IX International Physics Conference in honor of F. Pianca

December 21-22, 2021
Online

BOOK OF ABSTRACTS

Pre-word

Due to Covid-19 is still controlling our lives, the **IX International physics conference in honor of F. Pianca** will be held online on December 21-22, 2021.

The original idea of this conference is to let the students and young scientists meet each other, see how they look like and learn which science problems are of current interest abroad or in Latvia.

The first such conference was held in Riga in 1997 thanks to enthusiastic students that were developing their careers in science abroad. They did not want to lose contact with their colleagues working in Latvia and different other countries and enjoyed informal discussions about science. We want to re-establish this conference.

In most cases, we do not meet our colleagues from other countries often enough. Sometimes we do not even know other Latvians working in the same field in another country. The conference should bring together young Latvian scientists working abroad and in Latvia and foreign scientists interested in the scientific life of Latvia. It is particularly important for early-stage scientists who are looking for new knowledge and contacts with other researchers to build up their network.

The topics of the talks will be very diverse, so everyone will have the opportunity to broaden their horizons

The organizer of the conference:

Inga Pudza,

Faculty of Physics, Mathematics and Optometry,

Institute of Solid State Physics,

University of Latvia

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Time in RIGA (GMT +2)

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10:10	**Dr. Martins Zaumanis** *Empa materials science and technology, Switzerland*	**Connecting the dots: Communication at the Core of a Scientific Career**
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11:10	**Dr. Edgars Butanovs** *Institute of Solid State Physics, University of Latvia*	**Nanomaterials and thin films in Institute of Solid State Physics, University of Latvia: research directions and capabilities**
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15:00	**Dr. Maira Elksne** *University of Glasgow, United Kingdom*	**Improvements in GaN semiconductor technologies**
15:30	**M.Sc. Janis Sperga** *pureLiFi Ltd and University of Strathclyde, United Kingdom*	**LiFi: Connecting everyone and everything with light**

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14:30	**Dr. Aleksandrs Leitis** *EPFL, Switzerland*	**Metasurfaces for next-generation optics and biosensing**
15:00	**Dr. Karlis Dreimanis** *Riga Technical University, Affiliation - Latvia (residing on the Franco-Swiss boarder)*	**Particle Physics at LHC**
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F.P.-01

Connecting the Dots: Communication at the Core of a Scientific Career

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A scientist spends a lot time thinking about which difficult questions to tackle, how to come up with research methodology that would allow finding trustworthy answers, and how to best execute the planned tests. Is spending energy in this way the main driving force behind advances in science? Could it be that the way in which we share our knowledge is equally important for rising up the academic career stairs? Or does a career in academia simply depends on dumb luck? Well, perhaps all of the above are true.

In the presentation, I will show you how my hobbies that seemingly have nothing to do with science, have helped me to do better research. In other words – learning new skills and then connecting the dots for the benefit of communicating research has had a tremendous benefit for my career. My experience is not a recipe that you will be able copy, but perhaps hearing it will encourage you to jump into new ventures as well.

F.P.-02

Nanomechanics of 2D material membranes

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In the drive of technological advancement, we are in constant need of materials for better sensors, smaller electronic and mechanical devices. Two-dimensional (2D) crystals are promising to address these challenges due to their atomic thickness [1][2]. Here, we explore which properties make 2D membranes, like that of graphene, so interesting, application-wise promising, and compelling to explore.

We explain the fabrication of 2D material membranes and nanomechanical techniques used to probe these. We discuss their notable mechanical properties, and show how these are utilized as pressure and gas membrane sensors [3][4].

We also look at membranes with more complex effects in their nanomechanical motion. In particular, we investigate the influence of second-order phase transitions on the mechanical properties of 2D material membranes [5]. Finally, we theoretically substantiate this connection and experimentally verify it for materials of different condensed matter physics phenomena such as 2D layered antiferromagnets, ferromagnets, and their heterostructures.

[1] Lemme, M. C. et al. Nanoelectromechanical sensors based on suspended 2D materials. *Research* **2020,** 1–25 (2020). https://doi.org/10.34133/2020/8748602

[2] Steeneken, P. G., Dolleman, R. J., Davidovikj, D., Alijani, F. & van der Zant, H. S. J. Dynamics of 2D material membranes. *2D Mater.* **8**, 042001 (2021). https://doi.org/10.1088/2053-1583/ac152c

[3] Šiškins, M., Lee, M., Wehenkel, D. et al. Sensitive capacitive pressure sensors based on graphene membrane arrays. *Microsyst Nanoeng* **6**, 102 (2020). https://doi.org/10.1038/s41378-020-00212-3

[4] Rosłoń, I.E., Dolleman, R.J., Licona, H., Lee, M., Šiškins, M. et al. High-frequency gas effusion through nanopores in suspended graphene. *Nat Commun* **11**, 6025 (2020). https://doi.org/10.1038/s41467-020-19893-5

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F.P.-03

Nanomaterials and thin films in Institute of Solid State Physics, University of Latvia: research directions and capabilities

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In this talk, brief overview of research activities and capabilities in Thin Films Laboratory (Institute of Solid State Physics, University of Latvia, Riga) will be given. The Institute of Solid State Physics, University of Latvia (ISSP UL) is an internationally recognized research centre in materials science and cross-disciplinary research with modern infrastructure for the synthesis and analysis of various types of materials and 650 m^2 ISO class 4 - 8 cleanrooms. Thin Films Laboratory focuses on thin films science, deposition technologies and nanoscale materials (nanowires, nanoparticles, 2D materials) research. Some recent topics include but are not limited to growth and characterization of various functional core-shell nanowire heterostructures, nanoparticle and 2D materials synthesis for *ink-jet* printing, nanostructure manipulations *in-situ* scanning electron microscope, various metal oxide thin films deposition. Recent infrastructure upgrades for nanofabrication and thin film deposition at ISSP UL will be presented.

F.P.-04

Graphene nanoribbons as components in electric nano-circuits

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Graphene nanoribbons (GNRs) are considered promising candidates for all-graphene integrated circuits of nanoscale dimensions due to the possibility of controlling a broad range of electronic properties by bottom-up chemical self-assembly. Junctions connecting two or more GNRs are essential components for building such circuits and hence clear understanding of their electrical characteristics is critical. We have explored numerous GNR nanostructures containing quantum-dots[1], integrated metal-semiconductor-metal junctions[2] as well as defective nanoribbons[3]. Additionally, extensive screening of hundreds of thousands of disctinct configurations with numerical calculations [4] reveal the underlying structure-property relationships with crucial roles played by the bipartite symmetry of graphene, localized resonant states and geometry of the GNR junctions. Overall, our work defines the guidelines for engineering GNR junctions with desired electrical properties.

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[2] K. Čerņevičs, O. V. Yazyev, and M. Pizzochero, Phys. Rev. B, 102 (2020) 201406
[3] M. Pizzochero, G. B. Barin, K. Čerņevičs, S. Wang, P. Ruffieux, R. Fasel, and O. V. Yazyev, J. Phys. Chem. Lett.,12 (2021)4692
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F.P.-05

The Importance of Spatial Thinking in Teaching Physics

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A vast literature in physics education has documented students' difficulties in reading, constructing, and interpreting graphs. As a result, students with strong spatial abilities outperform their peers because they can better cognitively represent information, visualize, and create concepts. The extensive use of visual reasoning in physics discoveries such as Galileo's laws of motion, Maxwell's laws, Faraday's electromagnetic field theory, or Einstein's theory of relativity has been implicated in research on the cognitive processes underlying these discoveries. The majority of physics problems require manipulating spatial representations such as graphs, diagrams, or physical models. Spatial ability refers to the perception of spatial information such as dimensions, distances, and shapes, as well as the mental representation of that information and the processing of that information through various transformations such as mental rotation, visualizing from another perspective, or spatial reasoning. In this literature review, we will focus on various studies that have been done on the relationship of spatial visualization to solving kinematics problems such as predicting 2D motion of an object, transforming through one frame of reference to another, or interpreting kinematics graphs.

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F.P.-06

The ATLAS Detector at the LHC

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The contemporary theory of fundamental building blocks describing matter and its interactions is the Standard Model (SM). It unites electromagnetic, “weak”, and “strong” forces within a single theoretical framework – missing only a rigorous treatment of gravity to account for the full set of fundamental interactions.

Proton-proton collisions at the Large Hardon Collider (LHC)[1] provide a sustained source of events featuring high energy SM interactions. The ATLAS detector[2] surrounds one of the LHC collision points and is designed as a general-purpose detector capable of reconstructing properties of most SM particles emerging from the collision point.

This enables ATLAS to make precision tests of the SM while also tackling many of the unresolved topics in particle physics including Dark Matter[3] and the recent emergence of “B anomalies”[4].

ATLAS detector upgrades such as NSW[5] and ITk are underway to prepare ATLAS for the High Luminosity LHC which will enable ATLAS to refine many of its measurements and expand its searches.

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F.P.-07

Improvements in GaN semiconductor technologies

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GaN HEMTs are widely used in power amplifier applications, due to their superior properties, such as wide band gap, high critical field, high electron mobility, low intrinsic carrier density and high electron mobility. However, device self-heating is still the main challenge with the existing technology and limits devices from achieving theoretical power levels of 40 W/mm.
Various ways of reducing he channel temperature within these devices have been investigated. A method of planar distributed gates have been shown to reduce the temperature peaks within the device by 30°C by introducing inactive, heat absorbing areas within the device channel/gate regions. It's been done by plasma treatment thus keeping the device mesa planar which lead to low gate leakage currents.
Planar distributed gate devices show improved performance due to the efficient heat dissipation in the device channel demonstrating that this technology has a huge potential for high power applications.

Acknowledgement: I would like to thank the staff of the James Watt Nanofabrication Centre for the support and assistance in this work.

F.P.-08

LiFi: Connecting everyone and everything with light

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Mobile connectivity is one of the cornerstones of modern society. However, it also poses one of its biggest challenges. With the advent of industry 4.0, the internet of things (IoT), and augmented reality, up to a 5-fold increase in monthly global data traffic is expected by 2026 [1]. The increasing demand requires a major bandwidth expansion for the current radiofrequency (RF) communication solutions requiring increasingly novel and complicated designs, e.g. sub-mm wavelength antennas [2].

In the recent decade, the field of optical wireless communications (OWC) has emerged as a viable wireless technology to complement the existing and developing RF-based solutions [3]. Compared to RF, in OWC, the information is carried by light, which is intensity-modulated [4]. A fully bi-directional networked OWC system is called LiFi (short for light-fidelity) [5].

In this talk, we will discuss the main principles and describe the technology at the core of LiFi. Furthermore, we will describe the advantages of LiFi based communication in everyday life and industry. Finally, a brief outlook and challenges of LiFi research and development will be presented.

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F.P.-09

Describing Data: A Visual Survival Kit

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A number by itself does not tell you anything - its context, its presentation, and its emphasis deliver the message. Effective visuals begin with the main idea to convey to the viewer, and build elements around this main idea. This talk will be about the foundations for visualizing data, focusing on different data structures and how they are communicated, along with good and bad examples. My background as a mathematician will play into the themes, as I will emphasize the key concepts and differences of data to be presented, rather than the specific tools for creating them (some tools will be discussed).

F.P.-10

Deciphering experimental spectroscopic data using machine learning

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Understanding the structure of working functional materials remains a challenge, because the choice of experimental techniques that provide atomic-level information and are also suitable for operando studies is extremely limited. Among those few, an invaluable tool is X-ray absorption spectroscopy (XAS). XAS provides unique information about the environment around the absorbing atoms, but the accuracy of conventional approaches for XAS data analysis is, however, limited, when they are applied to heterogeneous, disordered structures, which are common for functional materials.

Recent developments in data-enabled discovery methods provide a key to this problem. Machine learning methods can be successfully used to correlate XAS features with the descriptors of 3D local structure.[1] Here we demonstrate the potentiality of this method on the example of studies of particle size and shape effect on X-ray absorption near edge structure (XANES) spectra of monometallic nanoparticles,[2] and operando extended X-ray absorption fine structure (EXAFS) studies of alloy formation in Cu-Zn nanocatalysts for CO_2 electroreduction.[3]

[1] J. Timoshenko, A. I. Frenkel, *ACS Catal.*, **9**, 10192 (2019)

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[3] J. Timoshenko, H. Jeon, I. Sinev, F.T. Haase, A. Herzog, B. Roldan Cuenya. *Chem. Science* **11**, 3727 (2020)

F.P.-11

Nonlinear plasmonics with monocrystalline gold

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Plasmonic nanostructures allow to controllably enhance linear and nonlinear light-matter interactions by concentrating the electromagnetic fields at the scales below the diffraction limit. This feature is highly desired for many applications, e.g. bio- and chemical sensing, photocatalysis, metamaterials, etc. However, success of further advancements largely depends on the reduction of electromagnetic losses in plasmonic materials, which constitutes the most ubiquitous problem of current device prototypes. In this talk I will present experimental investigation of the plasmonic properties of (quasi-) monocrystalline gold flakes, [1] which emerged recently as a material platform to supersede the traditionally-used polycrystalline gold films. In particular, I will discuss anisotropy in the second-order nonlinear optical response from {111} surface of crystalline gold which is markedly absent at the polycrystalline surfaces. [2] Also, I will present our recent results on two-photon luminescence microscopy which reveals that hot carrier excitation and relaxation dynamics is significantly altered when the gold thickness approaches mesoscopic dimensions.

[1] S.Boroviks et al., Interference in edge-scattering from monocrystalline gold flakes, Optical Materials Express 8 (**2018**) 3688, DOI: 10.1364/OME.8.003688

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F.P.-12

Electromagnetic methods for production of aluminium metal matrix composites

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Aluminium metal matrix composites (MMC) are perspective materials for wide range applications in automotive, aerospace and other industries where material mechanical properties and weight ratio is crucial. MMC manufacturing through metallurgical route two challenging tasks can be set – firstly, reinforcement introduction into the melt and secondly, particle agglomerate dispersion. For the first task typical obstacle is poor particle wettability, while in second task particles added to a liquid metal tend to form agglomerates due to van der Waals and interfacial forces. Most of currently used manufacturing methods through metallurgical route are effective only for small quantities or are time consuming, so new MMC manufacturing methods are still needed.

By using electromagnetic field, it is possible to induce liquid metal flows in contactless manner. It has been shown that travelling magnetic field generated by permanent magnet dipole induce intense liquid metal flows in the melt even through thick crucible walls. Depending on the application the flow can be adjusted by changing the rotating dipole size, position, and rotation frequency. This research focusses on application to use such stirrer as an alternative to mechanical stirrer in stir casting MMC production process.

Combined AC and DC magnetic fields creates oscillating electromagnetic force which may induce cavitation in liquid metals. Cavitation bubble collapses are believed to be the mechanism of particle agglomerate braking and particle dispersion in metal. For some alloy and particle pairs the results are promising and further development process of the method is in progress.

F.P.-13

Biophotonics for patient care: building a translational research team at a medical center in the United States

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Biophotonics is a rapidly advancing interdisciplinary field at the convergence of light and biological matter. With a formal background in Physics and PhD training in biophotonics under the guidance of Dr. Jānis Spīgulis, I have been passionate about developing and applying light-based technologies for improving patient care. This talk will highlight my experiences building a translational research team within the Department of Dermatology of the Vanderbilt University Medical Center in Nashville, Tennessee, the United States. Dr. Eric Tkaczyk founded the Vanderbilt Dermatology Translational Research Clinic (VDTRC.org) in 2016 as a platform for direct translation of biophotonics for clinical impact in dermatology, oncology, and related specialties. The mission is seamless integration of technology-based patient care and translational research. I will also share our experience starting a new field of bedside confocal videomicroscopy. Through a reflectance confocal microscope, we noninvasively studied individual immune cells moving in the upper microvessels of human skin.

This work was supported by the European Regional Development Fund (project number: 1.1.1.2/VIAA/4/20/665).

F.P.-14

Metasurfaces for next-generation optics and biosensing

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Novel two-dimensional metamaterials, known as metasurfaces, have emerged as a breakthrough platform for controlling electromagnetic wave properties at the nanoscale. These metasurfaces consist of subwavelength nano-antennas, also called meta-atoms, which can be engineered at will to obtain on-demand optical functionalities. In this talk, I will show how these metasurfaces can be tailored to realize compact sensor devices capable of ultra-sensitive molecular fingerprint detection without the need for spectrometry, tunable lasers or moving mechanical parts [1,2]. Additionally, a novel high throughput and CMOS-compatible nanofabrication process of metasurfaces operating in the technologically important mid-infrared spectral range will be demonstrated. The versatility of the method is illustrated by realizing spectrally selective metasurfaces, highly-efficient meta-optical elements and optofluidic sensor devices for label-free and real-time monitoring of protein-lipid interactions [3]. In the final part of the talk, I will demonstrate how the functionalities of the metasurfaces can be further extended by incorporating active phase change materials into the meta-atom design, which has an untapped potential for next-generation tunable optical components [4].

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F.P.-15

Particle Physics at LHC

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Particle physics is the most fundamental of physics disciplines, which seeks answers to the most fundamental of questions about the nature of our Universe. The working theory describing particle physics is the Standard Model (SM), the most succesful theory in science to date.
Despite its success, we know that it is incomplete and thus strive to find holes in the theory, which could provide answers to the unknowns of our Universe, such as the origin and nature of the dark matter and the reasons behind the matter/anti-matter asymmetry.
At the Large Hadron Collider (LHC), high-energy proton (and lead ion) beams are collided in order to recreate the conditions of the early Universe and investigate the phenomena that might give us clues about the true nature of the cosmos we inhabit.
In order to perform these investigations, four major experiments are situated on the LHC ring - ATLAS, ALICE, CMS and LHCb.
Latvia is a member of the CMS collaboration.