theoretical models in the field of materials science and energy, and significantly contributing to knowledge about the development of new materials and their potential for use in energy harvesting technologies. As a result of the research, theoretical models have been developed that allow predicting which materials could be suitable for solar energy technologies, including borazole (BN) nanotubes formed using boron-boron (B-B) and nitrogen-nitrogen (N-N) bonds, as well as carbon nanotubes obtained from Me-graphene. New surface and interface structures of perovskite materials have been proposed that could be used in the catalytic splitting of water to produce oxygen and hydrogen. The research team has discovered that imino groups in the allotropic structure of carbon are able to regulate the forbidden energy band of the material. These properties make graphdiene the most promising photocatalyst for water splitting and carbon dioxide (CO_2) reduction. A new photocatalyst based on cobalt-phosphorus-coated molybdenum disulfide (Co-P@MoS_2) has been developed, demonstrating high efficiency in photocatalytic reactions and unlocking new possibilities for energy conversion technologies. In addition, the researchers developed a method for precisely determining the superconducting transition temperature under non-equilibrium conditions, expanding fundamental knowledge of superconductor properties.

Art History

Elita Grosmane, Ieva Ose, Baiba Dumpe, Irita Žeiere, Baiba Vaska, Imants Lancmanis. "ART HISTORY OF LATVIA, Volume I: Prehistory and Middle Ages: 9th Millennium BC – 1562" (Latvijas mākslas vēsture I: Aizvēsture un viduslaiki. 9. g. t. pr. Kr. – 1562"). Edited by Elita Grosmane. Riga: Art

Academy of Latvia Institute of Art History; Art History Research Foundation, 2024. 528 pp., 799 images. ISBN 9789934882463 (EN), ISBN 9789934882456 (LV).

Art Academy of Lavia Institute of Art History, Institute of Latvian History at the University of Latvia, National History Museum of Latvia.

Synthesizing the results of long-term research and new discoveries, the publication, created in collaboration between art historians and archaeologists, covers the art and architecture created in the territory of Latvia from prehistory to the end of the Middle Ages, for the first time examining the heritage of these periods in various fields in such a broad and versatile way. The volume covers the art and architecture created in the territory of Latvia from prehistory to the end of the Middle Ages. Its editor Elita Grosmane has written about the origins of architecture, urban planning, sacred architecture and fine art, as well as prepared historiography and historical background. Ieva Ose (Institute of Latvian History at the University of Latvia) wrote chapters on medieval castles and town walls, Baiba Dumpe (National History Museum of Latvia) – on pottery, Irita Žeiere (National History Museum of Latvia) – on textile arts, Baiba Vaska – on metalwork and Imants Lancmanis – on the applied arts of early historical styles.

With this publication, the Institute of Art History continues the research and publishing project, in which three volumes (III (in 2 books), IV, V), which tell about the period from 1780 to 1940, have already been published since 2014 under the editorship of *Dr.habil.art.* Eduards Kļaviņš. The volume together with the parallel Latvian edition was supported by the target programme of the State Cultural Capital Foundation "Cultural Events of National Importance".

Law sciences

Daiga Rezevska. General Principles of Law: Natural Rights, Legal Methods, and System Principles. Leiden, Boston: Brill|Nijhoff, 2024, 166 pp. ISBN: 978-90-04-69051-6.

University of Latvia, Faculty of Law.

The book by *Dr.iur.* Daiga Rezevska comprises contemporary legal theory pertaining to Democratic States based on the Rule of Law from the perspective of general principles of law. It explains in detail, theoretically and based on the specific case law, the phenomenon of general principles of law – as a source of law and directly applicable legal norms. It is a work of legal theory, legal philosophy, and legal method, but it will also assist scholars and practitioners in the transitional justice field as it shows how this theory of general principles of law has assisted Latvia to move away from the socialist legal tradition.

History

Frīdrihs Bernhards Blaufūss. Dzīvesgājums = Friedrich Bernhard Blaufuß. Lebenslauf. In Latvian and German languages, with summary in English. Edited and translated by Beata Paškevica. Rīga: Latvian National Library 2023. 247 pp. ISBN 9789934610486.

Authors
Beata Paškevica, Holger Zaunstöck, Tomas Grunewald.

National Library of Latvia, Research Centre of Francke Foundations Halle (Germany).

Leading researcher at the National Library of Latvia, Beata Paškevica, *Dr.phil.,* has translated the autobiography “Lebenslauf" of Friedrich Bernhard Blaufuss (Friedrich Bernhard Blaufuß, 1697–1756), compiled the edition, commented on it, created a bibliography of Blaufuss's texts, as well as developed the review “On the Life and Literary Activities of Friedrich Bernhard Blaufuss”. The manuscript of Friedrich Bernhard Blaufuss's autobiography has been kept in the Unity Archives in Herrnhut for several centuries, where it was discovered, transcribed and translated by Beata Paškevica. In collaboration with Prof. Holger Zaunstöck, head of the Research Centre of Francke Foundations in Halle, and researcher Thomas Grunewald, she prepared it for publication.

F.B. Blaufuss's autobiography is both a personal and subjective, as well as a timeless text about a person's relationship with God and the search for his mission in the world. Blaufuss is an apt observer of the conditions and people of his native Thuringia, Halle, and Vidzeme. After studying at the University of Halle, Blaufuss was sent to work in Vidzeme. Working in the parishes of Vidzeme and at Riga St. Jacob's Church, he became a supporter of the Herrnhut Brethren congregation in the Riga artisan community. He had to stand trial in the investigation process against the Brethren congregation in the Russian Empire. What he experienced during this time undermined his health, forcing him to focus on medical topics in the pages of his autobiography. Blaufüss can be perceived as an Augustine of Vidzeme, who struggles with obstacles created by himself and external circumstances in the process of spiritual development.

“Lebenslauf” is an important source for researchers of the history of various fields – medicine, pharmacy, religion, literature, theology, philosophy and architecture. The book has aroused international interest and is highly regarded in international Pietistic research. It is promoted by the Franke Foundations in Halle. A more extensive review in German is expected in issue 83 of the periodical “Unitas Fratrum”, which will be published in the spring of 2025.

APPLIED SCIENCE

Data processing systems and computer networks

A high-speed data transmission system has been developed using directly modulated quantum cascade laser technology for long-wave infrared free-space optical communications.

Authors
LAS foreign member Xiaodan Pang, PhD Hamza Dely, PhD Mahdieh Joharifar, PhD Laureline Durupt, *M.sc.ing.* Armands Ostrovskis, PhD Richard Schatz, PhD Thomas Bonazzi, PhD Gregory Maisons, PhD Djamal Gacemi, PhD Toms Salgals, PhD Lu Zhang, LAS corresponding member Sandis Spolītis, PhD Yan-Ting Sun, PhD Rafael Puerta, PhD Xianbin Yu, PhD Isabelle Sagnes, PhD Konstantinos Pantzos, PhD Angela Vasanelli, *Dr.sc.ing,* Vjačeslavs Bobrovs, PhD Carlo Sirtori, LAS full member Oskars Ozoliņš.

Riga Technical university (RTU), Institute of Photonics, Electronics and Telecommunications
(IPET), Latvia,
École Normale Supérieure (ENS), France,
Université Paris-Saclay (UPS), France,
mirSense, France,
KTH Royal Institute of Technology (KTH), Sweden,
RISE Research Institutes of Sweden (RISE), Sweden,
Ericsson Research, Ericsson AB (Ericsson), Sweden,
Zhejiang University (ZJU), China.

Our team of researchers at RTU has made significant contributions to advancing long-wave-infrared (LWIR) free-space optical (FSO) communication, an area of growing importance due to its low atmospheric propagation loss and high resilience to turbulence. By synthesizing resources and high-level expertise from leading partners such as KTH, ENS, UPS, mirSense, Ericsson, RISE, and ZJU, we organized a comprehensive system-level exploration. Our efforts led to a groundbreaking achievement: a record-breaking 60 Gbps transmission speed in the LWIR using unipolar quantum optoelectronics, a fivefold improvement over the previous record. These advancements, underpinned by cutting-edge quantum cascade laser (QCL) technology and highly sensitive detectors, were recently recognized through a publication in the prestigious journal of Nature Communications and two invited papers at the Optical Fiber Communication (OFC) conference and Journal of Lightwave Technology (JLT), among others. These innovations are pivotal for enabling reliable, high-speed connectivity in challenging non-terrestrial environments and establishing LWIR FSO communication systems as a foundation for future communication infrastructure and sustainable technological progress.

System analysis, modelling and designing

Cognitive robot perception and interpretation of high-level instructions with natural language concepts.

LAS full member Modris Greitāns, LAS full member Guntis Bārzdiņš, *Mg.sc.comp.* Pēteris Račinskis, PhD Jānis Ārents, *Mg.sc.ing.* Oskars Vismanis, Mg.sc.ing. Toms E.Zinars.

Institute of Electronics and Computer Science,
Institute of Mathematics and Computer Science, University of Latvia.

Scientists from the Institute of Electronics and Computer Science (EDI) together with colleagues from the Institute of Mathematics and Computer Science, University of Latvia (IMCS UL), have created a unique technology which can construct a 3D semantic map of a robot's surroundings and interpret natural language commands. The technology uses "concept vectors" – uniform representations of text and image data – and large language models. The semantic map associates a position in space with such a "concept vector", using range measurements from a depth camera or LiDAR in combination with images processed by the vision-language model. The natural language instruction parsing module converts free-form voice or text instructions into sequences of simple, pre-programmed robot actions, and the objects required for executing the plan are located in the semantic map. This technology allows the robot's users to give commands, e.g. "take the green apple and put it on the platter", then have the robot's perception system locate the objects ("green apple", "platter") and sequentially execute the actions ("pick", "place").

The goal of this technology is to encourage the use of smart industrial and mobile robots in dynamically changing environments, as well as intuitive human-machine collaboration facilitated by natural language interaction. The technology has received positive feedback from representatives of the ABB Latvija and NATRIX teams.

Additional information:
https://www.edi.lv/RoLISe_T4_1
https://www.youtube.com/watch?v=VHnHAN7kAE8&t

Polymers and composite materials

The first flight of the European space launcher Ariane-6 with cryogenic insulation material developed in Latvia.

Authors
LAS full member Uģis Cābulis, *Dr.sc.ing.* Vladimirs Jakušins, *Mg.chem.* Laima Vēvere, *Mg.sc.ing.* Beatrise Stūre-Šķēla.

Latvian State Institute of Wood Chemistry.

On July 9, 2024, the long-awaited first flight of Europe's latest generation space launcher Ariane-6 took place. Liquefied hydrogen and oxygen are used as rocket fuel for both the main and upper stages of Ariane-6. The insulation of these fuel tanks is very important, as the insulation material must withstand the cryogenic shock that occurs at very low temperatures (up to -253°C) and the loads that occur during rocket liftoff. The Polymer Laboratory of LSIWC has been cooperating with the European Space Agency for a long time and the composition we developed was selected as the cryogenic insulation material for the Ariane-6 upper stage. The development of the material and technology took place in close cooperation with the European Space Agency; the material was designed, developed, tested and certified from the laboratory model to the space flight.

Additional information:
https://kki.lv/en/latest-news/lsiwc-research-receives-recognition-latvian-academy-sciences

Bio-organic chemistry

Biomimetic method for producing spider silk.

Authors
Mg. Viktors Romaņuks, PhD Jēkabs Frīdmanis, *Mg.* Anna Līna Bula, *Dr.chem.* Alons Lends, *Mg.* Kristīne Senkāne, *Mg*. Gundars Leitis, *Dr.chem.* Gints Šmits, *Dr.phys.* Krišjānis Šmits, LAS full member Sergejs Gaidukovs, PhD Benjamin Schmuck, PhD Anna Rising, LAS full member Kristaps Jaudzems.

Latvian Institute of Organic Synthesis (LIOS), University of Latvia, Riga Technical University, Karolinska Institutet, Sweden.

Spider silk is one of the strongest materials found in nature, and scientists have been actively studying its properties and attempting to replicate it for several decades. This biomaterial stands out

due to its unique strength and elasticity combination, surpassing even Kevlar and steel. Additionally, spider silk is biocompatible and biodegradable, making it a promising material for applications in materials science, medicine, and cosmetics. However, producing spider silk proteins (spidroins) from spiders on an industrial scale is not feasible due to their cannibalistic and territorial nature. This limitation has driven the development of alternative biotechnological methods for obtaining spidroins.

Under the leadership of LAS academician Kristaps Jaudzems, LIOS, in collaboration with its partners, has developed an innovative method for producing artificial spider silk fibres with enhanced physical properties. By combining the production of spidroins in bacteria with chemical modification of the obtained material, artificial fibres were obtained, the extensibility of which is almost twice as high as that of natural spider silk. This approach not only improves the mechanical properties of the fibres but also allows them to be adapted to specific requirements. For example, to reduce the impact of the environment on the properties of the fibres, which has been one of the most significant shortcomings of artificial spider silk until now.

Biotechnology of medical processes

Innovative microfluidic technology for personalized pancreatic cancer treatment.

Authors
Mg. Karīna Goluba, PhD Vadims Parfejevs, PhD Evita Rostoka*, Mg.* Kaspars Jēkabsons*, Mg.* Ilze Blāķe*, Mg.* Anastasija Neimane, Annija Anete Ule, PhD Roberts Rimsa*, Mg.* Reinis Vangravs*, Dr.* Andrejs Pčolkins, LAS full member Una Riekstiņa.

University of Latvia.

Pancreatic adenocarcinoma is one of the most aggressive types of cancer, with approximately 90% of patients succumbing to the disease within five years of diagnosis. Due to its frequent resistance to standard therapies, there is a pressing need to develop individualized treatment approaches. Within the framework of the State Research Programme (VPP) Fotonika project, our team has developed a groundbreaking microfluidic device that replicates the complex interactions between tumor and blood vessel. This advanced device enables precise modeling of drug effects within the tumor microenvironment, allowing for the evaluation of vascular permeability and biomarkers, studies of metastasis, and testing the sensitivity of individual patient tumor cells to various therapies. Microfluidic organ-on-chip technology holds immense promise for enhancing treatment efficacy and advancing the fight against pancreatic cancer.

Organic chemistry

Crystal engineering paves the way for customizable and long-glowing organic materials.

Authors
M.Sc. Artūrs Mazarevičs*, Dr.chem.*Artis Kinēns, *Dr.chem.* Kaspars Leduskrasts, LAS full member Edgars Sūna.

Latvian Institute of Organic Synthesis.
Among various luminescent materials, phosphorescent materials may display slowly-fading emission compatile with human reaction speed. This long-lasting emission is of great value in various aplications such as data encryption, oxygen sensing, bioimaging and optoelectronics. While purely organic materials are cheap and non-toxic, the manipulation of their long-lasting emission remains a significant scientific challange.

Researchers from the Latvian Institute of Organic Synthesis have demonstrated a crystal engineering approach that allows switching on and off phosphorescence, as well as manipulating the length of the emission in purely organic materials. Until now, the lack of convenient methods to manipulate purely organic material long-lasting emission has hampered their use in everyday life.

Agricultural biotechnology

Faba Bean Diseases and Research on the Diversity of the Genus *Botrytis.*

Authors
LAS corresponding member Biruta Bankina, *Mg.agr.* Jānis Kaņeps, *Dr.agr.* Gunita Bimšteine, LAS corresponding member Zinta Gaile, *Mg.agr.* Ieva Plūduma-Pauniņa, *Mg.biol.* Elīna Brauna-Morževska, *Mg.biol.* Ance Roga, LAS corresponding member Dāvids Fridmanis, PhD Frederik Stoddard.

Faculty of Agriculture and Food technology of Latvia University of Life Sciences and Technologies (LBTU),
Latvian Biomedical Research and Study Centre,
University of Helsinki.

The expanding sowing area of faba bean (*Vicia faba* var. *minor*) has led to a more rapid spread of diseases, which can significantly reduce yield and its quality. Research on faba bean diseases and their development characteristics, with a particular focus on identifying the causal agents of diseases, was initiated in 2014.

The most significant disease of faba beans chocolate spot is caused by several fungi from the genus *Botrytis*. The well-known species *B. fabae* and *B. cinerea*, as well as the less-studied *B. fabiopsi*s, have been identified. For the first time, *B. pseudocinerea*, *B. medusae*, and *B. euroamericana* were identified in faba beans, and their pathogenicity was confirmed.

Research on the diversity of pathogens enhances our understanding of their potential spread across different regions, and contributes to the development of scientifically based plant protection strategies.

New knowledge about vitamin E compounds – tocotrienols in dicot seeds.

Authors
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Institute of Horticulture.

Most oil crops as a source of tocotrienols belong to the monocot class. Until now, it was assumed that they are rare in plants of the dicot class. Within the framework of project LZP 2020/1-0422, a large-scale study of the seeds of plants belonging to the dicotyledonous class was carried out, as a result of which the dominance of tocotrienols was found in more than 10 genera and 3000 species. An environmentally friendly HPLC method has been developed, described and submitted for patenting for the extraction of vitamin E compounds. A validated taxonomic approach to identify plant species with high tocotrienol content. The results obtained within the project are a turning point in the knowledge of tocotrienols in the seeds of dicot plants and valuable information for the pharmaceutical and food industries has been obtained. The research has resulted in 15 scientific articles and 1 registered patent.