NANO AND INTEGRATED PHOTONICS WORKSHOP

19-22 APRIL, 2021
ONLINE

NIP

NANO AND INTEGRATED PHOTONICS WORKSHOP

PARTNERS

Aston University | AIPT Aston Institute of Photonic Technologies

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INSTITUT DE RECHERCHE femto-st SCIENCES & TECHNOLOGIES

FORTH INSTITUTE OF ELECTRONIC STRUCTURE AND LASER

MULTIPLY

International Mobility and Training Programme in Photonics for Experienced Researchers

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 713694.

Workshop topics

The goal of this workshop is to cover the latest progress in nano- and integrated photonics areas. Having an online format offers a forum for scientists, engineers and researchers to discuss and exchange novel ideas, results, experiences and work-in-progress on all aspects of photonics. The program will facilitate discussions on various current hot topics.

- **SEMICONDUCTOR INTEGRATED DEVICES**
- **BIO-MEDICAL INTEGRATED DEVICES**
- **MICRO-RESONATORS AND FREQUENCY COMBS**
- **NANO-PHOTONICS**
- **PLASMONICS**
- **NOVEL MATERIALS**
- **3D LASER PRINTING OF THE INTEGRATED DEVICES**
- **META-SURFACES**
- **THZ SOURCES AND DETECTORS**

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| 19-22 April, 2021

Organising committee

Prof.Edik Rafailov

ASTON UNIVERSITY, UK

chair of the Workshop

Prof.Sergei Turitsyn

ASTON UNIVERSITY, UK

Dr.Maria Farsari

FORTH/IESL, GREECE

Dr.Auro Perego

ASTON UNIVERSITY, UK

Dr.Egor Manuylovich

ASTON UNIVERSITY, UK

Dr.Maria Chernysheva

LEIBNIZ-IPHT, GERMANY

Natalia Manuilovich

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Prof.Grigorii Sokolovskii
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ICFO, SPAIN

WORKSHOP PROGRAMME

19 APRIL

Novel materials

20 APRIL

Novel light sources

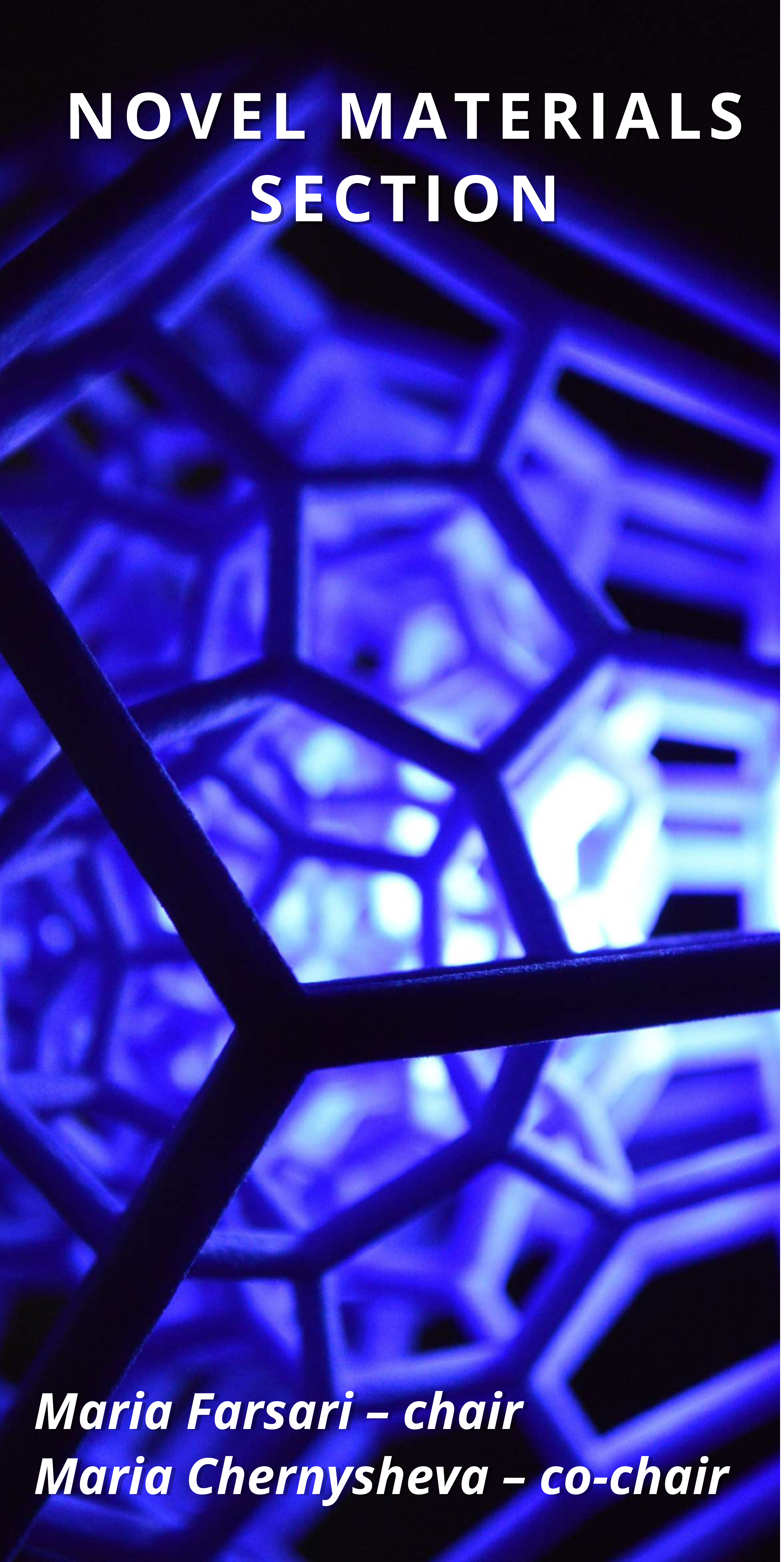
21 APRIL

Micro-resonators and frequency combs

22 APRIL

Advanced concepts

SPEAKERS



DR.MARIA FARSARI

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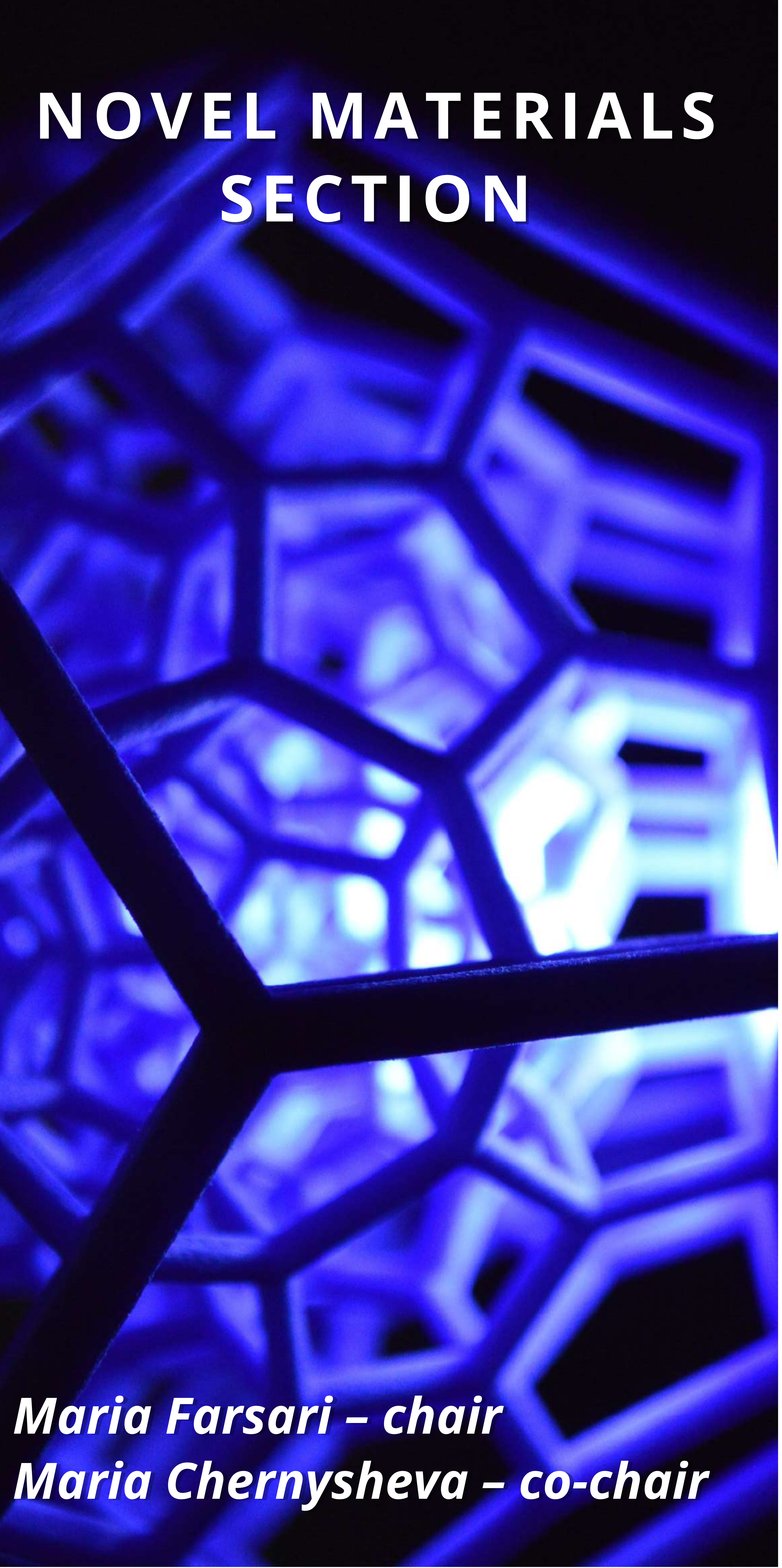
3D MICRO/NANO PRINTING

Multiphoton Lithography is a laser-based additive manufacturing technique which allows fabrication with resolution down to a few tens of nanometres. Based on nonlinear absorption, Multiphoton Lithography has unique capabilities that no-other technique can provide. It has been implemented with a variety of materials and several components and devices have been fabricated such as metamaterials, biomedical devices, photocatalytic systems and mechanical models

The unique capability of Multiphoton Lithography lies in that it allows the fabrication of computer-designed, fully functional 3D devices. In this talk, I summarize the principles of microfabrication, and present recent research in materials processing and functionalization of 3D structures. Finally, I discuss future applications and prospects for the technology.



DR.TATJANA GRIC

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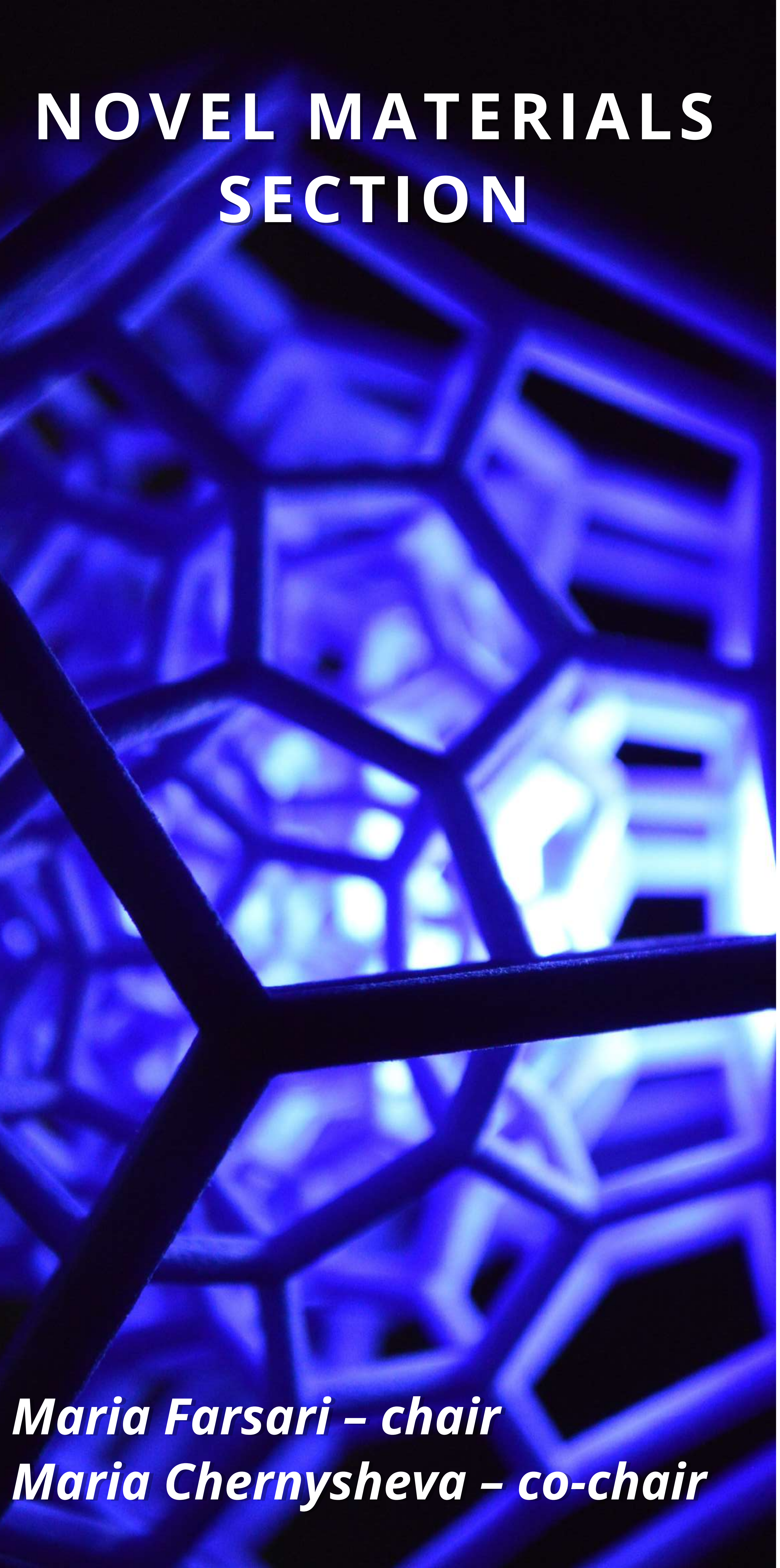
APPLICATIONS OF THE METAMATERIAL FORMALISM

Early detection of a tumormakes it more probable that the patient will, finally, beat the cancer and recover. The main goal of broadly defined cancer diagnostics is to determine whether a patient has a tumor, where it is located, and what is its histological type and severity. Here, we present, in the first time to our knowledge, the studies on metamaterial properties of biological tissues to identify healthy and cancerous areas in the brain tissue. The results show, that the metamaterial properties strongly differ depending on thetissue type, if it is healthy or unhealthy one. The obtained effective permittivity values were dependent on various factors, like the amount of different cell types in the sample and their distribution. Based on these findings, the identification of the cancer affected areas based on their effective medium properties was performed. These results proved the metamaterial model capability in recognition of the cancer affected areas. The presented approach can have a significant impact on the development of methodological approaches toward precise identification of pathological tissues and would allow for more effective detection of cancer-related changes. We suggest the highly effective recognition of the cancerous specimens in stained brain biopsies.



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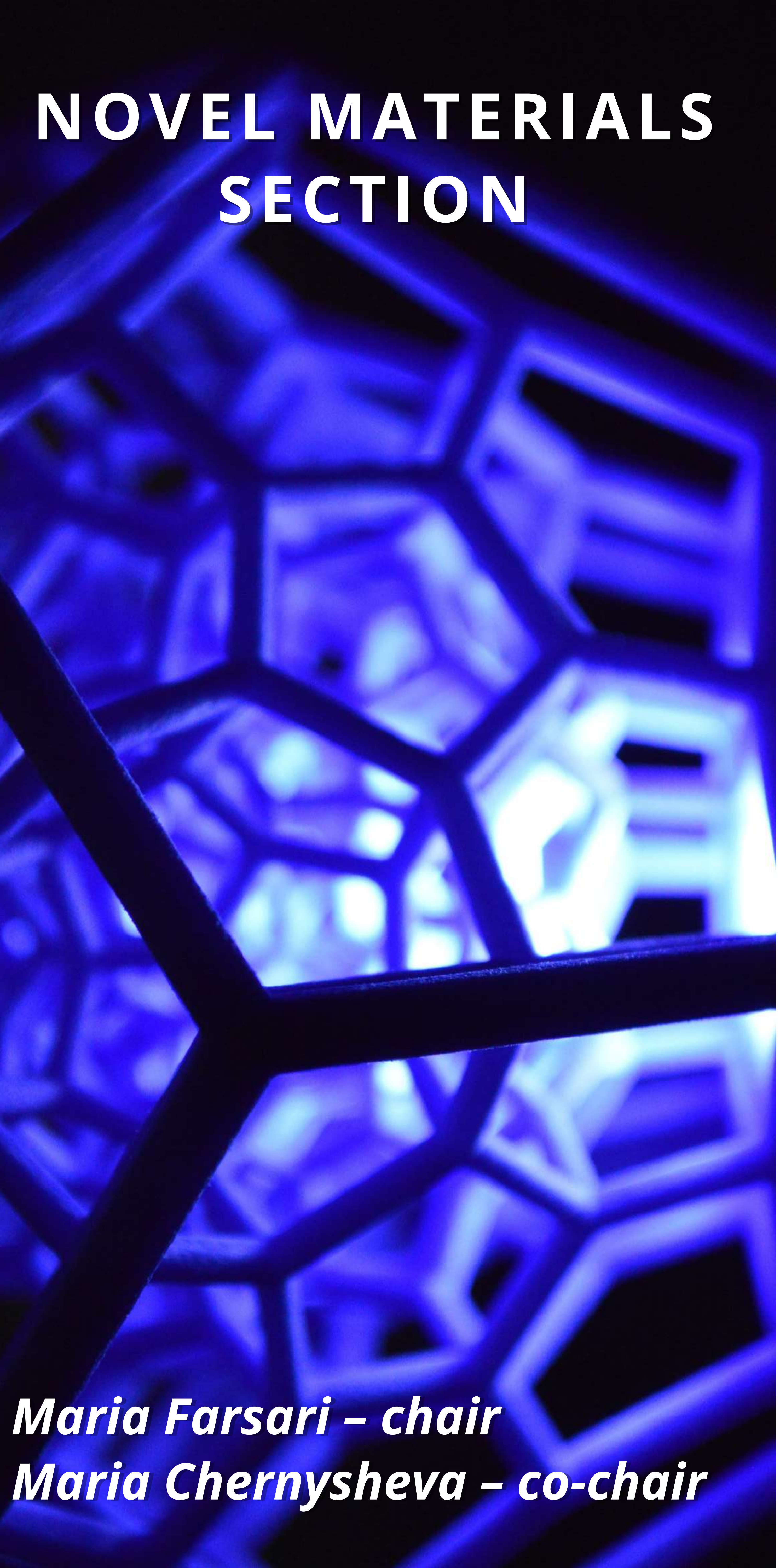
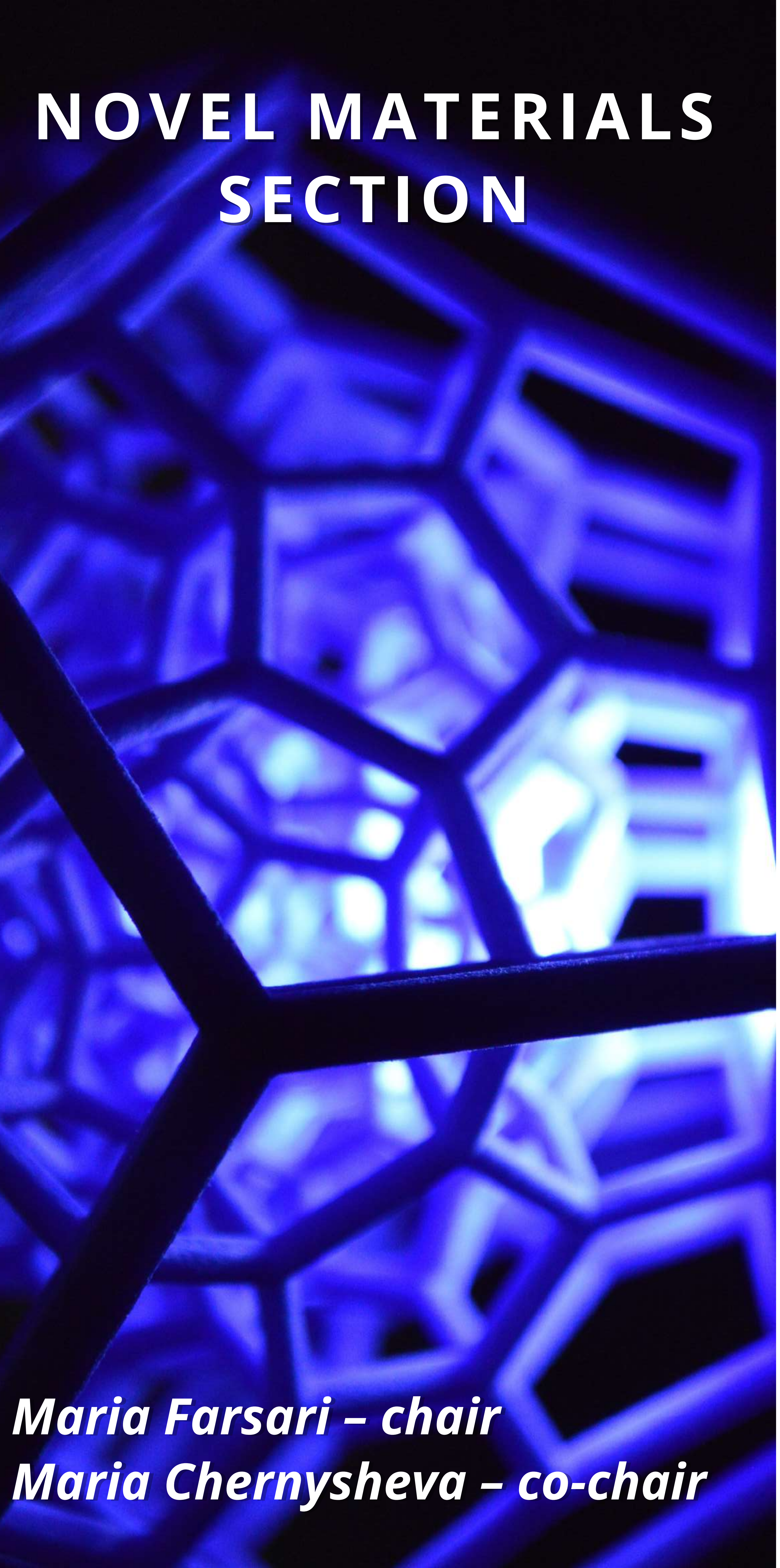
DEVELOPING MULTIFUNCTIONAL PHOTO-THERMAL BIOMATERIALS FOR BONE CANCER TUMOUR THERAPY

Survival for osteosarcoma (bone cancer) patients is poor despite the aggressive use of surgery, chemotherapy, and/or radiotherapy. Therefore, to improve the clinical outcome safe and effective therapeutic materials are required. The minimum key requirements for an effective biomaterial targeted towards osteosarcoma therapy are (1) to eradicate any residual post-surgical tumour without being cytotoxic to the surrounding tissue and (2) to provide a suitable platform for the regeneration of new bone. Furthermore, biomaterials which possess multi-functionality e.g. antimicrobial properties would also be of significant patient benefit, reducing infections and the need for associated surgical revisions. We have developed (and patented) a series of novel of gallium doped bioactive glasses demonstrating antineoplastic characteristics and bone regeneration in vitro. We now wish to develop multifunctional bioactive glasses by incorporating photo-thermal therapy which has the potential to help treat residual metastatic cancers without the need for further invasive surgical procedures. We aim to develop a suite of non-toxic bismuth doped bioactive glasses with optimised photo- thermal potential and antimicrobial properties



to promote bone regeneration and kill cancer cells by hyperthermia. So far we have managed to formulate and successfully manufacture and characterize glass compositions containing 0-4% Bi_2O_3. These glasses were shown to be cytocompatible to healthy human osteoblasts (bone cells) both in direct contact (cells seeded on top of a glass disc) and indirect contact (supplementing cell culture media with glass leachable) experiments. The next and final step of this research will be the optimisation of the photo-thermal model and ultimately the hyperthermia experiments using bone cancer cells.



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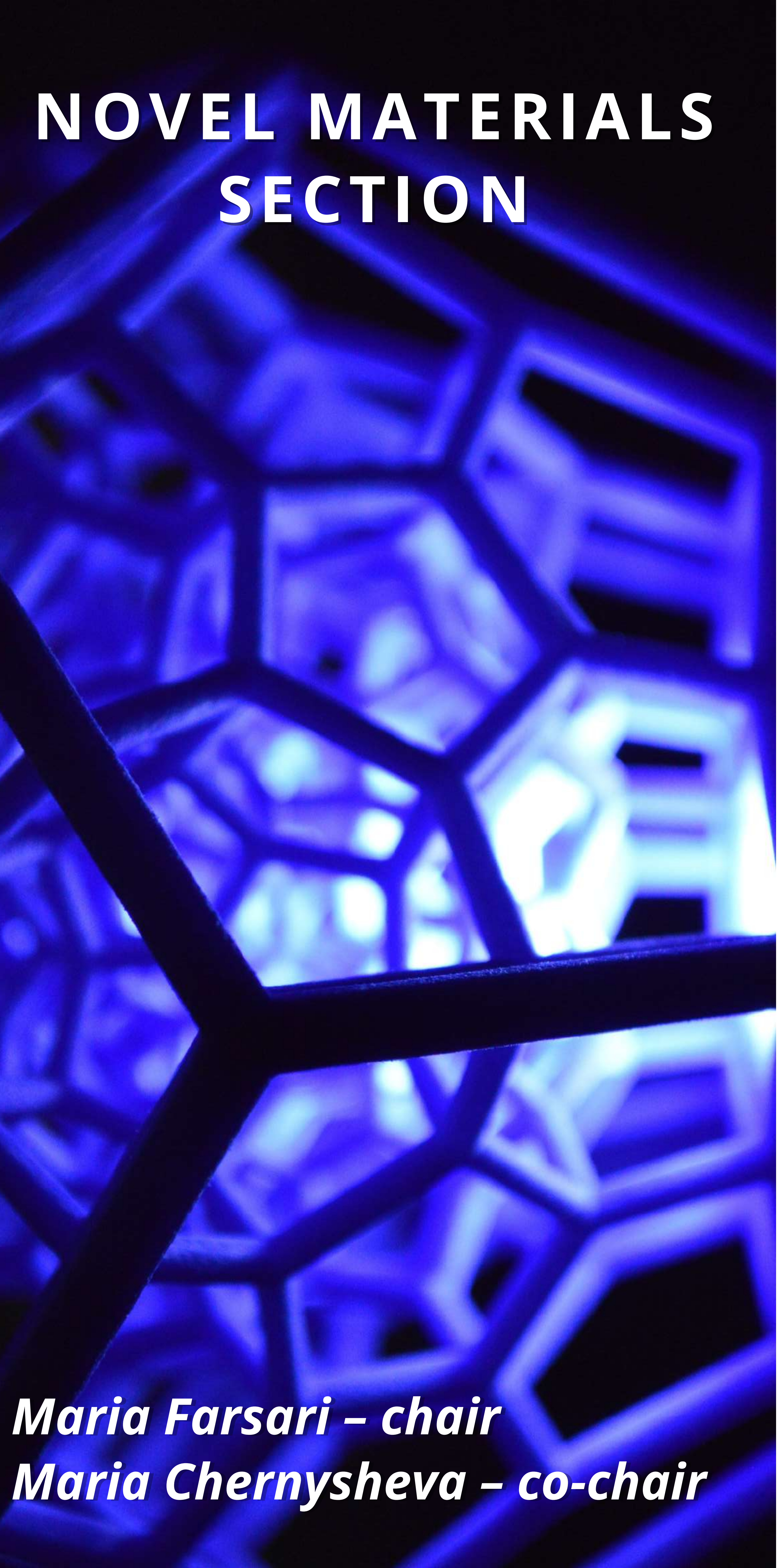
FIBERS MEET NANOSTRUCTURES AND META-SURFACES: A PLATFORM FOR OPTICAL TRAPPING AND BOOSTING INCOUPLING EFFICIENCIES

The interfacing of nano-structures or meta-surfaces with the end faces of optical fibers represents a promising approach to unlock novel types of functionalities within a multitude of fields including biophotonics, quantum technologies or optical sensing. Here commonly used top-down implementation strategies are hard to employ in case fibers are considered due to the intrinsic mismatch of the fiber geometry with wafer-based technology.

Within this presentation, we would like report on our recent results that consider two implementation pathways to circumvent the mentioned bottleneck, namely (i) modified electron-beam lithography and (ii) 3D nano-printing. Both approaches allow for the implementation of nano-structures on the end-face of optical fibers leading to significant performance improvements compared to fibers with blank end faces. These improvements are shown here on the examples of (i) boosting in-coupling efficiencies into fibers at almost grazing incidence (80°) via dielectric nano-structures (percent-level efficiencies) and (ii) optical trapping of micro-beads and bacteria using only one single-mode fiber via the integration of dielectric meta-surfaces, reaching numerical apertures as large as 0.88.



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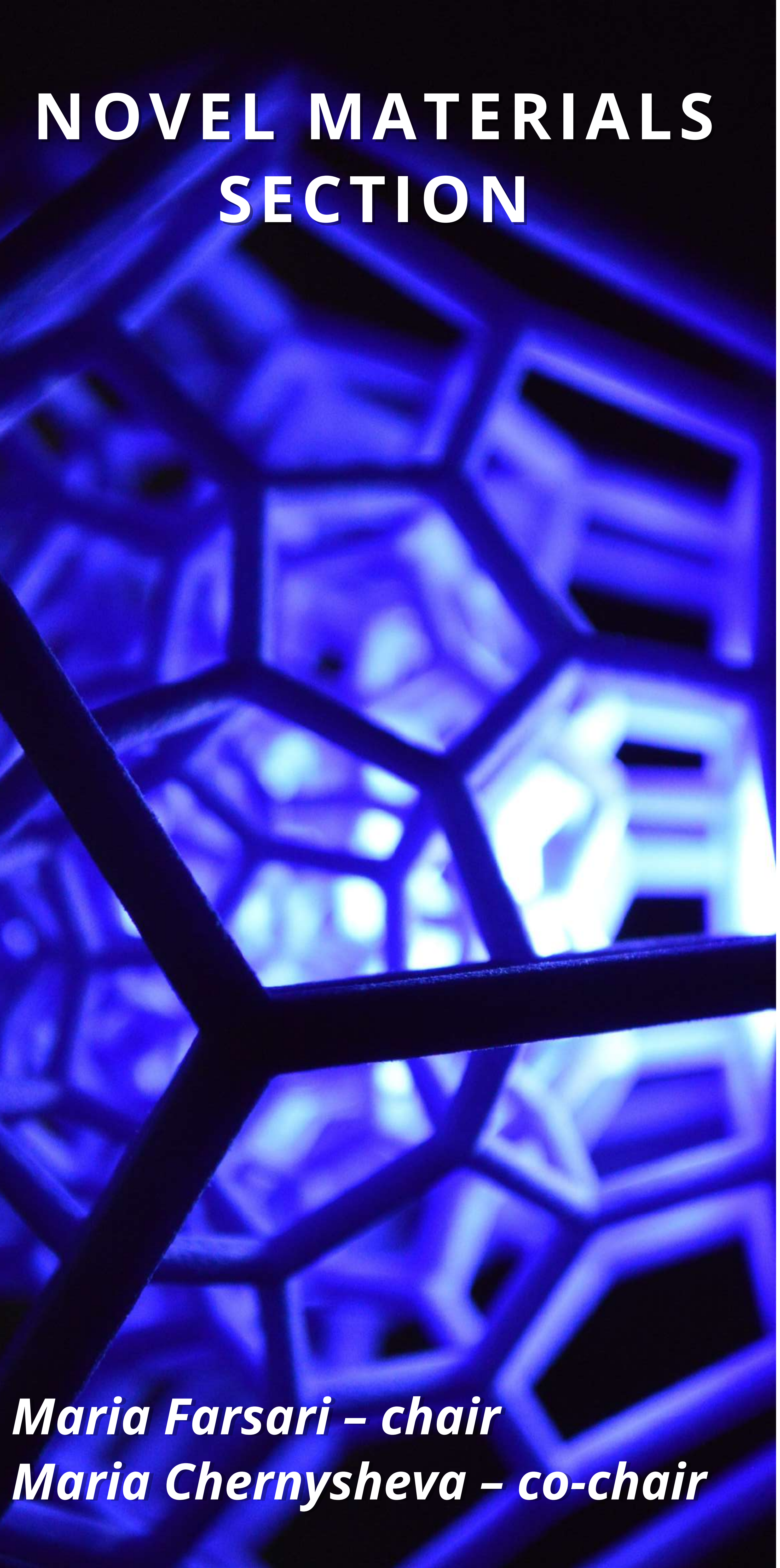
ORGANIC SMALL MOLECULE INTEGRATED PHOTONICS

The initial, landmark integrated photonic devices relied on silicon and III-V materials, and recent advances in material fabrication and deposition methods have enabled a plethora of new technologies based on materials with higher optical nonlinearities, including 2D materials and organic polymers. However, nonlinear optical (NLO) organic small molecules have not experienced similar growth due to a perceived environmental instability and to challenges related to intra and intermolecular interactions. Because NLO small molecules have NLO coefficients that are orders of magnitude larger than conventional optical materials, developing strategies to fabricate optical devices could enable significant performance improvements. In recent work, we combined conventional top-down fabrication methods with bottom-up techniques to develop on-chip optical devices that incorporate NLO optical small molecules. These hybrid systems provide access to optical behavior and performance not attainable with conventional material systems. In this presentation, I will discuss a couple examples of NLO small molecule integrated resonators, including Raman lasers and all optically-switchable devices.



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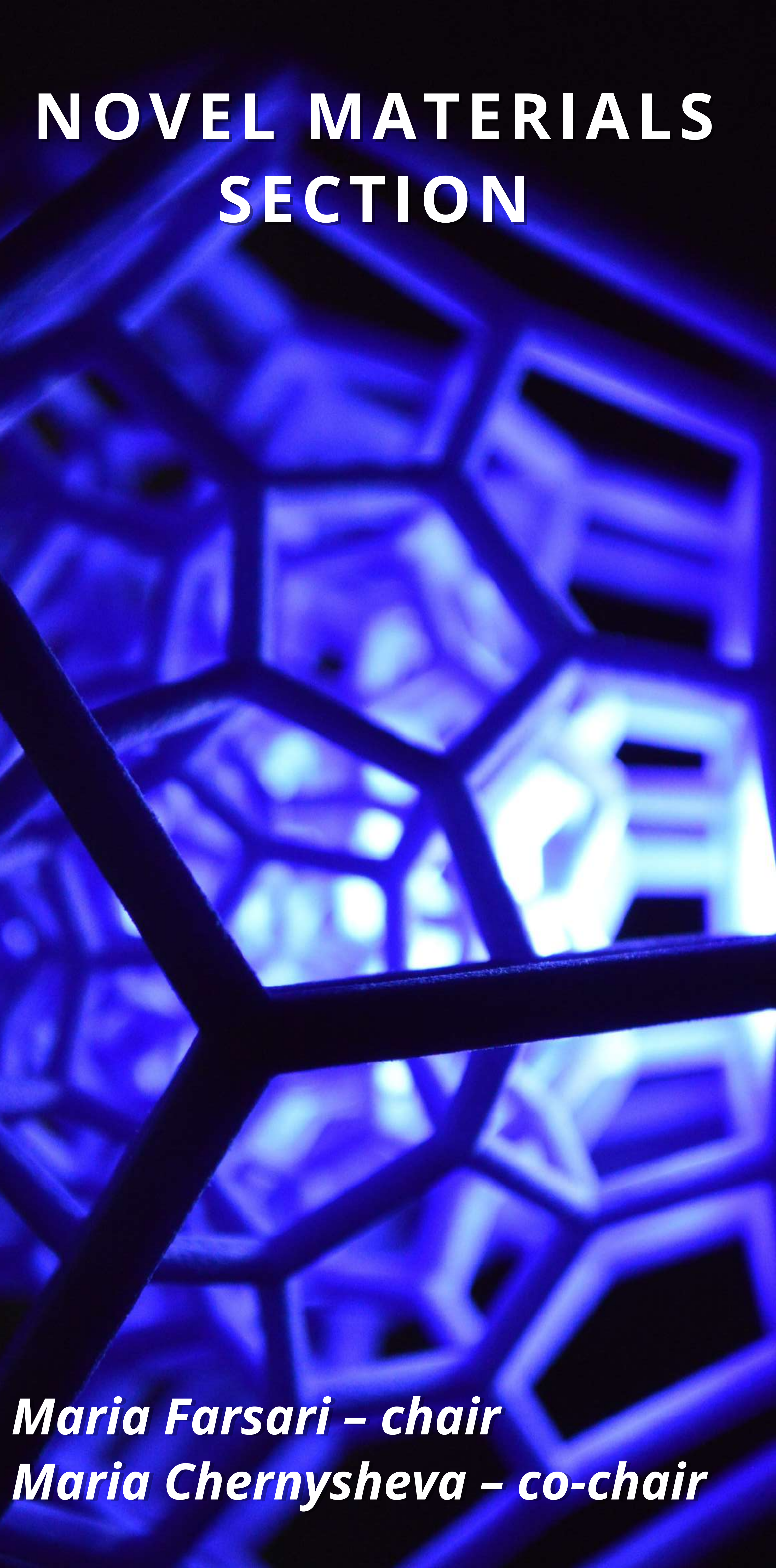
2D MATERIALS INTEGRATED NONLINEAR PHOTONICS

In this talk, I will discuss our recent results on nonlinear optics with two-dimensional layered (e.g., graphene, transition metal dichalcogenides, and black phosphorus) materials. The results show the advantages of utilizing low-dimensional nanomaterials for various integrated nonlinear photonic and optoelectronic applications, such as wavelength converters, and ultrafast lasers. Further, I will present our recent advances employing hybrid structures, such as two-dimensional heterostructures, plasmonic structures, and silicon/fibre waveguides integrated structures.



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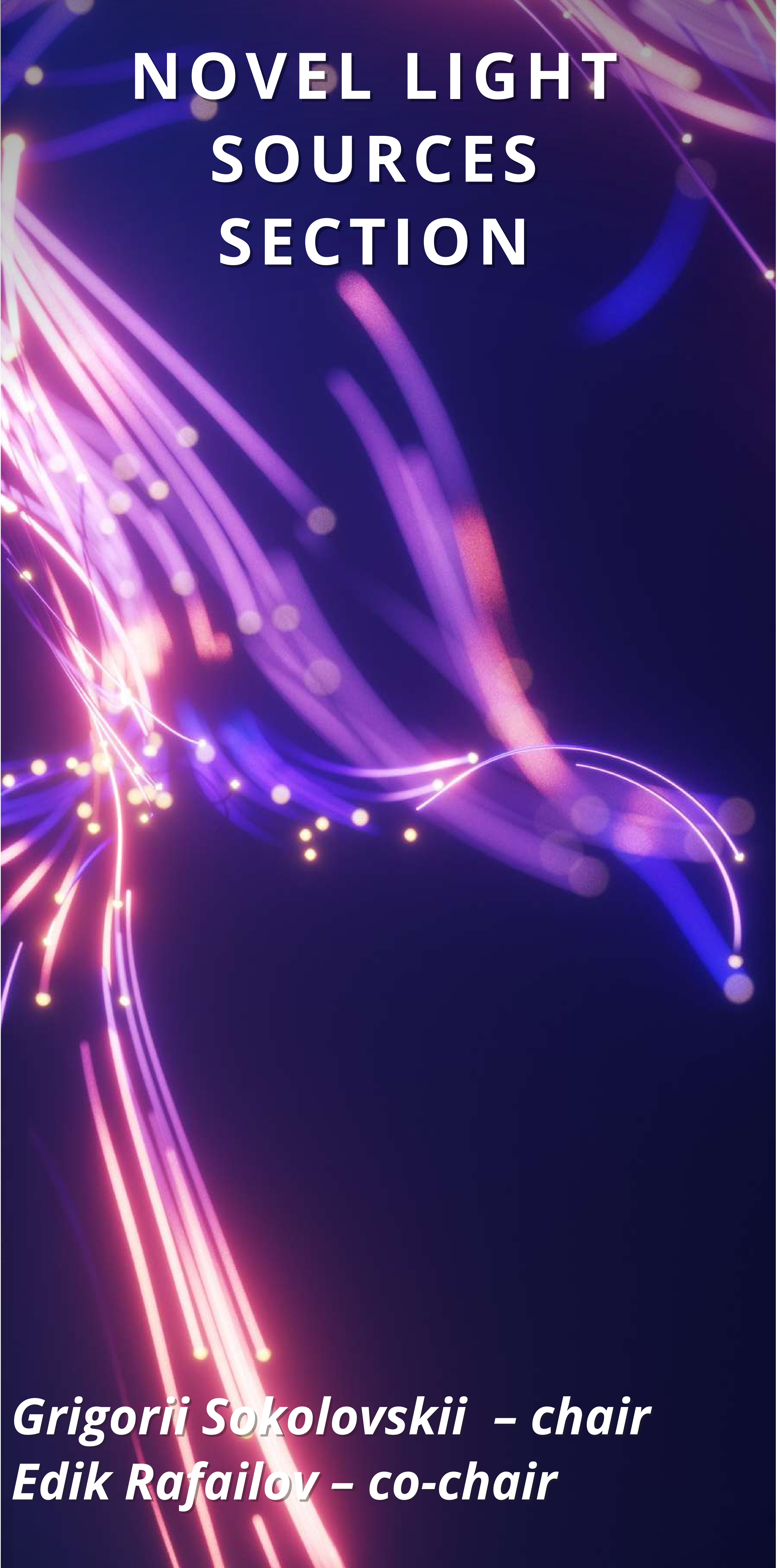
PHOTONIC WIRE BONDING AND 3D NANOPRINTING IN PHOTONIC INTEGRATION – FROM LAB DEMONSTRATIONS TO PRODUCTION

Additive nano-printing by multi-photon polymerization allows equipping single-mode photonic integrated circuits with micro-optical components. In this talk, we overview our capabilities in building integrated optical systems with in-situ printed optical micro-lenses and mirrors and photonic wire bonds (PWB).
3D nano-printing of facet-attached micro-lenses and mirrors features low coupling losses by precise mode matching of optical components with widely different mode profiles. Moreover, the alignment tolerances can be relaxed by expanding the off-chip beam profiles, allowing for passive assembly of single-mode optical systems. Micro-mirrors give additional design freedom and combine vertically and horizontally emitting components into compact assemblies. The PWB approach enables flexible assembly of systems with a small footprint in fully automated fabrication processes. The technique, in which pre-aligned chips are connected with 3D-printed freeform waveguides, lends itself to rapid prototyping and large-scale production. Expanding on these 3D-printed photonic elements for coupling, we overview recently addressed application in a broad range of scientific and industrial applications that cover astronomy, scanning probe microscopy, and optical wafer-level probing.



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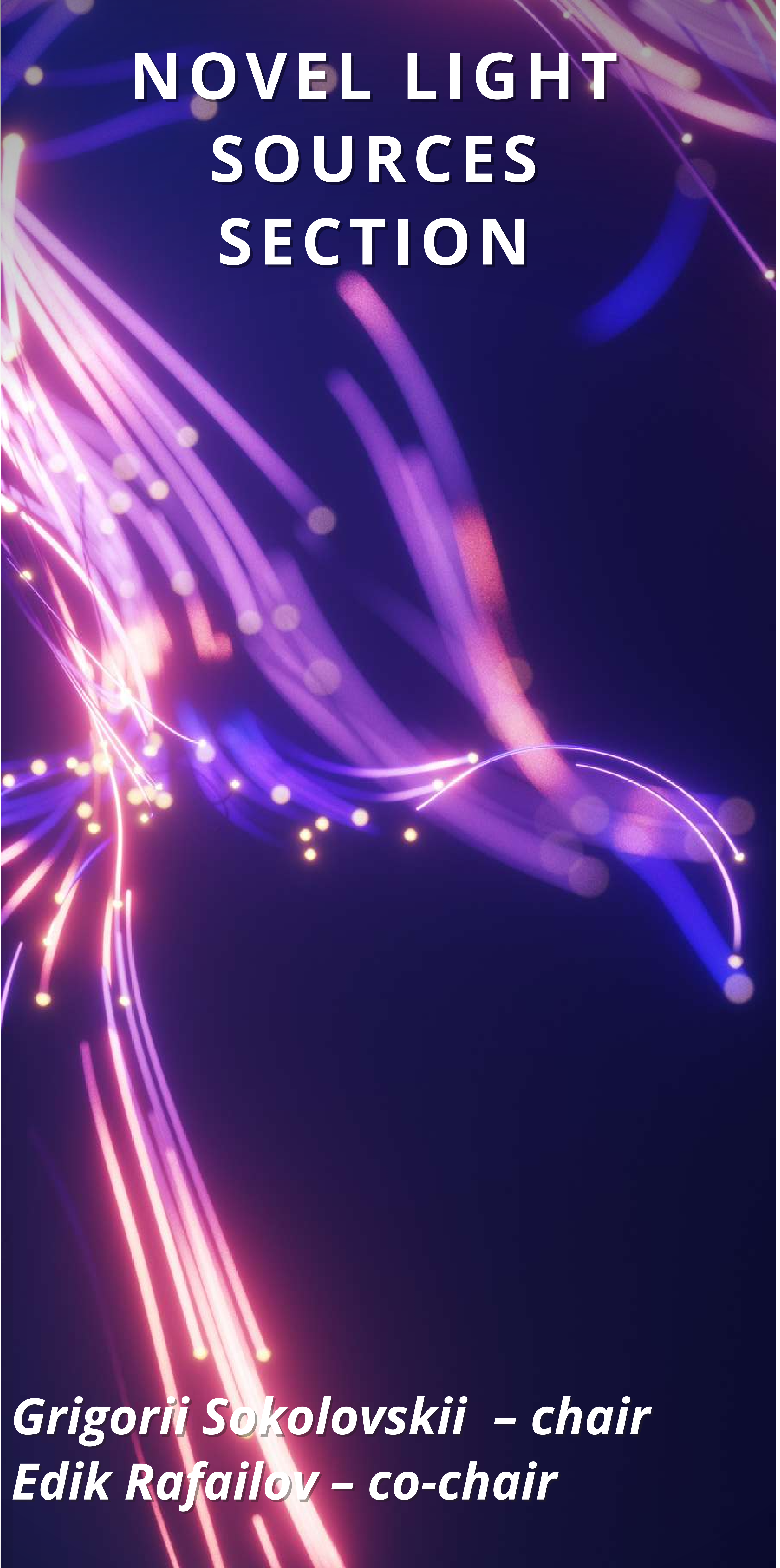
METAMATERIAL ENHANCED UNIPOLAR QUANTUM OPTOELECTRONICS

The development of a high-performance optoelectronic technology in the wide THz range (1 – 50 THz) is highly demanded for technological applications and for answering to fundamental physical questions. This presentation will give an overview on Unipolar Quantum Optoelectronics, which consists on a new generation of semiconductor devices operating at room temperature in the mid-infrared (lambda ~ 10 µm) with bandwidth in the order of 10 GHz. One of the key issue of the improvement of this technology has been in the use of sub-wavelength metallic patch-antenna resonators, that act as metamaterials and funnel the light into extremely small elements. Sensitive ultrafast devices are required for free-space communications, light detection and ranging (LIDAR), for high resolution spectroscopy and in observational astronomy systems. In the near future the photonic integration of these devices will extend the realm of quantum technologies further in the infrared and THz range.



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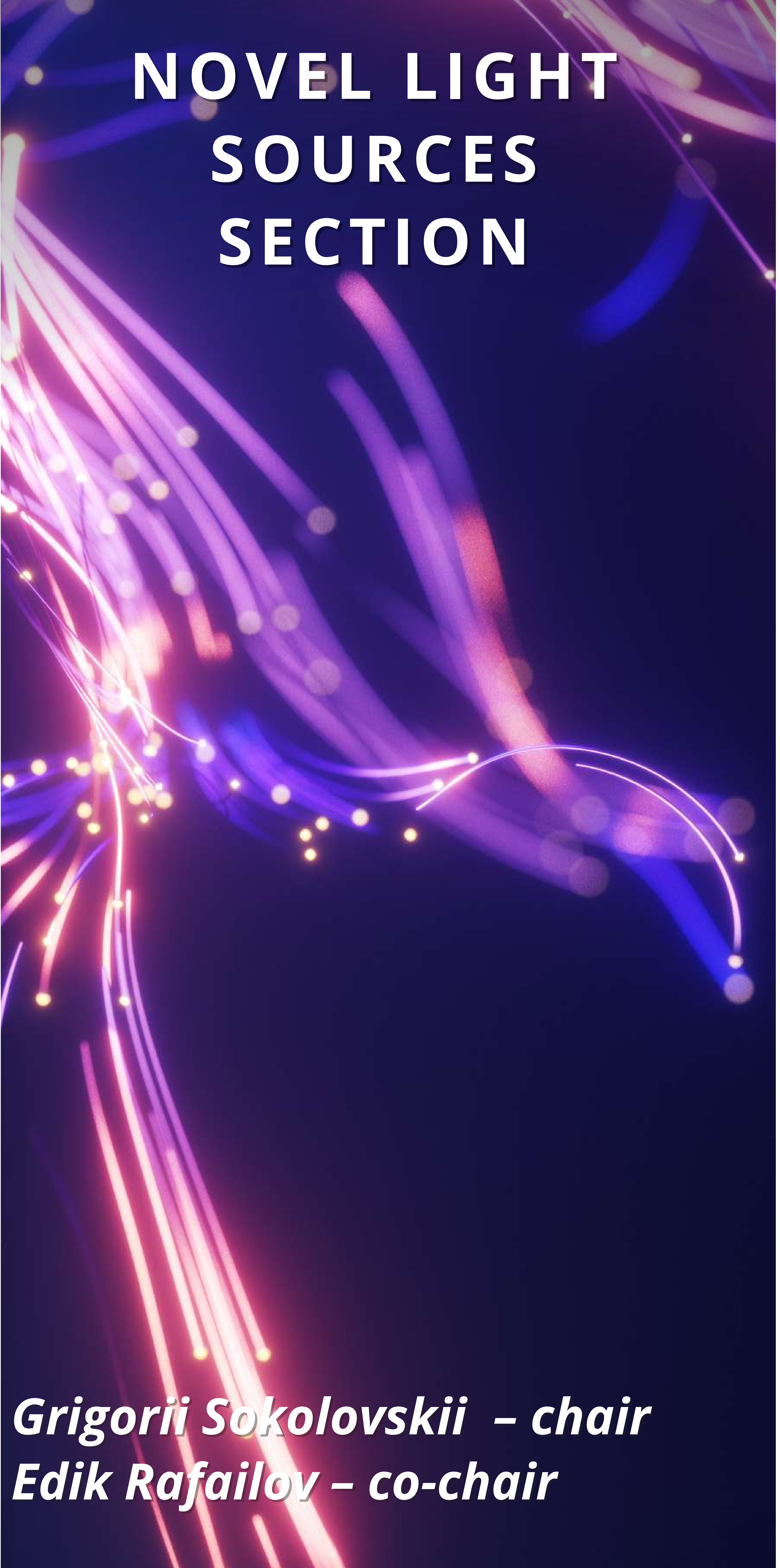
QUANTUM DOT BASED COMPACT TERAHERTZ SOURCES AS A PLATFORM FOR FINE SPECTROSCOPIC AND IMAGING APPLICATIONS

We present the results and persepctives of quantum dot based photoconductive antennas for downconverting optical wavelength radiation to the highly sought after terahertz spectral band. These antennas allow pumping with wavelenghts around 1.2 um, and thus are perfect candidates for further integration. These antennas succesfullly generate both pulsed and continious and pulsed terahertz radiation under wide range of pumping conditions. The use of compact quantum dot basedultrafast semiconductor lasers as pump sources opens up the possibility for fine spectroscopic and imaging applications in ultra-compact standalone package.



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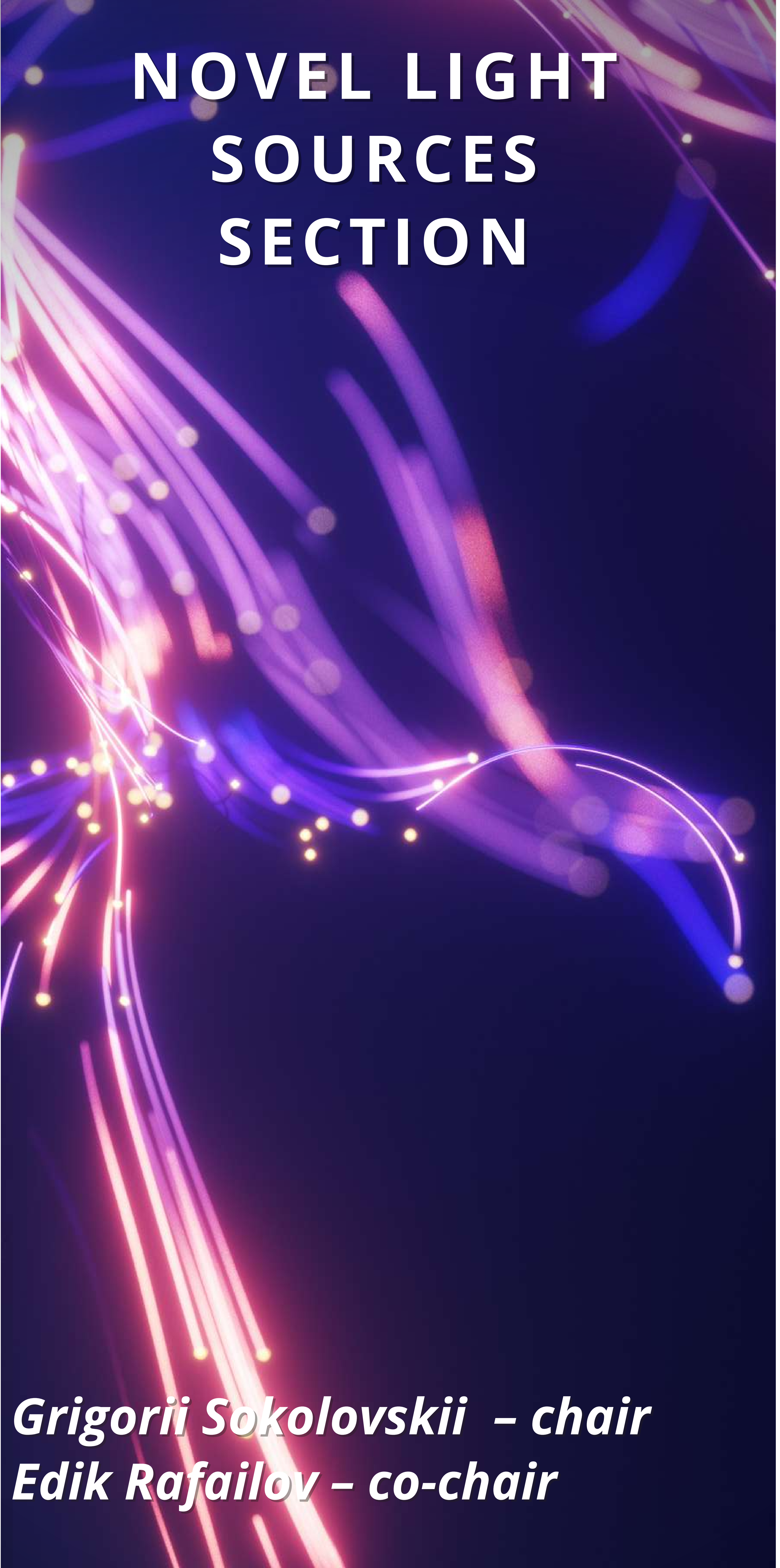
PLASMONIC PHOTODETECTOR RESPONSIVITY ENHANCEMENT TROUGH LASER INDUCED CRYSTALLIZATION

Metal-semiconductor-metal plasmonic nanostructures offer a great potential in efficient and ultrafast photodetection by enhancing the electrostatic and optical local fields. Here, we investigate both, free-space, and waveguide-integrated germanium plasmonic photodetectors and the possibilities to further increase their efficiency by material processing techniques. We show that short-pulse laser-induced crystallization of the nanostructured semiconductor in the integrated photodetectors could significantly improve the device performance attributed to a higher charge mobility and a lower recombination rate. To monitor and control this spatially-selective material processing technique, the degree of crystallization was simultaneously investigated by local Raman spectroscopy. Due to improved electrical properties in the semiconductor, the measured internal quantum efficiency of the free-space Ge photodetector was significantly increased by one order of magnitude while for the waveguide-integrated germanium plasmonic photodetectors the internal quantum efficiency was enhanced by more than two orders of magnitude. The demonstrated devices and the semiconductor processing techniques can be utilized in various nanoplasmonic applications for efficient and fast on-chip detection offering significantly improved device performance and modification capabilities due to laser-induced semiconductor crystallization.



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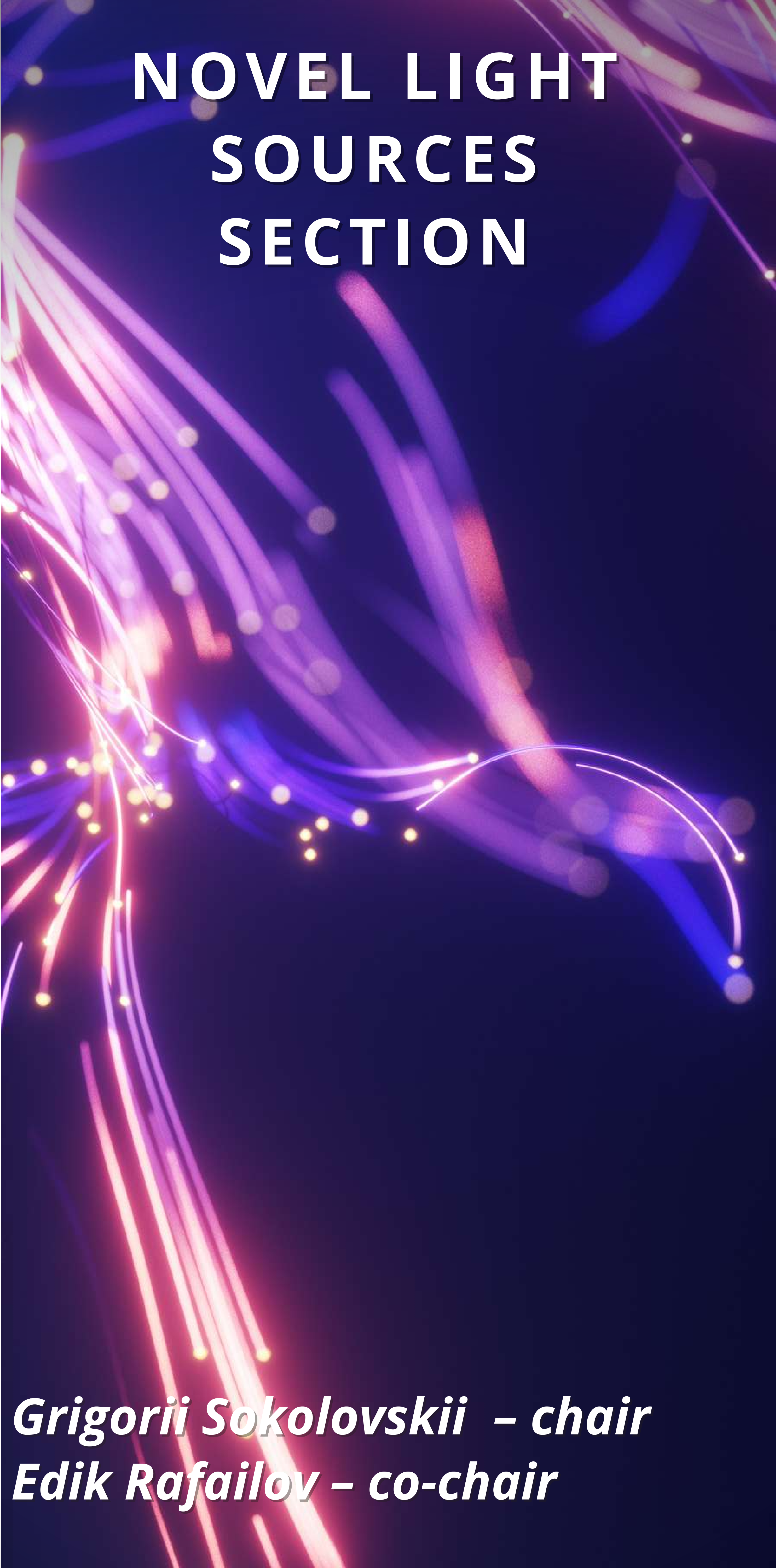
HIGH-POWER MID-INFRARED QUANTUM-CASCADE LASERS

Quantum-cascade lasers (QCL) attract great attention of the research community since the first publication by Kazarinov and Suris proposing the principle in 1971, and especially since the first realization in 1994 by Faist et al. This attention results in ~9k publications with ~160k citations according to Web of Science. The main feature of QCLs distinguishing them from the conventional semiconductor lasers (so-called laser diodes) is their unipolarity resulting in the photon emission via transition of an electron in the conduction band from one quantum level to another instead of recombination of an electron-hole pair. In addition to a review of the state of the art in high-power mid-infrared quantum cascade lasers, this report will discuss the recent progress of QCLs at the Ioffe Institute, including 8 μm QCLs of the record-high output power of over 13 W as well as wavelength-swept single-frequency generation of U-shaped QCLs with side mode suppression of more than 25 dB.



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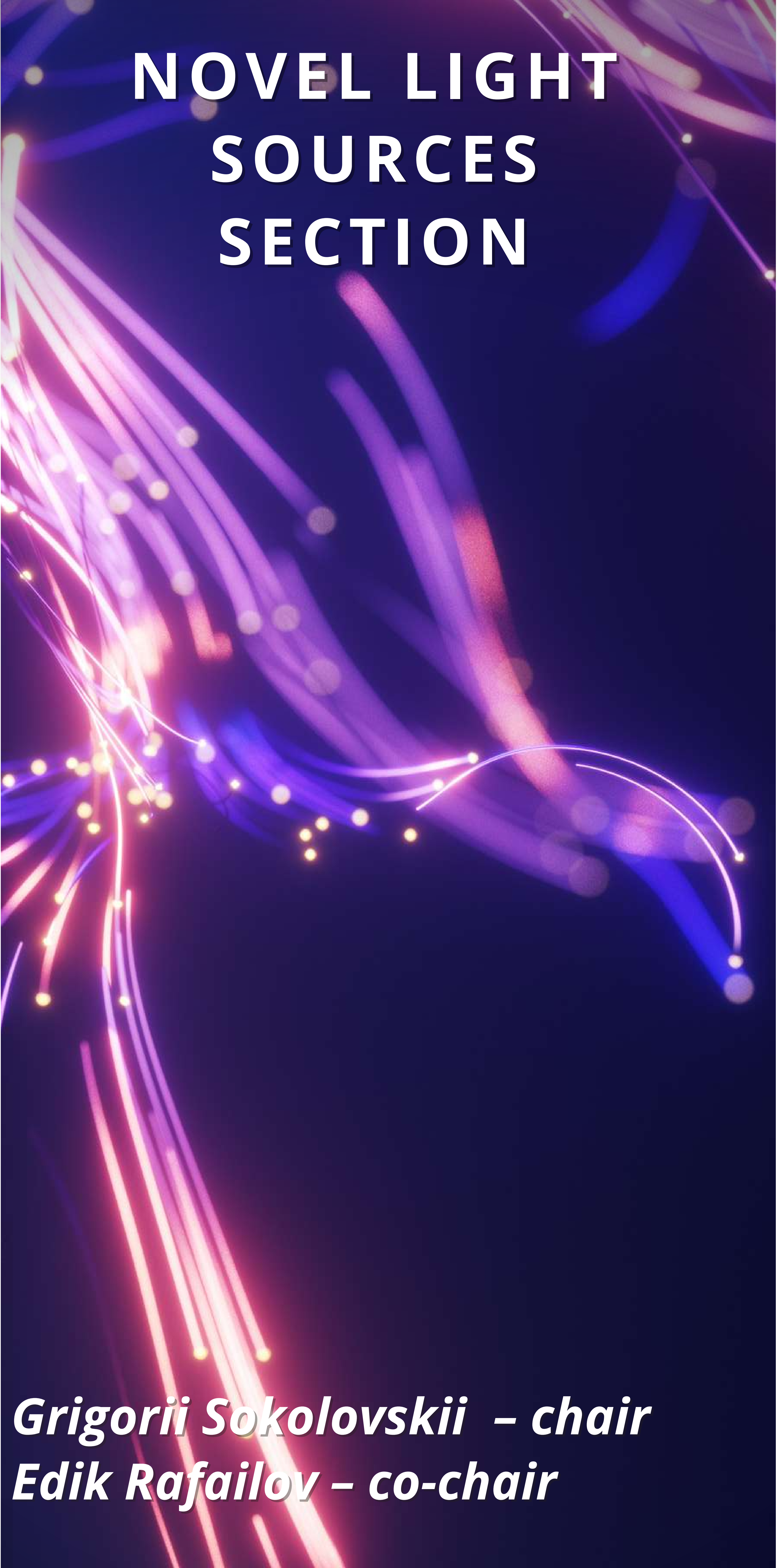
NONLINEAR META-OPTICS

Optical metasurfaces are arrays of optical antennas, with sub-wavelength size and separation. Metasurfaces represent an original concept of flat optics with no classical analogs. They allow for the ultimate miniaturization of optical components, as well as the enabler of new functionalities not possible to date. In the past two decades, the optical properties of metasurfaces have been intensely studied in the linear regime, with either metallic or amorphous dielectric nanostructures.

A few years after the development of linear flat optics, the sub-wavelength physics of its nonlinear counterpart has gained increasing attention, with frequency conversion effects observed first in the hot spots associated to localized plasmon resonances in metal nanoantennas and then in association to Mie-type multipolar resonances in dielectric nanostructures. This transition to the nano-world has marked an important turning point for 60-year-old nonlinear optics, with the role of phase matching being replaced by that of spatial overlap between near-field resonances occurring in dissipative open nanostructures in a non-Hermitian regime.

In this presentation I will provide a general overview on the new branch of Nonlinear Meta-Optics, from modelling to fabrication and experiments, with a focus on the most performing nonlinear nanophotonic platform, which is based on two-dimensional arrays of chi(2) semiconductor nanostructures.



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HIGH-TEMPERATURE THZ QUANTUM CASCADE LASERS: NOVEL DESIGNS AND MBE GROWTH CHALLENGES

Over the past two decades, the operation temperature of terahertz quantum cascade lasers (THz QCLs) has continuously increased from cryogenic level to the current record value of 250 K (about -23°C). Will it be possible to make room temperature THz QCL? In my talk, I will try to answer this intriguing question. I will discuss the state-of-the-art and future prospects of high-temperature THz QCL designs with three- and two- GaAs/AlGaAs quantum wells in period. Also, the MBE growth issues of multi-layered semiconductor structures for high-temperature THz QCL will be discussed.

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SINGLE–MOLECULE SENSING WITH OPTOPLASMONIC MICROCAVITIES

Optoplasmonic microcavities are sensors developed in the past decade that combine the high quality factors of dielectric microcavities and the small nanometer-scale localization of electric fields by metal nanoparticles to achieve exceptional sensitivity for detecting single molecules in solution. These sensors have enabled the detection of single ions, enzyme activity and various ligand reactions/interactions. I will describes the photonic working principle of these sensors with a focus on the experimental aspects.

Reference: Optical Whispering Gallery Modes for Biosensing | SpringerLink

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MICROCOMBS BASED ON LASER CAVITY SOLITONS

Dissipative solitons are self-confined pulses which appear in driven and lossy systems when the phase dispersion is balanced by the nonlinear phase-shift. Temporal cavity-solitons belong to this class and have been largely studied in a 'driven' configuration, where an external pumping source is resonantly coupled in the nonlinear micro-resonator to sustain and excite the solitary pulses. More recently, we demonstrated that it is possible to generate localised pulses in a configuration where the micro-cavity is inserted in a fiber laser loop. We reported the observation of laser cavity-solitons [1], which have previously attracted large attention especially in spatial configurations. By merging their properties with the physics of both micro-resonators and multi-mode systems, this scheme represents a fundamentally new paradigm for the generation, stabilisation and control of solitary optical pulses in micro-cavities.

In general, laser cavity-solitons are a highly efficient class of cavity-solitons because they are intrinsically background-free. This is in stark contrast to cavity-solitons obtained in nonlinear Kerr cavity driven by an external source and described by the well-known Lugiato-Lefever equation. Currently, these self-localised waves form on top of a strong background of radiation, usually containing 95% of the total power for bright configurations [2].

Our laser cavity-solitons cover a spectral bandwidth exceeding 50 nm and are induced with average powers more than one order of magnitude lower than those typically used in state-of-the-art soliton micro-combs [1]. Very importantly, in stark contrast to temporal cavity-solitons based Lugiato-Lefever systems, our bright laser cavity-solitons are background-free, and we achieve a mode-efficiency [2] above 75%, compared to typical 1% - 5% for bright solitons realised with standard approaches. Moreover, we can affect the soliton repetition-rate with a simple approach. The free-spectral range of the fiber cavity can be affected by a delay line that modifies the fibre cavity length and, hence, the mode-spacing. In turn this tunes the position of the mode of the system and the repetition rate of the micro-comb.

In this presentation, we will discuss the range of existence of Turing patterns and solitons and possible approaches to their generation and control in our system.

References

[1] H. Bao, et al. Laser Cavity-Soliton Microcombs. Nat. Photonics 13, 384 (2019).

[2] X. Xue, et al. Microresonator Kerr frequency combs with high conversion efficiency. Laser Photonics

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FREQUENCY COMBS IN CHI-2 MICRORESONATORS: ENERGY CONSERVATION AND DRESSED STATES

I will discuss the multi-sideband second harmonic generation in high-Q ring microresonators. This will include development of the easy-to-take-home photon-energy conservation based picture of the comb build up and engage few analogies with the text-book quantum mechanics allowing to calculate the threshold conditions for parametric frequency conversion into an arbitrary sideband order. I will connect chi-2 photonics to the Roman God two-faced Janus, and demonstrate how chi-2 nonlinearity in microresonators can act differently across the broad-band spectrum and manifests itself as either Kerr or Pockels effects. I will be reporting diverse families of combs, including the ones featuring the optimal power conversion. The talk will be built bottom up to make it accessible to colleagues with basic background in physics and optics.

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PARAMETRICALLY DRIVEN CAVITY SOLITONS

Dissipative solitons in Kerr cavities have been attracting a lot of attention this past decade. They have shown promise for many applications such as ranging, computing, data transmission as well as microwave generation.
In this talk, I will introduce parametrically driven Kerr solitons. I will show how Kerr cavity solitons can be excited at twice their carrier frequency and discuss the advantages of such parametric solitons over their externally driven counterparts. In particular, I will discuss how their multiplicity extends the application pool of Kerr solitons to Ising machines and random number generation.

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DISPERSIVE KERR SOLITON GENERATION IN A MICRORESONATOR VIA BICHROMATIC PUMPING

Microresonator-based frequency combs generated in monolithic high-Q microresonators have attracted significant research interest since their initial demonstration in 2007. In particular their small footprint and the possibility of chip-scale integration enables a large number of applications, including their use for optical frequency synthesizers, astrocombs, optical coherent communications, LIDAR, and dual-comb spectroscopy. Importantly, the discovery of dissipative Kerr solitons in microresonators has demonstrated new ways to generate low-noise and broadband frequency combs.

Most of the microcomb research has been focused on pumping a microresonator with a single CW laser. In this talk, I will present the ideas and experimental results for dispersive Kerr soliton generation in a microresonator via bichromatic pumping. Bichromatic pumping of a resonator is shown to enable rich nonlinear dynamics including:

1. Deterministic soliton generation
2. Spectral extension and synchronization of microcombs
3. Bright-dark soliton pair generation

ADVANCED CONCEPTS SECTION

Daniel Brunner – chair
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LIGHT SHEET MICROSCOPY FOR FAST FUNCTIONAL VOLUMETRIC IMAGING

In Light-sheet fluorescence microscopy (LSFM), a sheet of excitation light is produced onto the sample plane. The generated fluorescence is then collected using a microscope objective placed orthogonal to the excitation light sheet plane. LSFM allows for a highly efficient excitation and collection of the generated signal. Altogether, such scheme minimizes light dose onto the sample and results in a decreased photobleaching and phototoxicity effects while providing high signal to noise images. LSFM, being based on an intrinsic plane illumination has been put forward as an interesting candidate for volumetric (3D) imaging. I will present a LSFM microscope for 3D imaging during extended periods of time. Also, by incorporating an electrically tunable lens (ETL) fast volumetric imaging can be achieved. I will present the use of such system to image the spontaneous Ca2+activity in 3D of primary neuron cultures in hydrogels. The obtained data is then processed to calculate the connectivity maps in the 3D neuron cultured in hydrogels.

ADVANCED CONCEPTS SECTION

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Edik Rafailov – co-chair

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TOWARDS AUTONOMOUS OPTICAL NEURAL NETWORKS LEVERAGING 3D INTEGRATION

In recent years photonic neural networks have been identified as promising systems for ultra-high speed neural network hardware with the potential of increasing energy efficiency. Numerous breakthroughs have been achieved, yet a fully integrated implementation of a stand alone photonic neural networks is still to be demonstrated. I will discuss how the fundamental challenge of scalable integration of parallel neural network remains very relevant, and how neuro-inspired 3D photonic integration provides a viable future strategy.

AUTHORS: BRUNNER, D.; PORTE, X.; MOUGHAMES, J.; JACQUOT, M.; KADIC, M.; LARGER, L.;

ADVANCED CONCEPTS SECTION

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ULTRAFAST PHOTONIC CONVOLUTION PROCESSING

Optical computing methods are seeing a resurgence of popularity due to recent advances in integrated photonics and neuromorphic engineering. Photonic systems are very suitable for analog computing approaches with moderate accuracy, yet very high processing speed. These features hold promise for implementing photonic accelerator systems for computationally expensive tasks such as matrix vector multiplications (MVM). Here I will introduce a nanophotonic approach for realizing chip-scale MVM-units. Using phase-change photonic devices allows for creating parallel processing circuits in which analog multiplications can be carried out at high speed in parallel. In combination with the development of novel light sources, photonic approaches offer new opportunities for creating brain-inspired hardware for artificial intelligence applications.

ADVANCED CONCEPTS SECTION

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SPATIAL MODE MULTIPLEXING/SYNTHESIZING FOR ENERGY HARVESTING IN ULTRAFAST PHOTONICS

High-power sources of femtosecond pulses are interesting for material processing, remote sensing, spectroscopy, laser particle acceleration, and different high-field physics branches. For these aims, the fiber systems have the advantages of large single-pass gain, high mode quality, and low environmental sensitivity. Their main disadvantage is a strong contribution of nonlinear effects rising with a fiber length (gain) and preventing the ultrashort pulse peak power/energy scaling.
The way of resolving this issue is temporal and spatial scaling of pulses reducing their peak intensity and, thereby, nonlinear effects. The first way was realized as chirp-pulse amplification/oscillator schemes for both fiber and solid-state systems. However, further progress of such “fundamental mode” systems becomes challenging. On the other hand, the method of mode size scaling faces the issue of mode structure and quality degradation. As was shown, such a control can be provided by mechanisms of nonlinear mode self-cleaning in mode-locked solid-state oscillators and passive multi-mode fibers. The main idea here is not suppressing the higher-order modes but their synthesizing in a coherent and stable large-area mode.

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The different approaches to such synthesizing were proposed:

1. Coherent addition of independently amplified pulses in a fiber network (array)
2. Mode sieve in a structured large mode area fiber based on the transverse mode decoupling
3. Spatial mode condensation in a multimode fiber

We suggest that the last mechanism can be enhanced essentially by a gain profiling in a multimode/photonic-crystal fiber. In particular, such mode-cleaning sectors can be integrated into multistage amplification systems without loss of power/energy enhancement.

As an additional technology providing the femtosecond pulse energy enhancement, the integrated coherently driven active resonators were proposed. This technique, realized as the driven active micro- resonators, could be alternative to a fiber network. We demonstrate that such systems' inherent issues, i.e., nonlinear effects, gain saturation, and near-threshold instabilities, could be overcome by realizing the soliton-like regime in a micro-resonator. The important factor in this endeavour is optimal and coherent mode matching between driving/driven photonic systems.

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STRONG-FIELD INTERACTIONS AND ULTRAFAST NANOPHOTONICS

Studies of the interaction of high, and ultrashort laser fields with nanostructures provide insight into local fields and charge dynamics under extreme conditions. Clusters and nanoparticles represent a well-established platform for analyzing correlated and cooperative effects in strong-field laser-matter interactions. Particularly challenging is the time-resolved characterization of the dynamics near the optical breakdown. Here, the relevant strong-field dynamics unfolds on sub-cycle time scales, and can be controlled with the light waveform [1]. For sufficiently high fields, nanoplasmas can be generated, where internal fields are essentially screened instantaneously as for a perfect conductor. The related dynamics has been theoretically predicted [2], and could recently be experimentally confirmed with our studies [3], cf. Fig. 1.

We recorded electron kinetic energy spectra and identified characteristic cutoff signatures with isolated nanospheres at intensities near and beyond the onset of the dielectric breakdown. We found a substantial departure from previously reported cutoff behaviour . Generalized 3D-transport simulations for SiO_2 nanoparticles unambiguously assign a sudden change in electron cutoff energies to ionization-induced metallization.

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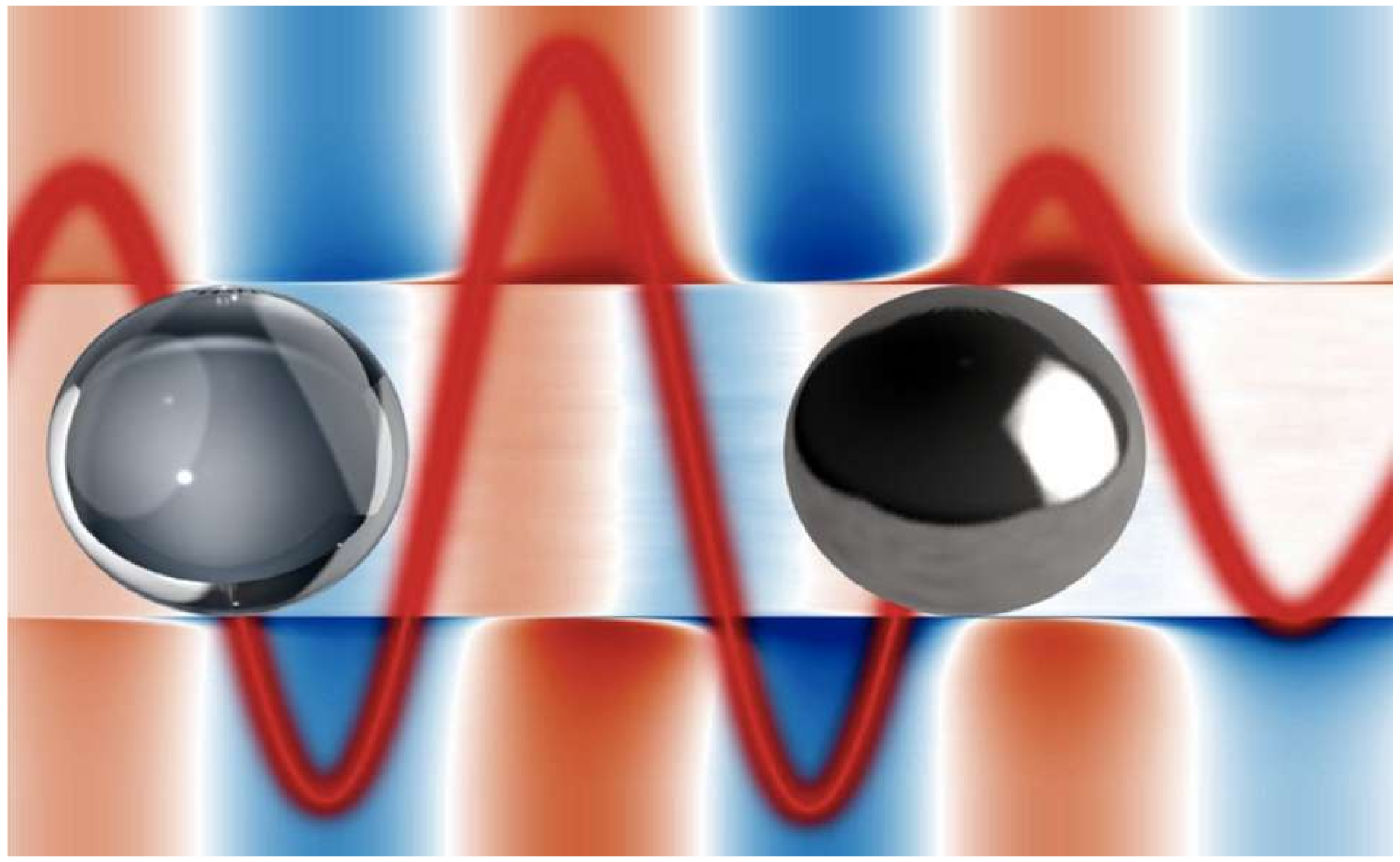

Fig. 1 Few-cycle laser driven metallization of dielectric nanoparticles. The laser field is depicted as red line (time is progressing to the right). Resulting fields from the nonlinear interaction in- and outside the particles are shown in false color. The metallization results in a characteristic phase shift between inner and outer fields and eventually the complete screening of fields inside the particle.

These conclusions were tested and confirmed with further experimental data for other dielectric, semiconducting, and metallic nanoparticles [3].Strong laser field interaction with nanoparticles may not only create plasmas but also a unique environment for strong-field driven molecular dynamics on the particles surface. The talk will highlight work, where we have used our recently developed nanotarget reaction-microscopy [4], to investigate reactions induced by laser- interaction with water decorated nanoparticles. We find that proton formation and other reactions are driven by the local near-fields [4], with remarkable differences between single particles and their dimers [5].

References

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[2] C. Peltz et al., Time-resolved x-ray imaging of anisotropic nanoplasma expansion, Phys. Rev. Lett. 113, 133401 (2014)
[3] Q. Liu et al., Ionization-induced sub-cycle metallization of nanoparticles in few-cycle pulses, ACS Phot. 7, 3207 (2020)
[4] P. Rupp et al., Few-cycle laser driven reaction nanoscopy on aerosolized silica nanoparticles, Nature Com. 10, 4655 (2019) [5] P. Rosenberger et al., Near-field induced reaction yields from nanoparticle clusters, ACS Phot. 7, 1885 (2020)

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PROBING INFLUENCE OF MOLECULAR ENVIRONMENT AND DYNAMIC POLARIZATION IN PHOTOEMISSION DELAYS

The advancement of attosecond chronoscopy has made it possible to reveal ultrashort time dynamics of photoionization [1]. Ionization delay measurements in atomic targets provide a wealth of information about the timing of the photoelectric effect [2], resonances, electron correlations and transport. The extension of this approach to molecules, however, presents great challenges. In addition to the difficulty of identifying correct ionization channels, it is hard to disentangle the role of the anisotropic molecular landscape from the delays inherent to the excitation process itself.

Other than that the feature of dynamic polarizability in case of molecules, especially the larger ones, makes the problem even harder, however presents a rich play ground to see collective electron dynamics. Here, we first present the measurements of ionization delays from ethyl iodide around the 4d giant dipole resonance of iodine, which could disentangle the contribution of electron propagation effect within the molecular (ethyl group in this case) environment exclusively to the ionization delay. In the second case to illustrate the effect of molecular dynamic polarization effect on ionization delay, we used ionization of C60 molecule around its well know giant dipole resonance at 20 eV. In both the cases, we employed attosecond streaking spectroscopy where an attosecond extreme ultraviolet (XUV) pulse ionizes the molecule around the energy of the respective giant resonances and the released electron is exposed to the ponderomotive force of a synchronized near- infrared (NIR) field, which yields a streaking spectrogram. Comparative phase analysis of the spectrograms corresponding to iodine 4d or C60 valance electrons with neon 2p emission permits extracting overall photoemission delays in both cases. In the ethyl iodide case the experimental results are compared to classical Wigner propagation [3] and quantum scattering [4] calculations. Here the outgoing electron, produced via inner shell ionization of the iodine atom in ethyl iodide, and thereby hardly influenced by the molecular potential during the birth process, acquires the necessary information about the influence of the functional ethyl group during its propagation.

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We find significant delay contributions that can distinguish between different functional groups, providing a sensitive probe of the local molecular environment [5]. This would stimulate to perform further angle resolved measurements in molecules to probe the potential landscape in three dimension. In case of C60, the measurements are compared with simulations involving classical and quantum mechanical descriptions of fullerene under the effect of near infrared short laser pulses and subsequent propagation effect. This indicates a clear signature of dynamic polarizability of the target and also some contribution of Eisenbud-Wigner-Smith type of delay.

References

[1] F. Krausz and M. Ivanov, "Attosecond physics", Rev. Mod. Phys. 81, 163-234 (2009).
[2] M. Schultze, et al. Delay in Photoemission. Science 328, 1658-1662 (2010).
[3] T. Zimmermann, L. Ortmann, C. Hofmann, J. M. Rost and A. S. Landsman, "Attosecond streaking delays in multi-electron systems", arXiv:1804.09583v1 (2018).
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CUSTOMISED 3D SCAFFOLDS FOR DEVELOPING HUMAN STEM CELL-BASED ORGANOIDS IN ADVANCED RESEARCH, PERSONALISED MEDICINE AND COSMETICS

With recent progress in the field of human induced pluripotent stem cells (iPSCs) for production of human cell models in vitro it faced challenges in generating reproducible functionalities, e.g. neural networking, skin sensing, innervated muscles The use of biomaterial scaffolds that would enable the development and guidance of neuronal networks in physiologically relevant architectures and dimensionality. Two-photon polymerisation (2PP) enables precise microfabrication of three-dimensional structures for such aims. This talk summaries the identification biomaterials that support the growth and differentiation of human iPSC-derived neural progenitors into functional neuronal networks (MESO_BRAIN) and skin-sensing and muscle-motor models within recently awarded grant PLATFORMA. 2PP scaffolds with tailored topographies therefore provide an effective method of producing defined in vitro functional human organoids for applications in disease modelling, personalised pharmaceutics, cosmetics and transplantology.

AGENDA

NOVEL MATERIALS.
19.04 AGENDA (UK TIME)

NIP
NANO AND INTEGRATED PHOTONICS WORKSHOP

11.00 – 12.00 Plenary talk by **Dr.Maria Farsari** *“3D micro/nano printing”*

12.00 – 12.30 Coffee Break with discussion

12.30 – 12.50 **Dr.Tatjana Gric** *“Applications of the metamaterial formalism”*

12.50 – 13.20 Invited talk by **Dr.Philipp Dietrich** *"Photonic Wire Bonding and 3D Nanoprinting in Photonic Integration – from Lab Demonstrations to Production"*

13.20 – 14.50 Lunch Break

14.50 – 15.50 Plenary talk by **Prof.Zhipei Sun** *“2D materials integrated nonlinear photonics”*

15.50 – 16.20 Invited talk by **Prof.Markus Schmidt** *“Fibers meet Nanostructures and Meta-surfaces: a platform for optical trapping and boosting incoupling efficiencies"*

16.20 – 16.40 Coffee Break with discussion

16.40 – 17.00 **Dr. Lucas Souza** *“Developing multifunctional photo-thermal Biomaterials for bone cancer tumour therapy”*

17.00 – 17.30 Invited talk by **Prof.Andrea Armani** *“Organic small molecule integrated photonics”*

NOVEL LIGHT SOURCES.
20.04 AGENDA (UK TIME)

NIP
NANO AND INTEGRATED PHOTONICS WORKSHOP

10.00 – 11.00 Plenary talk by **Prof.Carlo Sirtori** *“Metamaterial enhanced Unipolar Quantum Optoelectronics”*
11.15 – 11.30 Coffee Break with discussion
11.30 – 12.10 Invited talk by **Dr.Andrei Gorodetsky** *"Quantum Dot Based Compact Terahertz Sources as a Platform for Fine Spectroscopic and Imaging Applications"*
12.10 – 12.30 **Dr.Torgom Yezekyan** *“Plasmonic photodetector responsivity enhancement trough laser induced crystallization”*

12.30 – 13.30 Lunch Break

13.30 – 14.30 Plenary talk by **Prof.Grigorii Sokolovskii** *“High-Power Mid-Infrared Quantum-Cascade Lasers”*
14.30 – 15.10 Invited talk by **Prof.Giuseppe Leo** *“Nonlinear Meta-Optics”*
15.10 – 15.20 Coffee Break with discussion
15.20 – 16.00 Invited talk by **Dr.Rustam Khabibullin** *“High-temperature THz quantum cascade lasers: novel designs and MBE growth challenges”*

MICRO-RESONATORS AND FREQUENCY COMBS.
21.04 AGENDA (UK TIME)

NIP
NANO AND INTEGRATED PHOTONICS WORKSHOP

10.00 – 11.00 Plenary talk by **Prof.Frank Vollmer** *"Single-molecule sensing with optoplasmonic microcavities"*
11.15 – 11.30 Coffee Break with discussion
11.30 – 12.10 Invited talk by **Dr.Alessia Pasquazi** *"Microcombs Based on Laser Cavity Solitons"*
12.10 – 12.40 Invited talk by **Prof.Dmitry Skryabin** *"Frequency combs in chi-2 microresonators: Energy conservation and dressed states"*

12.40 – 13.30 Lunch Break

13.30 – 14.00 Invited talk by **Dr.François Leo** *"Parametrically driven cavity solitons"*
14.00 – 14.20 **Dr.Shuanhyou Zhang** *"Dispersive Kerr Soliton Generation in a Microresonator via Bichromatic Pumping"*

ADVANCED CONCEPTS.
22.04 AGENDA (UK TIME)

NIP
NANO AND INTEGRATED PHOTONICS WORKSHOP

10.00 – 11.00 Plenary talk by **Dr.Pablo Loza-Alvarez** *“Light sheet microscopy for fast functional volumetric imaging”*
11.00 – 11.30 Invited talk by **Prof. Wolfram Pernice** *“Ultrafast photonic convolution processing”*

11.30 – 12.30 Lunch Break

13.30 – 14.00 Plenary talk by **Dr. Daniel Brunner** *"Towards autonomous optical neural networks leveraging 3D integration"*
14.00 – 14.20 **Dr.Vladimir Kalashnikov** *“Spatiotemporal mode multiplexing/synthesizing for energy harvesting on femtosecond level”*
14.20 – 14.30 Coffee Break with discussion
14.30 – 15.00 Invited talk by **Prof. Matthias Kling** *“Strong-field interactions and Ultrafast Nanophotonics”*
15.00 – 15.20 **Dr.Shubhadeep Biswas** *“Probing influence of molecular environment and dynamic polarization in photoemission delays”*
15.20 – 15.50 **Dr. Sergei Sokolovski** *"Customised 3D scaffolds for developing human stem cell-based organoids in advanced research, personalised medicine and cosmetics"*

WORKSHOP DATES

19-22 April, 2021