INSTITUTE OF SOLID STATE PHYSICS
UNIVERSITY OF LATVIA

ACTION PLAN

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Action Plan 2021, Institute of Solid State Physics, University of Latvia

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TABLE OF CONTENTS

CONCEPT OF ELABORATION OF RESEARCH PROGRAMME 2021-2023-2027

The Institute of Solid State Physics, University of Latvia (ISSP UL) is an internationally recognised leader in the materials sciences and cross-disciplinary topics in Baltic Sea Region. Its scientific capacity and the research and innovation ecosystem are currently being further developed through the Center of Advanced Material Research and Technology Transfer project "CAMART^2". ISSP UL aims to transfer excellence in materials science and solid-state physics into highly educated people and into innovative products, processes and services.

An important challenge for the Institute is to translate the new knowledge coming from fundamental research into real innovation potential. The research will be directed towards the application-driven R&I domains where discoveries can make the change thus initiating and establishing the value chain. ISSP UL has created a suitable ecosystem that allows new ideas to be feasible.

The upgraded infrastructure, which includes advanced technology facilities and a reasonably complete set of instrumentation for the main contemporary methods for materials research and characterization, is by its nature an interdisciplinary one, since the outcomes of its use can be deployed in many R&I domains, fulfil specific industrial needs or find industrial applications in fields different from those for which they have been initially produced.

In addition to the existing highly developed ISSP UL experimental and technology infrastructure, which includes spectroscopy and microstructure research tools and more than 600 m^2 of clean-room space for thin film deposition, nanofabrication and characterization, it is important to synergy with world-leading large-scale X-ray absorption spectroscopy (XAS) research facilities (as PETRA-III/DORIS (Hamburg), SOLEIL (Paris), ELETTRA (Trieste), and ESRF (Grenoble) synchrotrons). Also, access to a number of new ESFRI facilities, such as European Spallation Source (ESS) and X-Ray Free Electron Laser Facility (XFEL) can drive innovative solutions thanks to their unique analytical techniques and expertise. Institute's computational resources (LASC - Latvian SuperCluster) are remarkably scaled-up and complemented by access to International High-Performance Computing centres, like HELIOS (Japan), Piz Daint (Switzerland), CINECA MARCONI (Italy).

Much attention in the Institute is devoted to the education and renewal of professional and highly qualified scientific personnel. Adequate and specific curricula – updated master's programme has been developed as the basis for future creation of knowledge and industrial competitiveness of young researchers. A lot of effort is dedicated to ensuring cooperation with international partners, institutions of higher education, training of students and specialists as well as to attracting entrepreneurs and investors.

The Research Programme will serve as "entry-point" for advanced materials-related R&D&I challenges, inquiries, and proposals. It will help to launch projects with a scope wider than that of a specific single research domain.

The Research Programme should be synchronized at the appropriate time period with:

- Horizon Europe Programme (2021–2027), linking basic material research in Pillar I, with applied material research in Pillar II;
- Europe Green Deal 2050;
- EURATOM (EUROfusion) 9th Framework Program (2021– 2025) and its Addendum (2026 – 2027);
- CAMART2 Project (2021 – 2023).

The long-term mission of the ISSP UL Research Programme 2021-2023-2027 and strategic development plan is to raise Institute's scientific capacity and to better integrate into the European Research Area by heightening the involvement in joint research programs and projects with EU Member States, especially within the Baltic Sea region.

The mid-term milestone in Research Programme for ISSP UL is the year 2023, the year to complete the Teaming project CAMART^2, when it comes to evaluating the planned achievements in quantified Key Performance indicators format, as well as when full sustainability of the Institute must be achieved and demonstrated.

The short-term activities will be prepared for each year within this period. The First Annual Action Plan is prepared for the year 2021.

Important challenge for the Institute is to translate the new knowledge coming from fundamental research into real innovation potential, included in Research Programme as new initiatives:

- Organ-on-a-chip and Lab-on-a-chip devices for biomarkers. The project will address application in personalized and precision medicine and will be based on expertise in easy-to-use microfluidic device design and fabrication capabilities of ISSP UL for creating a novel and impactful biological study test-bed.
- Polymer photonics technology platform. This platform offers standardized polymer photonic device preparation methods to academics and industry. This system is based on three main parts – computational simulations of optical devices, materials and element fabrication workflow, and producible photonic elements.

The new initiatives are pursued within the traditional strength of the ISSP UL based on the three research priorities of the Institute:

- Science: theory and experimental studies;
- Technology and experimental methods;
- Application: applied research and innovation of materials for radiation conversion (sensors, displays, scintillators, and detectors), materials for photonics and electronics, and materials for energy harvesting and storage.

ACTIVITIES AND MEASURES

INTRODUCTORY REMARKS

The updated Institute's long-term Strategy and Research Programme 2021-2023-2027 as a roadmap for its implementation is explicitly focused on fundamental studies and applied research of advanced functional materials towards technological needs and industrial challenges.

In the year 2021 ISSP UL will focus on photonics, energy harvesting and storage, and emerging biomedical issues. Creativity into the development of research-innovation ecosystem including advanced programs for university students, improving the in-person learning process, by taking into account the on-line skills developed during the pandemics, developing new forms of networking.

Training and motivation of research staff as well as of university students to develop their professional skills across Institute's research-innovation ecosystem will be promoted, in particular by acquiring skills to work with technological and research equipment located in Clean Rooms, Spectroscopy Laboratory, and partially in other Horizontal Laboratories.

For the development of new competitive ideas, it is essential to provide research activities within the interdisciplinary cross-laboratory collaboration. As an example: we plan to intensify the support of the collaboration between Laboratory of Materials for Energy Harvesting and Storage and our both Theoretical laboratories on the topics of next-generation battery materials, materials optimization and materials processing; "green" nanotechnologies will be the leading milestones.

CURRENT SITUATION AND FUTURE ACTIVITIES

Sustainable Human Resources (HR) Plan is being developed, however, given the general demographic situation in Latvia, it needs to be further improved in order to attract more students to STEM studies and to ISSP UL. An efficient management of HR is a must in order to increase the scientific capacity. Further improvement can be expected due to more resources for hiring scientific staff becoming available with the implementation of our research projects.

An increase in the quality of the research results measured by the average SNIP per publication in the next years will be further stimulated by the new merit-based budget distribution scheme and by the requirements included within the new research projects.

For intensifying project proposal's writing, an adequate service is provided, and extra personnel has been hired to offer an everyday support to project proposal developers.

Despite the travel limitations imposed by the COVID-19 pandemic, the ISSP UL researchers were active in disseminating their results at international conferences, most of which were organized as on-line events. More than 60 oral/poster presentations were held at 15 scientific conferences/workshops. In most cases, abstracts of these presentations have been published in conference proceedings.

The young researchers will be continuously supported by Institutes grants, providing as well opportunities to participate in summer-winter schools, workshops and conferences. In the current reality of COVID constraints, it is not possible to develop a realistic longer-term event planning, even in the cases of events in an online remote format. So, we will keep a close eye on all the opportunities that will open up.

Intensification of international collaboration will be further promoted by participating in - and as well organizing International scientific conferences. The tentative list of events and timeframe are subjects of change at any time in the current situation.

However, during 2021, one of the Institute's research team tasks will be the activities to start appropriate preparations for the International FM&NT-2022 conference scheduled for the spring of

2022 in Riga. We hope that it will be possible to hold the conference in the normal, "in-person" format.

NOTA BENE: BILATERAL PARTNER ACTIVITIES

To promote the bilateral collaboration between ISSP UL and RISE and KTH from Swedish partner side in the framework of CAMART^2 project, the **Scientist to Scientists (S2S) meetings** were proposed and organized based on R&D topics of mutual interest. This initiative started during 2019 with some discussions. During spring/summer 2020, several topics of interest were selected by ISSP UL. Specifically, relevant scientists were chosen at RISE, KTH and ISSP UL to organize the S2S discussions.

The goal of the matchmaking meetings is to find common collaboration interests, expand bilateral Latvia-Sweden research-innovation activities, organize short-term internships of undergraduate & graduate students, mature scientists and engineers, expand partner networks for generating joint "Horizon Europe" RIA project applications.

During the years 2019-2020, and just recently on January 2021, multiple S2S meetings were organized to cover a number of R&D topics. These include:

- Thin films & coating technologies:
  - Glass and coatings on glass (ISSP UL - RISE);
  - Wide-bandgap semiconductors like Ga_2O_3 and IrZnO for power electronics (ISSP UL - KTH);
- Flexible hybrid electronics and flexible printed sensors (ISSP UL - RISE);
- Biomedical systems (organ-on-chip) and biosensor systems (ISSP UL - KTH);
- Materials for energy harvesting and storage (ISSP UL - RISE);
  - Batteries (including Lithium-ion, Lithium metal, Sodium-ion batteries);
  - Carbon materials for energy application (graphene sheet stacks for electrodes for recycling application);
  - Hybrid thermoelectric systems and upconversion luminescent particles for applications in OLEDs for energy saving.
- Nanomaterials and ceramics in sensor applications (ISSP UL - RISE);
- Visual perception and image processing (augmented reality) (ISSP UL - KTH).

The main output of these meetings:

- Selection of collaboration topics;
- Joined R&D projects, e.g.:
  - "Physical Intelligence for Smart and Safe Human-Robot Interaction" submitted in ICT-47-2020, proposal number 101016867;
  - "Epitaxial Ga_2O_3 thin films as ultra-wide bandgap topological transparent electrodes for ultraviolet optoelectronics", project number LZP-2020/1-0345;
  - several in the preparation stage.
- Joint scientist papers, e.g.:

- S. Khartsev, N. Nordell, M. Hammar, J. Purans, and A. Hallén, "High-Quality Si-Doped β-Ga_2O_3 Films on Sapphire Fabricated by Pulsed Laser Deposition", Phys. Status Solidi B 2020, 2000362, DOI: 10.1002/pssb.202000362.

Many sub-topics have been selected in photonics, nanophotonics and lightwave optics. The selection of scientists in ISSP UL and KTH - RISE is in progress. A new meeting will be organized during 2021 regarding energy and nanomaterial applications in sensors.

Realization of Priority Research Directions will be based on the implementation of a number of measures including the development of step-by-step project application system within **16 Research & Innovation domains:**

- Theoretical material science and modelling;
- X-ray absorption spectroscopy;
- Optically active defects in silicon dioxide;
- Utilising up-conversion luminescence properties in nanoparticles for various applications;
- Electronic processes and charge transfer mechanisms in persistent luminescent materials;
- Novel materials for ionizing radiation and UV light dosimetry;
- Radiation defect studies in functional materials for scintillators and detectors;
- Thin films and coatings for electronic, energetic and biomedical application;
- 0D,1D,2D and mixed –dimensional nanomaterials;
- Development of organic light-emitting diodes and organic solid-state lasers;
- Third order non-linear optical effects in organic materials;
- Polymer photonics technology platform;
- Prototyping of microfluidic devices
- Visual perception and image processing in adaptive optics;
- Materials for batteries and hydrogen energy;
- Ferroelectric materials for electromechanical and electrocaloric application.

LIST OF ON-GOING FUNDAMENTAL AND APPLIED RESEARCH PROJECTS

Projects implemented include:

- 1 Horizon 2020 project;
- 3 EUROfusion projects;
- 3 COST projects;
- 2 EraNet projects;
- 1 European Agricultural Fund for Rural Development (EAFRD) project;
- 12 European Regional Development Fund (ERDF) projects;
- 3 National Research Program (CERN; COVID-19).
- 22 Latvian Council of Science Projects (FARF);
- 2 Rural support service projects;
- 16 Postdoctoral projects;
- 3 Latvia-Lithuania-Taiwan scientific cooperation projects;

- 1 Latvia - France Bilateral Program “OSMOZE” project;
- 1 Latvian-Ukrainian Bilateral Cooperation Project in the Area of Science and Technology;
- 1 Baltic-Norway-Luxembourg project.

The following project inventory in table form reflects the respective **research priorities of the Institute**.

Science: Theory and experimental studies	
Title	**Project Leader**
Theoretical prediction of new materials for intermediate temperature ceramic fuel cells	Denis Gryaznov
Theoretical prediction of hybrid nanostructured photocatalytic materials for efficient water splitting	Sergejs Piskunovs
First principles calculations of the nano-clusters of yttria in advanced ODS steels for reactors	Evgenijs Kotomins
Development of X-ray sensitive hybrid organic-inorganic systems	Aleksandrs Kalinko
Optical properties of advanced silicon dioxide-based materials for ultraviolet and high-power photonics	Linards Skuja
*Computational study of new proton-conducting perovskites for energy applications	Jurijs Mastrikovs
*Comparative analysis of radiation-induced processes in complex oxide crystals and ceramics for their application in fusion devices	Roberts Eglitis

*) Projects approved for financing in 2020, which will begin to execute in 2021.

Technology and experimental methods	
Title	**Project Leader**
Phosphorescent coatings prepared by plasma electrolytic oxidation	Krisjanis Smits
Novel transparent nanocomposite oxyfluoride materials for optical applications	Uldis Rogulis
Smart metal oxide nanocoatings and HIPIMS technology	Juris Purans
Application assessment of novel organic materials by prototyping of photonic devices	Martins Rutkis
Research of luminescence mechanisms and dosimeter properties nitrides and oxides using TL and OSL methods	Laima Trinkler
Novel persistent luminescent materials - red light emitters	Baiba Berzina
Up-conversion luminescence photolithography in organic compounds using nanoparticles/photoresist composition	Jurgis Grube
Development of novel scintillators for medical applications	Vladimir Pankratov
Microfluidic field flow fractionation for high throughput extra-cellular vesicle separation	Roberts Rimsa
Surface plasmon resonance enhanced light amplification and modulation	Aivars Vembris

in organic thin films	
Structural Modification of Carbene-Metal-Amide Complexes Towards Acquisition of Thermally Activated Delayed Fluorescence Blue Light OLED Emitters	Aivars Vembris
*Functional ultra wide bandgap gallium oxide and zinc gallate thin films and novel deposition technologies	Juris Purans
*Development of antiviral nanocoatings WO_3/Cu/WO_3 deposited by plasma vacuum technologies	Juris Purans
*Thin films of rare-earth oxy-hydrides for photochromic applications	Martins Zubkins
*Core-shell nanowire heterostructures of Charge Density Wave materials for optoelectronic applications	Boris Polyakov
*Development of mechanoluminescent thin films for real-time stress detectors	Virginija Vitola
*Antireflective electroluminescent coatings	Krisjanis Smits
*The study of radiation damage in garnet scintillators for high-energy physics and medical applications	Vladimir Pankratov
*Development of photonic elements towards polymer photonics integrated circuit	Gatis Mozolevskis
*Development of time and polarization resolved Kerr (effect) spectroscopy	Martins Rutkis

*) Projects approved for financing in 2020, which will begin to execute in 2021.

Applications	
Title	**Project Leader**
Nanostuctured Nitrogenated Carbon Materials as promoters in Energy Harvesting and Storage Technologies.	Janis Kleperis
Radiation damage studies in scintillator materials for high – energy physics and medical applications.	Anatolijs Popovs
Advanced polymer-ionic liquid composites for sodium-ion polymer batteries	Guntars Vaivars
Cycle life prediction of lithium-ion battery electrodes and cells, utilizing current-voltage response measurements	Gints Kucinskis
Investigation and optimization of cutting-edge lead-free PMUT platform: from materials to devices	Eriks Birks
*Computational study of new proton conducting perovskites for energy applications	Jurijs Mastrikovs
* Top quark and Higgs Boson studies in the CMS experiment, development of crystal scintillators, CMS sub-detector and particle accelerator technologies for applied applications, in collaboration with CERN	Anatolijs Popovs
*Functional ink-jet printing of wireless energy systems	Aleksejs Kuzmins
*Development of lead free ferroelectrics for application of electrocaloric effect	Andris Sternbergs

*) Projects approved for financing in 2020, which will begin to execute in 2021.

Postdoctoral projects	
Title	**Project Leader**
Quantum chemical and molecular dynamics study of advanced solids and nanomaterials: challenging road to reality	Dmitry Bocharov
Influence of crystallite size and composition on the formation of polarons in nanocrystalline tungstates	Georgijs Bakradze
Advanced materials for sodium ion batteries	Gints Kucinskis
Blue thermally activated delayed fluorescence emitters for high efficiency OLEDs	Dalius Gudeika

Synthesis and characterization of Ga_2O_3 and ZnMgO thin films for applications in ultraviolet light detectors.	Ramunas Nedzinskas
Modern glasses and glass-ceramics for high-temperature luminophores containing different garnets activated by rare-earth and 3d-metal ions for high-power LEDs.	Monika Skruodiene
Research and improvement of the optical properties of persistent luminescent oxide ceramics	Virginija Vitola
Role of manufacturing process on structure and properties of NBT-based solid solutions	Marija Dunce
*Creation of organic light emitting diodes based on heavy metal-free emissive materials	Anna Pidluzhna
*Rare earth oxide-hydride thin films for photochromics and antimicrobial surface applications	Martins Zubkins
*Antimicrobial multifunctional nanocoatings obtained with HIPIMS technology	Zarina Umatova
*Towards a universal laboratory sensor on a chip from one graphene sheet: from photodetection to biosensing	Thomas Yager
*Microfluidic chip with multidetection module for evaluation of nPEF-induced gene expression	Arunas Stirke
*Portable diagnostic device based on an array of biosensors from 2D material sensing elements	Andrejs Ogurcovs
*Development of alternative cathode material for high energy density sodium ion batteries	Rakesh Saroha
*Pressure and strain tuning of charge and spin correlations in van der Waals materials	Sudeshna Samanta

*) Projects approved for financing in 2020, which will begin to execute in 2021.

With a comparative success in the year 2020 national project calls, 28 new projects will be launched in 2021:

No.	**Project call**	**Submitted proposals 2019/ 2020**	**Funded projects 2020**	**Success rate 2020, %**
1	FARP -1	24	6	25
2	FARP -2	26	5	19
3	FARP – extra call	20	5	25
4	PostDoc	14	8	57
5	ERDF	10	4	40

The success rate depends strongly on the type of the project as well as on a piece of good luck in the presence of a very high competition and limited financial resources.

New opportunities open up in 2021 to participate in:

- Horizon Europe Program Calls;
- EURATOM (EUROfusion Program) WP Project Calls;
- Europe Green Deal Project Calls;
- ESA project Calls;
- EuroNanoMed III project Calls;
- ERA-NET EnerDigit project Calls.