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Conference program

Sunday, March 16th

Chairman: Zoran Grujić

16.00 – 16.30	**Registration & opening**
16.30 - 17.00	**Darko Zibar** *Advancing the next generation of photonic systems using machine learning*
17.00 - 17.20	**Vladimir Đoković** *Nitrogen-doped graphene quantum dot-aromatic amino acid hybrids: synthesis, interface interactions, and photoluminescence properties*
17.20 – 17.40	**Dušan K. Božanić** *Circular dichroism in photoemission from amino acid functionalized carbon nanostructures*
17.40 – 17.55	**Milica Nedić** *On compact topological edge modes in photonic ribbon lattices*

Monday, March 17th

Chairman: Brana Jelenković

16.00 - 16.30	***Refreshment & workshop photo***
16.30 - 17.00	**Vladan Vuletić** *Neutral-atom arrays for quantum computing and cavity QED*
17.00 - 17.20	**Jiazhong Hu** *Stark many-body localization in continuous one-dimensional bose gas*
17.20 – 17.40	**Wenlan Chen** *Observation of near-critical Kibble-Zurek scaling in Rydberg atom arrays*
17.40 – 18.00	**Jovana Petrović** *Compact Topological Edge States in Flux-Dressed Graphene-Like Photonic Lattices*
18.00 – 18.20	**Vladimir Bogavac** *Industrial talk CIP d.o.o.*

Chairman: Pavle Andjus

BioQantSense

Funded by the European Union

20.00 - 20.30	**Francesco Riboli** *All-optical multilevel physical unclonable functions*
20.30 - 20.50	**Caterina Credi** *Bioorthogonal magneto-plasmonic nanoclusters for microfluidic-based sorting and sensing of cells*
20.50 - 21.10	**Francesca Torrini** *Photoswitchable opto-Lab-on-a-Chip for real-time and label-free cell analysis via classical and quantum holographic imaging*
21.10 – 21.30	**Giacomo Mazzamuto** *Mapping neuronal populations with Light-Sheet Fluorescence Microscopy*
21.30 – 21.50	**Giulia Adembri** *Technology Transfer for Photonic Innovation at CNR-INO*

Tuesday, March 18th

Chairman: Jovana Petrović

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17.00 - 17.20	**Nina Owschimikow** *Digitalization in Teaching – Means or End in itself?*
17.20 – 17.40	**Dragana Ilić** *Photometry of the Universe on Petascale data regime with the Rubin Observatory LSST survey*
17.40 – 18.00	**Edi Bon** *Main Sequence of Quasars and Variability Expectations*
18.00 – 18.20	**Jelena Mitrić** *Invisible Defense with Luminescent polish for Anti – Counterfeiting*

Chairman: Francesco Riboli

BioQantSense

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20.00 - 20.30	**Wolfgang Fritzsche** *Multipled biosensing using plasmonic nanoparticles*
20.30 - 20.50	**Brana Jelenković** *Advances in quantum imaging for biomedical applications*
20.50 - 21.10	**Vira R. Besaga** *Quantum approaches to polarization-based sensing*
21.10 – 21.30	**Josué R. León-Torres** *Phase imaging with undetected light via off-axis holography*
21.30 – 21.45	**Patrick Hendra** *Characterization of Rubidium-Doped KTP (RKTP) Waveguides as a Versatile Photon Pair Source*
21.45 – 22.00	**Sergio Tovar - Perez** *Quantum phase shift holography with undetected light*

Wednesday, March 19th

Chairman: Biljana Ristić

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17.00 - 17.20	**Pavle Andjus** *The NIMOCHIP Story: Past, present and future*
17.20 – 17.40	**Ivana Drvenica** *Exploring Mechanobiology of Red Blood Cells in Diabetes by Label-Free Optics-Based Approach*
17.40 – 18.00	**Radoš Stefanović** *Optics-Based Assessment of Red Blood Cell Adaptations to Ercise: Insights from Ektacytometry and Flow Cytometry*
18.00 – 18.15	**Vladimir Atanasoski** *Heart Rate Estimation from PPG Signals at Large Proximal Arteries*

Chairman: Aleksander Kovačević

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20.30 - 20.50	**Goran Isić** *Two-dimensional material thickness determination using atomic force microscopy and deep learning*
20.50 - 21.10	**Marko Radović** *Optical Dynamics and photnic effects in Cerium Dioxide Nanocrystals*
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Chairman: Goran Mashanovich

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17.00 - 17.20	**Nikola Vuković** *Modelling of THz quantum cascade laser dynamics*
17.20 – 17.35	**Marija Ćurčić** *Free alignment precession based magnetometer with optical re-pumping*
17.35 – 17.50	**Aleksandra Kocić** *Stabilization of laser wavelength for improved performance in Cs-based optically pumped magnetometers*
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Abstracts

The NIMOCHIP Story: Past, present and future

Pavle Andjus[1]

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Abstract. In 2023 NIMOCHIP, a diagnostic invention was officially protected as a trade mark. This talk will initially present the generation of the initial idea born after the discovery and study of a series of effects of immunoglobulin G from Amyotrophic Lateral Sclerosis, a devastating neurodegenerative disease. It will further be shown how this idea led to the concept of a lab-on-a-chip innovative diagnostic device. Finally, some experience will be shared regarding the road to the marketing of the device.

Acknowledgment: PRIZMA grant ID 4242 Science Fund RS.

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Voltage Imaging for Studying Alzheimer's Disease

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Abstract. In addition to developing new drugs for the treatment of Alzheimer's disease (AD), researchers have begun exploring alternative therapies that utilize physical agents such as electrical, magnetic, and photonic pulses. For example, sensory and photonic stimulation at 40 Hz gamma (but not at other frequencies) has shown promise in reversing AD-related pathologies. What distinguishes 40 Hz? We hypothesized that stimuli at 40 Hz might summate more efficiently (temporal summation) and propagate more effectively between cortical layers (vertically) and along cortical laminae (horizontally), compared to inputs at 20 Hz or 83 Hz. To investigate these hypotheses, we developed a new mouse model of AD that combines a hallmark AD pathology (amyloid plaques, 5xFAD) with the expression of a fluorescent voltage indicator (VSFP). We used brain slices from these AD model mice. Extracellular (synaptic) stimuli were delivered to cortical layer 4 (L4). Using a fluorescent voltage indicator (VSFP) expressed in cortical pyramidal neurons (excitation 475 nm, emission 520 nm), we simultaneously monitored evoked cortical depolarizations at multiple sites with a 1 kHz sampling frequency and a full-frame camera sampling interval of 1.02 ms. Experimental groups (AD-Female, CTRL-Female, AD-Male, and CTRL-Male) were tested at three stimulation frequencies (20, 40, and 83 Hz). Despite our initial hypothesis, two parameters—temporal summation of voltage waveforms and the strength of propagation through the cortical neuropil—did not reveal any distinct advantage of 40 Hz stimulation. Significant physiological differences between AD and Control mice were found at all stimulation frequencies tested, while the 40 Hz stimulation frequency was not remarkable.

Support: Cure Alzheimer's Fund #65539; NIH grant #NS138991; Science Fund RS "NIMOCHIP" Grant #4242; and IBACS Seed Grant.

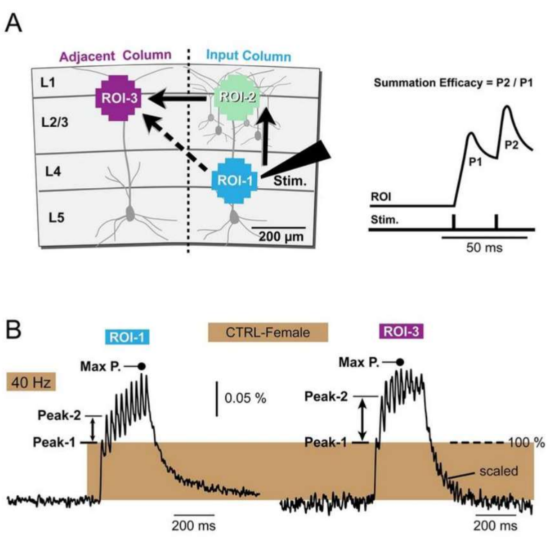

Figure. Temporal Summation. (**A**) Left: Experimental outline. The stimulation electrode is positioned in layer 4 (L4). Electrical signals may propagate between three ROIs (1-3). Black uninterrupted arrows indicate "*canonical propagation*", while the dashed arrow is a "*non-canonical prop.*" Right: Synaptic summation efficacy is defined as the amplitude ratio of Peak-2 to Peak-1 (P2/P1). (**B**) Cortical response at ROI-1 (left) and ROI-3 (right), upon ten stimulation pulses at 40 Hz. The optical signal amplitude at ROI-3 is scaled to match Peak-1 (P1) in ROI-1 (e.g., normalized to P1). The height of the brown rectangle is set to 100% of Peak-1, to illustrate the relative amplitude gain in Peak-2.

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Heart Rate Estimation from PPG Signals at Large Proximal Arteries

Vladimir Atanasoski[1], Aleksandar Lazović[1], Predrag Tadić[2], Maša Tiosavljević[2], Marija Ivanović[1], Mirjana Stojanović[2], Boško Bojović[1], Aleksandra Maluckov[1], Ljupco Hadzievski[1], Jovana Petrović[1]

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Abstract. Photoplethysmography (PPG) is a noninvasive optical method widely used for cardiovascular monitoring. Its accuracy in heart rate (HR) estimation is challenged by different noise types, especially motion artifacts during physical activity. This study investigates HR estimation from PPG signals recorded at the carotid and brachial arteries before and after ercise, using red (660 nm) and near-infrared (880 nm) light sensors. A pulse-to-pulse time-domain method and a spectral analysis approach were employed. ECG was used as the gold standard. The results demonstrate that the red-light PPG sensor provides superior accuracy, achieving a root mean square error (RMSE) of 2.25 bpm, while spectral analysis exhibited significantly larger errors. When evaluated for heartbeat detection, the proposed approach achieved a sensitivity of 98.45%, a positive predictive value of 99.51%, and a detection error rate of 2.03%, highlighting its robustness in HR estimation. These findings underscore the potential of PPG sensors at large proximal arteries for accurate cardiovascular monitoring and multiparameter assessment, even in the presence of occasional motion artifacts.

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Quantum approaches to polarization-based sensing

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Abstract. We discuss polarization-based sensing using quantum states of light and the potential quantum advantage of such a sensing approach along with practical considerations for its application to studies of real samples.

For a range of sensing applications, polarization-based probing enables non-invasive and highly sensitive sample inspection. This holds valid especially for samples with complex structure that exhibit strong light scattering. Classical Mueller polarimetry and sensing with optical angular momentum allow precise characterization of sample birefringence, chirality, thickness, etc. Recently, polarization-based sensing using quantum light has gained attention. Different modalities, including reference-less and non-local measurements, have been proposed. Also, the application of different states of quantum light has been studied to pursue the improvement of measurement sensitivity and accuracy.

In our studies, we focus on the application of polarization-entangled biphoton states to perform nonlocal polarization-based sensing of various biological and technical samples. Among other findings, we have reported the potential of such a sensing scenario to increase measurement accuracy [1,2] and enable sample discrimination from a predefined set with only a few coincidence measurements [3]. We have demonstrated the practical applicability of the approach to samples with weak polarization response by probing monolayer cell cultures [4] and aqueous solutions of microorganisms with concentrations down to 100 cells in the sensed volume [5]. Recently, we have shown the diagnostic potential of the introduced method for scattering characterization in tissue mimicking phantoms with possible expansion of the method to other turbid media [6].

Here, we discuss the proposed approach of polarization-based sensing with polarization-entangled photon pairs, review the potential areas of application, and discuss the quantum advantage achievable with the method and the possible ways to realize it in practice.

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Circular dichroism in photoemission from amino acid functionalized carbon nanostructures

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Abstract. Photoelectron circular dichroism (PECD) measures the difference in the number of electrons photoemitted by right circularly polarized (RCP) and left circularly polarized (LCP) ionizing radiation, resolved according to photoelectron momenta [1, 2, 3]. This technique selectively probes specific orbitals involved in photoemission, yielding dichroic signals that can account for up to 20% of the total electron count. This report presents experimental evaluations of circular dichroism in photoemission from phenylalanine- and tryptophan-functionalized graphene oxide of varying degrees of chemical reduction, conducted at the DESIRS beamline of Synchrotron SOLEIL. The study analyzes the impact of amino acid-carbon nanostructure interactions on PECD in these hybrid nanosystems using density functional theory.

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Main Sequence of Quasars and Variability Expectations

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Abstract. Here we investigates the main sequence of quasars using the Eigenvector 1 (EV1) parametrization. It specifically examines the relationship between the relative strength of equivalent widths of Fe II emission and the Hβ emission line (RFe parameter) and the full width at half maximum (FWHM) of the Hβ emission line. The variability among quasars shows distinct trends along the EV1 main sequence. Quasars with broad Hβ lines and low RFe values (Population B) exhibit more significant optical variability. These quasars generally have lower Eddington ratios, leading to more substantial fluctuations in both the optical continuum and broad emission lines. This pronounced variability makes them suitable for reverberation mapping studies, where time delays between variations in the continuum and line emissions are used to probe the structure of the broad-line region. High Eddington ratio quasars, typically found in Population A with narrower Hβ lines and higher RFe values, display less optical variability. Their relatively stable accretion rates result in smaller amplitude changes in the optical continuum, with variability timescales that are longer and less noticeable over typical observation periods. We explore various mechanisms that may explain observed variability scales and amplitudes for different populations along the main sequence of quasars.

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W-state generation and verification in linearly coupled waveguide arrays

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State-of-the-art quantum devices used in quantum cryptography and computation reley on entanglement of quantum systems [1]. An entangled W state, defined as an equal-probability superposition of n pure states, is known to be particularly robust to loss [2]. Recent advancements in design and fabrication techniques have enabled the realization of waveguide arrays (WGAs) with arbitrary coupling matrices, providing a new resource for W-state generation and probing. Specifically, the WGA-based multiport equal-power splitters, designed either numerically [3] or by exploiting the self-imaging of light [4], can serve as W-state generators.

Here, we investigate the quantum walk of a single photon through the equal-power splitters as a mechanism for generating and verifying W-states. The bipartite entanglement is proved by evaluating von Neumann entropy [5]. The first subsystem being one waveguide, and the second containing the remaining waveguides. Then we trace out the second subsystem and check the von Neumann entropy of the reduced matrix. We note that in the W-state generators based on the WGAs that support self-imaging of light, entanglement can be easily tested by application of the exclusion principle. Namely, an interferometer that recombines all W-state modes into one is constructed simply as the WGA extension to the full propagation period. Finally, we investigate the robustness of entanglement in the presence of fabrication errors in the waveguide width, distance and refractive index.

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Bioorthogonal magneto-plasmonic nanoclusters for microfluidic-based sorting and sensing of cells

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Abstract. The separation of microparticles and cells is a critical process across a wide range of biomedical applications requiring continuous innovation in sorting technologies. Microscale sorting, in particular, enables to drastically reduce sample volumes while allowing for miniaturized and cost-effective devices with high sensitivity [1]. In this context, the development of microfluidic devices for the smart manipulation of functional nanomaterials opens new frontiers in separation processes, leveraging the precision and control inherent to microfluidic systems [2]. In this scenario, the present study focuses on the versatile fabrication of low-cost polymeric microfluidic platforms tailored for the smart manipulation of novel magneto-plasmonic nanoclusters (MPNcls) and plasmonic nanostars (AuNSts) that selectively bind analytes in a sandwich-like configuration, allowing for magnetic isolation, and optical detection. The MPNcls are composed by a magnetic core decorated with spherical gold nanoparticles (AuNPs) designed to achieve rapid magnetic responsiveness for effective cells separation in the presence of a static magnetic field. Additionally, AuNPs can be further functionalized with molecules (e.g. antibodies) to ensure specific interactions of the MPNcls with the biotargets cell of interest [3]. As a proof of concept, MPNcls-labelled SH-SY5Y neuroblastoma cells were successfully sorted by applying a static magnetic field at the detection chamber level external to the microfluidic device. With this regard, the use of 3D printing for the fabrication of microfluidic channels guarantees the customization of channel geometries that is crucial to optimize interactions between MPNcls and targeted analytes. Beyond separation, this microfluidic platform holds promise for application in the non-invasive analysis of targeted cells. To this end, AuNSts were decorated with bioorthogonal Raman reporters (RRs) and further self-assembled on the MPNcls-labelled SH-SY5Y for sensing through surface enhanced Raman spectroscopy (SERS). The use of bioorthogonal RRs exhibiting narrow peaks within the biological Raman-silent region (> 1800 cm-1) should minimize the background noise [4]. Finally, the high versatility of NPs functionalization combined with the scalability of the 3D printing process allows for seamless adaptation of this SERS-microfluidic platform to different clinical and research needs, paving the way for broader adoption of microfluidic technologies in diagnostic and analytical workflows.

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Numerical Simulation of Injection-Locked Fabry-Perot Lasers for Fast and Efficient Reconfigurable Photonic Neural Network Activations

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Abstract. With the world currently woven within the recent rush of artificial intelligence, the industry looks at photonics for high-speed, low energy consuming solutions to hardware neuron realizations [1]. Nevertheless, achieving a neuron's nonlinear operation remains an elusive target, with many attempts focusing on either hybrid optoelectronic integration or the pursuit of fully all optical approaches. The former showed immense reconfigurability at 10 Gb/s line-rates [2], while the latter boast low thresholds, latency, and no need for conversion between domains [3]. Injection-locked (IL) laser diodes (LDs) have been demonstrated to provide a reliable and simple activation module that consumes relatively low energy, allows for reconfigurability in the activation function and at the same time provides high output power to allow the activated signal to propagate to the next neural layer [4]. We expand on our previously experimentally demonstrated all-optical activations [5] and predict the operational rate increase to up to 10 Gb/s, by employing a dual optical injection (DOI) scheme that facilitates faster laser dynamics (Fig. 1(b,c)). Fig. 1(a) illustrates the operating principle of the proposed DOI nonlinear element (NLE). The role of the FP-LD is to provide the nonlinearity at λ_p, while the properties of the nonlinearity are subject to change with the variation in CW power at λ_c. The spectrum of the NLE's output is filtered using a bandpass filter (BPF) centered around λ_p to suppress the unnecessary wavelengths and enable NLEs cascadability in multilayer ONNs. With the additional continuous wave (CW) optical input, we manage to break the sub-pJ energy consumption per nonlinear operation barrier, demonstrating adaptive all-optical activation functions for 25 ps pulses with an energy efficiency of 375 fJ/NOP.

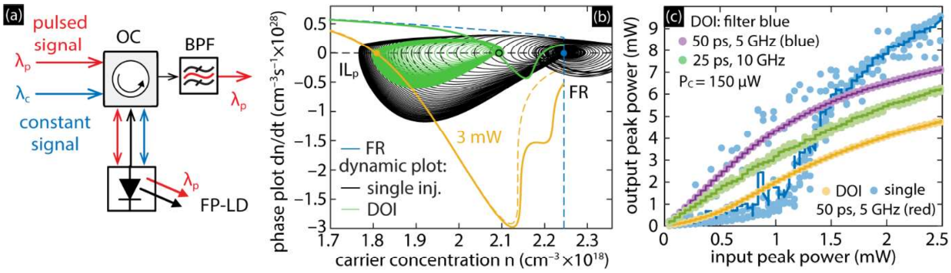

Figure 1. (a) NLE operating principle. (b) FP-LD phase plot under single injection and DOI. (c) NLE output power variation for different repetition rate, pulse width and BPF central frequency.

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Nitrogen-doped graphene quantum dot-aromatic amino acid hybrids: synthesis, interface interactions, and photoluminescence properties

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Abstract. Nitrogen-doped graphene quantum dots (NGQDs) were synthesized through a straightforward and rapid hydrothermal method using citric acid and urea as precursors. The resulting NGQDs were non-covalently functionalized (conjugated) with aromatic amino acids, specifically phenylalanine (Phe) and tryptophan (Trp). Atomic force microscopy analysis revealed that the NGQDs exhibit a disk-like morphology, with an average diameter of approximately 60 nm and an average height of around 0.4 nm. Following conjugation, the height of the particles increased to approximately 3 nm. UV-vis spectroscopy confirmed the successful conjugation of the amino acids to the NGQD nanostructures. Density functional theory (DFT) numerical calculations were conducted using three different N-doped clusters to further investigate the nature of the non-covalent interactions between NGQDs and the respective amino acids. Photoluminescence spectra demonstrated stable and intense fluorescence signals for both hybrids in the UV region. The most significant changes were observed in the case of Trp conjugation. Unlike phenylalanine, the non-covalent bonding of tryptophan to NGQDs significantly influenced the visible emission at around 500 nm, which originates from the surface states of the quantum dots.

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Exploring Mechanobiology of Red Blood Cells in Diabetes by Label-Free Optics-Based Approach

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Abstract. Prolonged hyperglycemia in diabetes mellitus (DM) profoundly affects red blood cells (RBC), altering their morphology, metabolism, and function. These changes lead to disruptions in hemorheology and microcirculation, significantly impacting vascular health and contributing to DM-related complications [1]. However, DM is often described as having "covertly abnormal" blood rheology[2]. This abnormality, particularly the impaired deformability of RBC, is a significant hemorheological indicator that is not always detectable by commercially available devices in clinical settings. To address this limitation, we propose novel mathematical and experimental approaches of label-free optics-based methods, including ektacytometry, flow cytometry and two-photon excitation fluorescence (TPEF) microscopy to investigate the mechanical and morphological characteristics of RBC in DM patients. RBC were isolated from blood samples of diabetic patients (n=13) and age- and sex-matched controls (n=11). RheoScan-D300 ektacytometer (RheoMeditech Inc., Korea) was utilized to evaluate the deformability of RBC, expressed as the elongation index (EI) under increasing shear stress (SS). Both freshly isolated RBC and RBC rigidified and oxidized using 0.5 mM tert-butyl hydroperoxide (TBHP), were analyzed using BD FACSCalibur flow cytometer (Becton Dickinson, USA) and home-constructed TPEF microscope.

We identified the first derivative of the EI at the one-half value of the deformability curve (dEI/dSS) as a more sensitive metric for assessing RBC response to SS in DM than the conventional EI parameter [3]. DM patients exhibited a significantly slower RBC deformability response than the controls, indicated by a decline in the dEI/dSS index at the half-maximum value of the deformability curve. Using 0.5 mM TBHP-induced oxidation, our results demonstrated that flow cytometry effectively identifies subpopulations of rigidified RBC based on forward and side scatter light distribution, as well as autofluorescence intensity changes possibly related to hemoglobin degradation [4]. Additionally, TPEF microscopy revealed altered RBC morphology and autofluorescence near the membrane, correlating with decreased deformability observed. Our findings suggest that the newly introduced metric dEI/dSS from ektacytometry analysis, along with the addition of other optics-based methods, provides a powerful tool for detecting subtle mechanobiological changes in RBC of DM patients.

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Multipled biosensing using plasmonic nanoparticles

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Abstract. A biosensing platform based on the localized surface plasmon resonance (LSPR) principle is introduced: Gold nanoparticles (80 nm diameter) are thereby used as sensor, any change in refractive index around the particles induces a change in resonance frequency, which is monitored using UV/VIS imaging spectrometry. By modification of the nanoparticles with highly specific receptors molecules (such as DNA, proteins or aptamers), a high specificity can be achieved for the respective target. The principle was demonstrated for both DNA [1,2] as well as protein detection [3]. The platform is capable of multiplex sensing, by using an array of immobilized nanoparticle spots, which can (by holding different receptors) detect the presence of multiple target molecules simultaneously in one assay [4,5].

For readout of the LSPR peak shift, imaging spectrometry is utilized. Different approaches with spectrally filtered light have been compared: One method is using liquid crystal tunable filter (LCTF), which is quite flexible but still complex and requiring costly equipment; the other one just a series of LEDs of different wavelength [6], allowing for a very simple and cost-efficient detection.

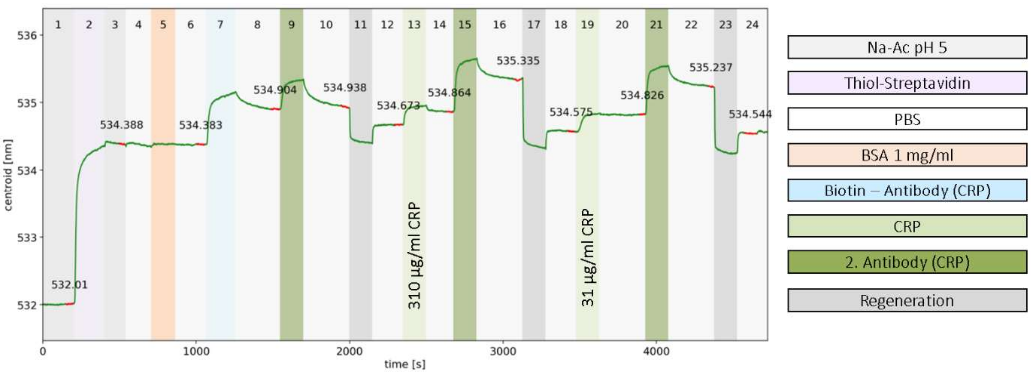

Figure 1. Sensogramm (LSPR peak wavelength centroid plotted over time) of the various steps (including sensor functionalization and control experiments) of a CRP protein detection assay. Different colors mean different (buffer/analyte) solutions. (From [3])

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Characterization of Rubidium-Doped KTP (RKTP) Waveguides as a Versatile Photon Pair Source

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Abstract. In recent years, there has been a growing interest in designing a nonclassical light source for applications in quantum technology **Error! Reference source not found.**. While the use of bulk correlated sources is reaching its optimal design and implementation, waveguide-based correlated sources can confine light in tight mode volumes and allow longer interaction lengths [2]. These sources can also be designed to be spatially and spectrally single-mode, allowing for high efficiency in coupling with fiber, as well as simultaneously achieving high spectral purity and brightness, which are all important parameters in implementing high-rate, high-quality multi-photon experiments **Error! Reference source not found.**.

A recent advance in the waveguide fabrication process via ion-exchange has prompted the use of rubidium-doped $KTiOPO_4$ (RKTP) as an alternative substrate that has low ionic conductivity and hence allows for the formation of homogeneous ferroelectric domains via electric field poling **Error! Reference source not found.**. The reduced ionic conductivity has made it possible to fabricate quasi-phase-matching (QPM) structures with a very small poling period.

To fully utilize the potential of such a chip-scale quantum device, it is necessary to understand its various operating modes, such as temperature-dependent spectral evolution and the rate of photon pair generation. This work presents a concrete investigation of a waveguide-based photon-pair source for both type-0 and type-II phase matching in a single ppRKTP waveguide as illustrated in figure 1.

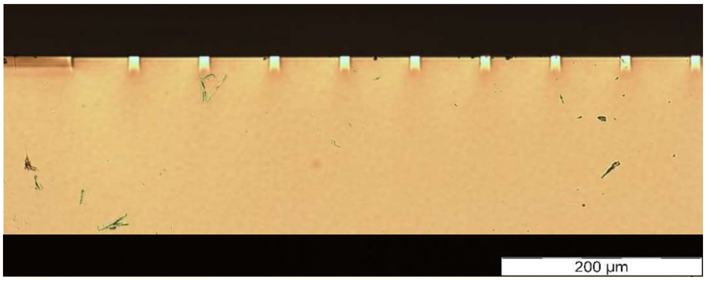

Figure 1. Microscope image of the crystal input facet with 20X magnification. Each waveguide input channel has width ranges from 3-7 µm.

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Stark many-body localization in continuous one-dimensional bose gas

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Abstract: Many-body localization, an emerging quantum phenomenon, challenges the fundamental principles of thermodynamics and has attracted significant attention. In this study, we demonstrate Stark many-body localization in a continuous one-dimensional Bose gas, a scenario that extends well beyond the conventional tight-binding model commonly employed in most discussions. This localization occurs within a background harmonic trap without any random disorder, where the potential gradient effectively halts thermalization. Contrary to prior studies on Stark localization, our findings reveal that an increasing gradient does not necessarily lead to greater localization. Instead, we observe a complex transition within this continuous interacting system. Unlike prior studies on Stark localization, the use of harmonic external force instead of a linear one makes us to observe a complex transition between different behaviors in our system. Another surprising result is that a higher initial density, which typically correlates with a higher collisional rate and thermalization rate, actually induces stronger localization in this 1D model. Additionally, we observe the emergence of a potential new bosonic insulator arising from the many-body localization, supported by measurements of zero compressibility over a chemical potential range of 100 nK (2 kHz).

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Photometry of the Universe on Petascale data regime with the Rubin Observatory LSST survey

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Abstract. We have entered the new era of next generation of all sky photometric surveys that promise to bring revolution in our investigations and understanding of the Universe. One of the most significant ones is the Legacy Survey of Space and Time (LSST) provided by the Vera C. Rubin Observatory, which is to start late 2025. The LSST is the ten-year long optical time-domain survey of superb performance that opens huge possibilities for both static and time domain astronomy. It is anticipated that the LSST will provide catalogue of tens of billions of objects (galaxies, stars, and Solar System objects), as well as detect and alert the community in real time of billions of time-domain events, i.e., 10 millions of time-variable events per night [1]. Thus, the LSST provides an unprecedented data set for studying various dynamical phenomena, including the active galactic nuclei (AGNs) which are known to be extremely variable sources on different timescales. Variability studies of AGNs offer the possibility to explore the environments of accreting supermassive black holes (SMBHs), and their role in the host galaxy evolution. In this contribution we will review the results of the SER-SAG accepted in-kind contribution to the Rubin LSST, dedicated to the studies of AGNs using innovative algorithms to detect and characterize photometric variability properties of AGNs [2].

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Two-dimensional material thickness determination using atomic force microscopy and deep learning

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Abstract. Two-dimensional materials are nanometer thin "sheets" comprising only several atomic monolayers of a material with a layered crystal structure, such as graphite, transition metal dichalcogenides, hexagonal boron nitride, etc. The optical properties of 2D materials, often exhibiting a strong dependence on thickness, have received a lot of attention over the past two decades, as numerous applications in various fields of photonics have been proposed [1].

We use atomic force miscroscopy (AFM) to investigate 2D material flakes prepared on oxidized silicon substrates. Although even atomically thin flakes are reliably observed on an AFM topography map (as in Figure 1b), even a small background variation, representing either the actual sample tilt or measurement artifacts (e.g. AFM scanner bow) [2], introduces a considerable uncertainty in assessing the material thickness t_{1D} as the step height along each scanning line (horizontal cross sections plotted in Figure 1f along lines indicated in Figures 1b and 1e), as demonstrated by the histogram in Figure 1c.

Here we describe a deep-learning-based algorithm for analyzing AFM images [3] which employs a U-Net [4] architecture in order to segment the measured sample topography into terraces corresponding to 2D material flakes. The terrace mask created by the U-Net is used as the input of a 2D topography regression model which yields a considerably improved background correction (as in Figure 1e) and, consequently, allows a reliable assessment of the thickness t_{2D}.

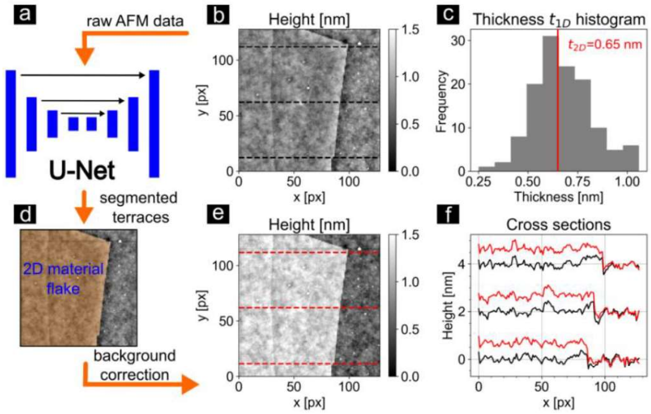

Figure 1. Schematics of AFM image analysis using a U-Net.

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Advances in quantum imaging for biomedical applications

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Abstract. Emerging fields of quantum imaging (QI) is promising to overcome limitation of classical imaging by exploring properties of entangled photons, enabling sub-shot-noise imaging and sub-wavelength resolution. We will highlight the latest development in QI presenting results by the two methods of QI, the quantum imaging with undetected photons [1] and the quantum ghost imaging [2].

Despite the apparent advantages, the quantum imaging methods are still in the phase of proofing the principle. The biggest challenge, preventing QI to step from the proof of principle demonstrations to the real world applications, is the low efficiency of the photon conversion by the spontaneous parametric down conversion (SPDC), which is the main source of entangled photon pairs for QI. SPDC is a nonlinear process in which the pump photon is split into two quantum correlated photons in nonlinear crystal (NLC).

We will present the resent advances for brighter SPDC [3], and discuss perspectives, based also on the novel materials for SPDC, for reaching the practicality of QI methods, necessary for the microscope configuration of QI system.

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Stabilization of laser wavelength for improved performance in Cs-based optically pumped magnetometers

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Abstract. We present the development and implementation of a cesium-based optically pumped magnetometer (OPM) with a focus on the wavelength stabilization of the frequency (i.e. wavelength) modulated (FM) VCSEL laser where conventional methods are not applicable. The magnetometer utilizes Free spin Alignment Precession (FAP) induced by resonant linearly polarized pump light. Experiment is performed in paraffin coated spherical glass cell containing Cs vapor. Used methods and experimental technique is similar to free spin precession (FSP) magnetometer presented by Grujic et.al. [1].

Our FAP based OPM is operated in two phases: optical pumping (OP) phase and readout phase (RP). In RP we passively detect decay of the FAP in intensity of transmitted light of a weak probe laser beam tunned to $F_g = 4 \rightarrow F_e = 3$ transition of D_1 line of the Cs atom. Precession of Cs atoms in magnetic field $\vec{B}_0$ imprints double Larmor frequency into the intensity of the probe beam, from which we estimate the intensity $|\vec{B}_0|$ of $\vec{B}_0$. In the OP phase Cs vapor is exposed to the FM pump beam. Modulation frequency is equal to the double of Larmor frequency and performed by square-wave modulation of the current intensity trough the VCSEL laser diode. For a first half period the laser frequency is tuned to $F_g = 4 \rightarrow F_e = 3$ to perform OP and produce spin alignment. In the second half period we aim for $F_g = 3 \rightarrow F_e = 3$ to recover (re-pump) part of $F_g = 4$ population lost during the first half period.

The main subject of this presentation are methods ensuring stable operation of the magnetometer by prevention of VCSEL's wavelength drift. This is achieved by observation of transmitted pump beam spectrum, shape recognition using correlations with previously recorded spectrums or using machine learning.

For the purpose a specialized software is developed that stabilizes the VCSEL laser diode wavelength. In the mentioned software we use **CubicSpline** interpolation to smooth the spectrum, then compare the current spectrum and previously recorded reference data using Pearson correlation in order to identify the best-matching spectrum. According to the best match, the error is calculated, and the correction is applied through PID-controlled mean VCSEL current. This stabilization ensures stable conditions for long-term operation of the magnetometer.

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The UrbObsBel PROJECT: HYPERSPECTRAL IMAGING INSTRUMENT

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Abstract. The Urban Observatory of Belgrade (UrbObsBel), hosted by the Astronomical Observatory of Belgrade, aims to investigate light pollution and urban dynamics in the Serbian capital using proven astronomical techniques. Our research will provide crucial insights into energy usage patterns and their significant impact on the environment and ecosystems. We have already installed, and plan to expand, a range of observational instruments covering the spectral range from visible light (400 nm) to infrared (13 microns), utilizing both broadband and hyperspectral imaging systems. In addition to studying urban processes, we will assess sky brightness and identify various sources of sky pollution, such as street lighting. This would be achieved mounting identical instruments at Astronomical Observatory of Belgrade (AOB) and at our Astronomical Station at Vidojevica (ASV). Until now we have acquired the following equipment: Web and file server, TESS-W photometer, Unihedron Sky Quality Meter, Hyperspectral Imaging (HSI) devices, FLIR and AllSky Camera

We have developed two visible and near-infrared (VNIR) HIS sensors following the guidelines provided by Salazar-Vasquez & Mendez-Vasquez [1]. These instruments, costing only 2% of commercially available HSIs, will be deployed to observe the urban area of Belgrade and its surroundings. They will enable us to perform simultaneous remote sensing across a spectral range from 400 nm to 1052 nm, covering up to 315 wavebands. Both sensors will facilitate the monitoring of short- and long-term changes in urban dynamics, such as using urban lighting as an indicator of environmental impact and urbanization trends.

We would like to acknowledge Đorđe Vuković, BEng from the Innovation Center at the Institute of Physics, Belgrade, and Professor Bogdan Nedić, DSc, from the Faculty of Engineering, Kragujevac, for their assistance with 3D printing.

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Mapping neuronal populations with Light-Sheet Fluorescence Microscopy

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Abstract. We present the latest advancements in high-resolution neuronal imaging from the Biophotonics Lab at CNR-INO and LENS, with a specific focus on Light-Sheet Fluorescence Microscopy (LSFM). This imaging technique has become an increasingly valuable tool for investigating neuronal populations in large samples, such as whole mouse brains, due to its intrinsic 3D imaging capabilities at sub-cellular resolution.

Our highly interdisciplinary group covers the entire LSFM experimental workflow, from sample preparation (optical clearing and staining) to the development of custom optical setups and advanced image post-processing tools (e.g., volumetric image stitching, cell counting). For sample optical clearing, we have optimized various protocols compatible with immunohistochemical labeling, enabling the study of different tissue types, including the adult human brain [1].

On the hardware side, our custom LSFM setups include a dual-view, inverted, dual-color system for large tissue slabs (up to 0.5 mm thick and several centimeters in lateral size) [2] and a single-view, dual-color system for whole organs (e.g., whole mouse brains) equipped with an autofocusing system that we developed [3]. Additionally, we are developing a new setup capable of simultaneous excitation and acquisition at four different wavelengths.

Given their high resolution, operating these instruments generates substantial amounts of data (several terabytes per sample, with acquisition rates up to 1 GB/s). We describe our image processing pipeline and the software tools we have developed to manage these large datasets, from volumetric stitching to automated cell localization using convolutional neural networks.

Finally, we present recent results from several scientific projects enabled by this workflow. We showcase point clouds of automatically localized neurons in the whole mouse brain and cell segmentation in large portions of the human cortex, specifically a sample from the Broca's area [4].

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From lab dreams to revenue streams: a personal perspective on bringing photonic integrated circuits to market

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Abstract. In this talk, we will provide a perspective on various aspects of bringing photonic integrated circuits to market. We will discuss the development of relevant photonic solutions and products that were successfully deployed, as well as current trends, markets and areas of development in the field of active photonic integrated circuits and components.

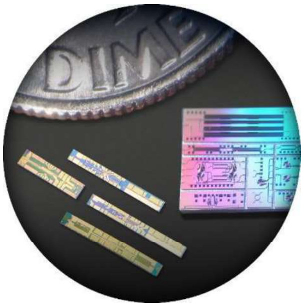

Figure 1. Various photonic integrated circuits in Indium Phosphide and Silicon.

Temperature Dependence of $Bi_{12}GeO_{20}$ Optical Rotatory Power

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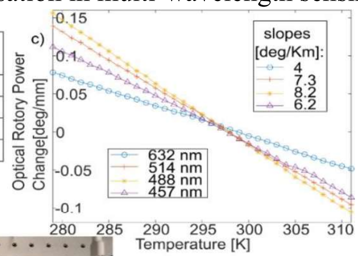
Abstract. Temperature and wavelength dependencies of optical effects are interesting for material science and for compensation methods in optical measurements. Optical activity (OA) can be used for temperature compensation of sensors based on Pockels and Faraday effect [1]. Although temperature can be measured more precisely by other methods, this is the only compensation for temperature at exactly the same optical path as the measurement. In this work, the OA of the $Bi_{12}GeO_{20}$ (BGO) crystal is measured on four wavelengths in the temperature range from 6 ℃ to 38 ℃. The experimental setup is shown in Figure 1a. The birefringent calcite, placed after the BGO, separates the beam into two orthogonal linear polarizations. Beam intensities are measured using a Quadrant photodiode and matched transimpedance amplifiers. The OA of the BGO is calculated using Δ/Σ normalization [2]. The BGO is placed on a Peltier element and their temperature is measured and adjusted using a thermoelectric controller [3]. Optical rotatory powers (ORP) at 22 ℃ for two crystal lengths are given in Figure 1b, showing a monotonous decrease with wavelength, contrary to Lenzo et al. [4], but same as Feldman et al. [5]. The ORP change with temperature from the measurement at 298 K is shown in Figure 1c, illustrating the decline of the slope with wavelength, excluding the measurement at 457 nm. The results increase the known wavelength range of the BGO's OA temperature dependence [2], providing a foundation for temperature compensation in multi-wavelength sensing.

b)

	L = 1.27 mm [°/mm]	L = 9.1 mm [°/mm]
632 nm	20.08	22.6
514 nm	40.9	37.58
488 nm	48.82	49.34
457 nm	59.84	61.54



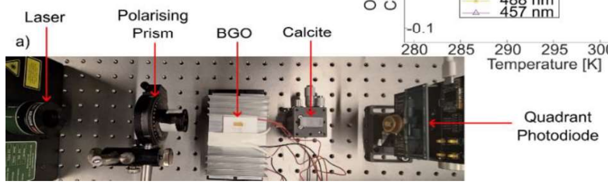


Figure 2. a) Experimental setup. b) Table of optical rotatory powers measured on room temperature. c) Optical rotatory power change with temperature

ACKNOWLEDGEMENTS: The authors are grateful to The Palace of Science for their support.

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Invisible Defense with Luminescent polish for Anti – Counterfeiting

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Abstract. We develop an innovative and simple luminescent polish which would serve as a concealed yet easily detectable marker for authenticity verification. Our product strives to be meticulously engineered to excel in two critical aspects: cost – effective manufacturing and uncompromising quality which could potentially outshine the competition in today's crowded market. We use well established classical ceramic method for synthesis of europium – doped yttrium vanadium oxide nanopowders (YVO_4: Eu^{3+}).YVO_4: Eu^{3+} is a well-known red ceramic phosphor. YVO_4 is chosen since it is an attractive host material for rare earth ions that could be well excited under UV light irradiation. By incorporating these nanoparticles into polish formulations we create a unique anti – counterfeiting solution: a luminescent coat for objects or documents, detectable under UV light, providing a reliable method for authentication. This has many advantages compared to traditional anti – counterfeiting strategies, such as barcodes, watermarks or micro printing, which are easily copied and difficult to effectively prevent counterfeiting. While luminescent ink has played a crucial role in authentication over the years, its complex application processes and limited versatility have become apparent drawbacks. The need for specialized printing equipment and trained personnel has led to increased production costs and logistical challenges. In stark contrast, luminescent polish can be effortlessly applied to a wide range of surfaces using conventional methods, making it accessible and cost – effective. Furthermore, luminescent polish offers a unique advantage in terms of visibility and durability. Its luminescent patterns are easily discernible under UV light, enabling quick and reliable authentication. Unlike luminescent ink, which can fade over time or be susceptible to wear and tear, luminescent polish adheres more robustly to surfaces, ensuring long – lasting security features.

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Free alignment precession based magnetometer with optical re-pumping

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Abstract. We study the performance of an all-optical atomic magnetometer, working at the room temperature. Its operation is based on the Free spin Alignment Precession (FAP) [1,2] induced by resonant linearly polarized and frequency modulated pump light. After the optical pumping, the decay of the spin polarization is detected in the weaker probe beam passing through the vapor cell. Further on, the information on the magnetic field and Larmor frequency are gathered via signal processing. Pump-probe measurements are performed on D1 line of cesium vapor. The process of optical pumping by amplitude-modulated light is lossy, hence a large fraction of the atoms is lost to quantum state with no contribution to magnetic field measurement process [3]. In order to improve sensitivity of this sensor, we employ the method of re-puming by using frequency-modulated light, where at the same time we perform pumping on the sensing quantum state and the recovery of the population from the uncoupled state.

We will present the scheme employed in our work and the results of this study. We will also compare the obtained results to the ones previously demonstrated by another type of optically pumped magnetometer whose operation is based on free spin precession (FSP) [3].

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On compact topological edge modes in photonic ribbon lattices

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Abstract. Topological insulation and the associated unidirectional propagation of edge modes have opened new avenues for light control, enabling the design of novel photonic devices with enhanced performance and stability [1]. The number of topologically protected edge modes, determined via the bulk-edge correspondence, is linked to changes in the bulk k-space Hamiltonian and is quantified by topological invariants—such as the winding number (Zak phase) in 1D and Chern numbers in 2D systems. This framework inherently implies a nonzero band curvature. In contrast, flatband (dispersionless) systems offer a distinct route for light control by supporting highly compact localized modes (CLMs). While topological protection and flatband localization are typically considered opposing effects, their interplay can significantly enhance the robustness of edge modes. Recent studies have demonstrated the existence of compact topologically protected modes [2,3].

Here, we systematically analyze this phenomenon in quasi-1D ribbon photonic lattices, considering four graphene-like ribbon configurations where the band curvature can be tuned by introducing an artificial magnetic flux in specific plaquettes. We investigate the emergence of compact topological edge modes in the presence of ribbon symmetries and geometric constraints. Additionally, we examine the robustness of CLMs against disorder and nonlinear effects and identify optimal lattice configurations for device design. Initial experimental efforts in realizing SP states [2], provide promising confirmation of our approach.

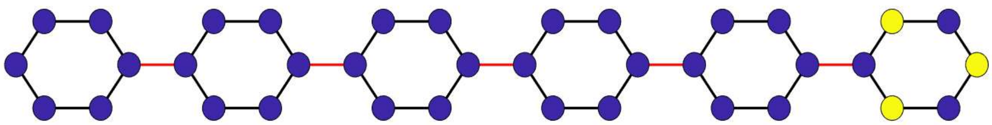

Figure 1. Compact topological edge state in graphene-like ribbon.

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Digitalization in Teaching – Means or End in itself?

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Abstract. The ongoing process of digitalization has been a transformative force in all areas of research and development. Unprecedented computing power, data rates, the miniaturization of sensors and computerized control of experiments have enabled rapid advances in particular in the study of complex systems. With progress in many areas of science now thus being data-driven, the basic skillset for experimental physicists has shifted to include not only the handling of a (digitalized) laboratory but also the handling and analysis of massive amounts of data. Data handling here also includes communication skills as increasing specialization among scientists requires sharing data and therefore documenting them in a widely understandable way.

In the context of teaching, however, to “digitalize” courses remains frequently limited to the format rather than the content by e.g. offering the course online, in hybrid format, publishing lecture notes and so forth. In particular for laboratory courses, which are notoriously costly in terms of space, equipment and personnel, it is often argued that an efficient use of digitalization is to “virtualize” laboratories and laboratory courses in order to make the courses more universally accessible and also more economical. This coincides with a tendency to additionally compress the time spent in the lab in order to accommodate programming and/or data analysis classes. With the current rise of artificial intelligence (AI), in particular generative AI, however, the future division of labor between humans and machines once more is set to shift. While it remains to be seen in which way theoretical, numerical and computational physics will be transformed by AI, hands-on laboratory skills and human observational capabilities are least likely to be replaceable by machines in the near future. In a time of digitalization and AI, practical training and experience is therefore becoming not less but rather progressively more important.

As a basis for discussion, we will present the concept and content of a reform we are undertaking currently in the basic laboratory courses for physics students at the Technical University of Berlin. The reform is aimed at maximizing the time spent gaining procedural knowledge and practical experience of modern laboratory routines and equipment. This also includes data handling via electronic laboratory notebooks, documenting data by suitable metadata and an outlook into the possible ways of applying AI and machine learning to aid the learning process.

Quantum phase shift holography with undetected light

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Abstract. Quantum phenomena along holography open a myriad of new perks in the sensing field. Our work succeeds to build holograms using nonclassical light states to overcome current detection limitations for wavelengths out of visible spectra.

Since its invention in the 20th century, holography has allowed us to retrieve more than just an object's intensity distribution. By exploiting the technique, sensing the object's phase distribution was possible. This perk endows holography with potential applications for sensing biological specimens [1]. Within the realm of in-line holography, digital phase shift holography (DPS) happens to be advantageous.

It consists of acquiring a number n of images ($n \geq 2$) where in each acquisition, the object beam is step-wise phase-shifted employing a phase-inducing element [2].

In early 2022, Töpfer and colleagues [3] proposed QHUL, a holography scheme based on quantum imaging with undetected photons. The scheme employs the DPS technique along nonclassical states of light to retrieve the hologram without detecting the photons that interacted with the sample. This feature is possible because the interferogram does not arise from the interference between object and reference beams but from the quantum interference occurring due to Mandel's induced coherence without induced phenomena [4]. We propose an alternative approach for hologram retrieval that aims to reduce the acquisition time currently achieved by setup. Our work implements the DPS technique through a reflective liquid crystal-type spatial light modulator. The aim is to use the QHUL taming property over both sampling and measured wavelength while keeping a short measuring time.

The experimental setup for our work is based in a nonlinear interferometer. A laser bidirectionally pumps the ppKTP crystal where spontaneous parametric down-conversion (SPDC) produces entangled photon pairs with a wavelength of 910nm for the signal and 730nm for the idler. The object to be imaged is placed within one of the idler modes preventing both modes from superposing. In those regions where the modes are superposed, interference between individual idler photons arises due to Mandel-induced coherence phenomena creating a contrast. Since signal and idler photons are entangled, the same process occurs in the signal mode, allowing us to measure these contrasts with a CMOS camera. The phase modulation is imprinted in the signal beam with a spatial light modulator (SLM) placed directly behind the object. For a number n equal to four phase shifts. The set of induced phase-shift goes as $\Delta\varphi_n = n\pi/2$ with $n = \{0, 1,2,3\}$. Hence, four intensity distributions are acquired, each carrying a phase shift from the set $\Delta\varphi_n$ and an integration time of 100ms. The acquisitions are post-processed and turned into the sample's phase distribution. Both acquisitions and phase distribution are shown in figure 1.

Our setup proved to accurately retrieve the intensity and phase distributions of an object using light that never interacted with it. Furthermore, the signal and idler produced in the SPDC process can be tamed to create holograms of objects using wavelengths for which the cameras present low efficiency in detection.

However, since the total exposure time required for a single-phase measurement scales as the number of acquisitions *n*, measurements of living biological samples remained out of the scope of the technique. As a strategy to address the integration time limitation, alternative holographic techniques beyond DPS can be implemented.

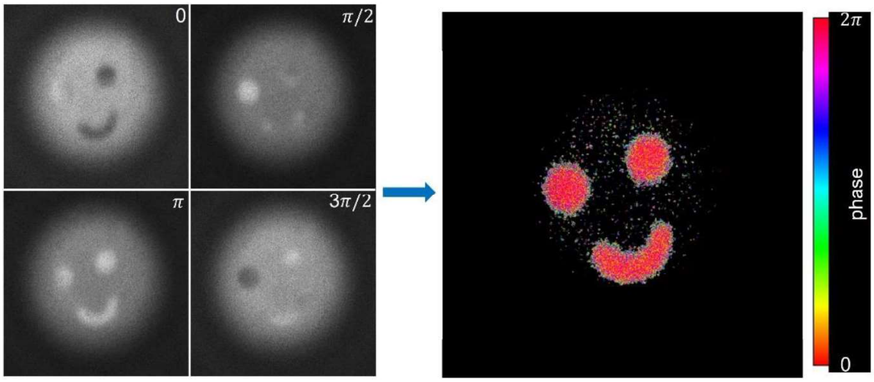

Figure 1. Intensity distributions of four different interferograms, each carrying a given phase shift. After processing, the interferograms are transformed into the object's phase distribution.

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Compact Topological Edge States in Flux-Dressed Graphene-Like Photonic Lattices

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Abstract. We report the existence of compact topological edge states on flux-dressed photonic graphene ribbons [1]. Robust localization is achieved through a synergy of Aharonov-Bohm caging and topological protection mechanisms. The topological nontriviality of the compact edge states predicted by theoretical derivations is confirmed by experimental estimation of an integer Zak phase obtained from the mean chiral displacement. Experiments are performed using direct femtosecond laser writing of a graphene ribbon photonic lattice having 0 or π synthetic magnetic flus. Mode stability is demonstrated by its exceptional localization and resilience to fabrication tolerances and input phase variations. Demonstration of the compact edge modes opens the door to exploitation of the synergy between flat-band physics and topology in secure information transfer and high-temperature superconductivity [2].

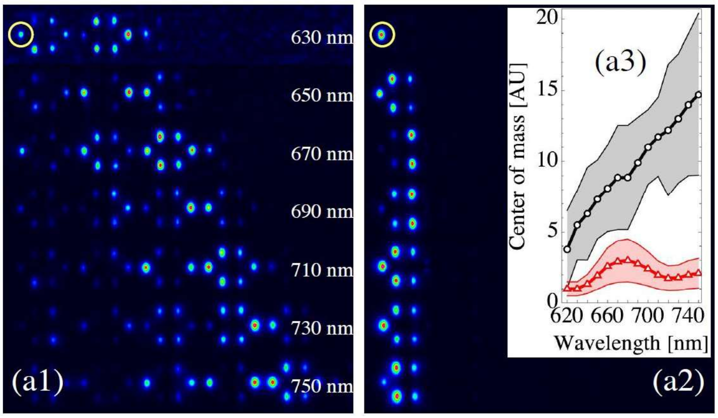

Figure 1. (a1), (a2) Output intensities measured for an edge site excitation of 0 and π flux lattices, respectively, by a set of wavelengths. (a3) The center of mass versus wavelength for 0 (black) and π (red) flux lattices.

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Solitary and traveling wave solutions to the Nonlinear Schrodinger equation that are localized in the transverse directions

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Abstract. Finding exact analytic solutions to various form of the Nonlinear Schrodinger equation (NLSE) is a rich area of research in the field of mathematical physics and nonlinear optics. A widely used method is the so-called Jacobi elliptic function expansion method where polynomials of Jacobi elliptic functions are used to obtain large classes of solutions [1]. The method has been successfully applied on a number of systems including the NLSE [1], the Gross-Pitaevskii equation [2] and many others [3,4]. The biggest drawback of the method until this point has been that it only produces solutions which are not localized in the transverse directions, but rather form a wave front. This is a drawback given that solutions which are localized in both transverse directions, widely known as spatial solitons [5], are of far greater practical interest.

In this contribution, I generalize the results of [1] to produce solitary wave solutions to the Nonlinear Schrodinger equation with an external potential which are localized in the transverse directions. By employing a quadratic term for the transverse variables in the argument for the Jacobi elliptic function, one can transform solutions from extended waves to localized waves that propagate in the longitudinal direction. The additional parameter interacts with the chirp parameter in the phase to inevitably produce chirped solutions. This is due to the fact that the two parameters form a coupled pair of differential equations. The external potential is needed to cancel out one of the terms in the expansion. Both solitary and periodic beam solutions have been obtained.

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New Phases of $BiFeO_3$ Perovkistes

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Abstract. Bismuth ferrite ($BiFeO_3$) is a prominent multiferroic material, renowned for its simultaneous ferromagnetic and ferroelectric properties. This presentation delves into the theoretical exploration of novel crystalline phases in doped bismuth ferrite structures, specifically focusing on holmium- and silver-doped $BiFeO_3$. Utilizing density functional theory (DFT), we investigate the stability and electronic/magnetic characteristics of these new phases, revealing a diverse array of properties that could enhance their application potential in advanced electronic and spintronic devices.

In the second part of the presentation, we show experimental findings on the change in electric resistance of $BiFeO_3$ upon doping with terbium. Through detailed atomic-level analysis using density functional theory, we elucidate the physical mechanisms underlying this observed phenomenon. This dual approach combining theoretical predictions with experimental validation provides a comprehensive understanding of the structural and functional modifications induced by dopants in bismuth ferrite perovskites.

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Optical Dynamics and photnic effects in Cerium Dioxide Nanocrystals

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Abstract. The present study provides a detailed photonics-based exploration of the mechanisms driving the insulator-to-metal transition in lanthanide oxide materials, with a focus on cerium dioxide. This work transitions from fundamental bulk material properties to the manifestation of nanoscale effects due to particle size reduction and culminates in the remarkable behavior of heavily doped nanocrystals exhibiting metallicity. Advanced optical spectroscopy techniques, including Raman, infrared, and spectroscopic ellipsometry, were employed as precision tools for tracking optical and electronic transitions. Raman spectroscopy revealed the broadening and softening of the F2g mode with Fe^{3+} doping, attributed to free carrier effects and electron-molecular vibrational coupling. Further, IR spectroscopy demonstrated the emergence of plasmon modes coupled with longitudinal phonons, particularly prominent in Nd-doped nanocrystals, signaling a semiconductor-to-metal transition. Spectroscopic ellipsometry provided insights into the material's bandgap evolution, with an observed increase due to the Burstein-Moss effect. The study concludes with a proposed electronic band structure model for cerium dioxide nanocrystals, offering a visualization of the insulator-to-metal transition. These findings underscore the vital role of optical methods in unraveling complex electronic phenomena and advancing material design for optical applications.

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All-optical multilevel physical unclonable functions

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Abstract. Disordered photonic structures are promising for the realization of physical unclonable functions—physical objects that can overcome the limitations of conventional digital security and can enable cryptographic protocols immune against attacks by future quantum computers [1]. The physical configuration of traditional physical unclonable functions is either fid or can only be permanently modified, allowing one token per device and limiting their practicality. Here we overcome this limitation by creating reconfigurable structures made by light-transformable polymers in which the physical structure of the unclonable function can be reconfigured reversibly [2]. Our approach allows the simultaneous coexistence of multiple physical unclonable functions within one device. The physical transformation is done all-optically in a reversible and spatially controlled fashion, allowing the generation of more complex keys. At the same time, as a set of switchable individual physical unclonable functions, it enables the authentication of multiple clients and allows for the practical implementations of quantum secure authentication and nonlinear generators of cryptographic keys.

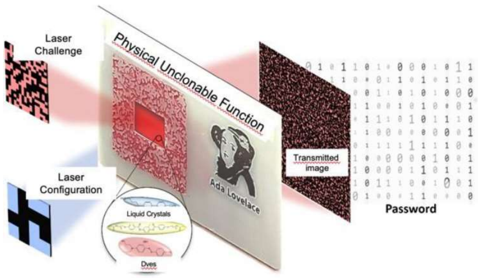

Figure 1. Scheme of the PUF token and its internal configuration (blue pattern), challenge interrogation (red pattern), transmitted speckle pattern, and generated password.

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Optics-Based Assessment of Red Blood Cell Adaptations to Ercise: Insights from Ektacytometry and Flow Cytometry

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Abstract. Red blood cells (RBC) are highly adaptable, particularly during ercise, when their membranes and cytoskeleton experience various mechanical and biochemical changes. Despite the crucial role of these adaptations, the impact of ercise-induced changes on RBC deformability and their susceptibility to oxidative stress remains poorly understood [1, 2], highlighting the need for further research and implementation of novel methodological approaches. This study investigated the potential of ektacytometry and flow cytometry as label-free optics-based methods to assess the effects of ercise on RBC deformability to dynamically changing flow conditions and erythrocyte response to oxidative stress. Blood samples were collected from five national-level basketball players at three time points: immediately after (IAT), 24 hours (24h), and 48 hours (48h) after training. Five healthy, age-matched sedentary individuals served as controls. Erythrocyte deformability was assessed using ektacytometry, measuring the elongation index (EI) under increasing shear stress based on laser diffraction patterns. To determine the level of oxidative stress, the autofluorescence of RBC was analyzed by using flow cytometry to measure the fluorescence intensities in spectral channels which corresponds to the excitation of 488/10 nm and emission wavelengths: FL1 (530/30 nm) and FL2 (585/40 nm). Both experiments were conducted under the baseline conditions and upon oxidation induced by 0.5 mM tert-butyl hydroperoxide (TBHP). Ektacytometry showed increased RBC deformability in athletes compared to control, evidenced by lower shear stress values at half-maximal EI (IAT= 3.09±7.8, 24h = 2±0.4, 48h = 2.17±0.4, CTRL = 9.36±6.6). Flow cytometry revealed lower autofluorescence in FL1 at IAT (1.92±0.1) and 24h (1.74±0.1) compared to CTRL (2.56±0.2), but highest at 48h (3.04±0.7). In the FL2 channel athletes showed lower autofluorescence than controls (IAT = 2.63±0.1, 24h = 1.81±0.2, 48h = 2.07±0.1 and CTRL = 2.93±0.1). Upon oxidation with TBHP autofluorescence was expectedly higher but followed the same pattern as under the baseline conditions, suggesting the protective effects of ercise against oxidative stress. These findings demonstrated the protective effects of ercise against oxidative stress and enhanced RBC deformability. Overall, the results emphasize the potential of label-free optics-based approaches for fast and useful diagnostics and assessment of ercise adaptations.

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Complex Nature of Many-body Effects in Quantum Dots

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Abstract. The Nobel Prize in Chemistry 2023 recognizes the discovery and synthesis of nanometer- sized semiconductor crystals, the properties of which are determined by quantum size effects [1,2]. When 2023 Laureates, Alei Ekimov, Louis Brus and Moungi Bawendi carried out their first work on quantum dots over 40 years ago, none of them anticipated the enormous impact these tiny crystals would have on our daily life. Their work [3-5], alongside the others, was part of the birth of nanoscience and nanotechnology. QD marks nanoparticles so small that their physical size determines the quantum mechanical states of the material's charge carriers.

QDs have emerged as a competitive platform for classical light-emitting devices (in the weak light–matter interaction regime, e.g., LEDs and laser), as well as for devices exploiting strong light–matter interaction at room temperature. Many-body interactions and quantum correlations among photogenerated exciton comples play an essential role, for example, by determining the laser threshold, the overall brightness of LEDs, multi-exciton-generation in MEG solar cells, and the single-photon purity in quantum light sources.

Along the overview of the historical context, I will review my contribution to the current understanding of many-body processes in QD: (1) multi-exciton-generation in the CdSe/CdTe "Russian Doll" QD and its application for MEG solar cells [6] (2) III-N QD as single photon sources in quantum information processes [7]. The ab-initio configuration- interaction calculations qualitatively explain the role the many-body states in the formation of the bi-exciton comples [8]. It corroborates the experimental results both for QIP single photon QD sources and MEG solar cells and suggest that the effective dielectric constant play the prime role in the formation of stabile and bound biexcitons. Bi-exciton energy was compared to excitonic one and the conditions for the entangled states was determined in GaN and InGaN QD as a function of QD size and in the entire visible spectra.

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Phase imaging with undetected light via off-axis holography

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Abstract. Quantum Imaging with Undetected Light (QIUL) utilizes the quantum correlations of photon pairs generated through spontaneous parametric down-conversion (SPDC) to obtain both amplitude and phase information of an object [1]. This technique allows for simultaneous illumination and detection across a wide spectral range, employing advanced detection technologies within the visible spectrum while examining the object at an unconventional wavelength. In this work, we present an experimental setup for QIUL that integrates Fourier off-axis holography with a hybrid-type induced-coherence nonlinear interferometer [2,3], combining Mach-Zehnder and Michelson interferometers to enable a broader range of angle tuning for both object and reference beams, thereby fully utilizing the capabilities of Fourier space [4,5]. Our approach in a wide-field configuration requires only a single shot to reconstruct the amplitude and phase data of an object, providing a compelling alternative to sequential multi-frame acquisition methods such as digital phase-shifting holography [6]. The image reconstruction process, illustrated in Figure 1, demonstrates how to extract amplitude and phase information from a single-photon hologram. A Fast Fourier Transform (FFT) of the hologram reveals the diffraction term containing object information, which is cropped and inverse Fourier transformed to yield a complex image from which amplitude and phase can be retrieved.

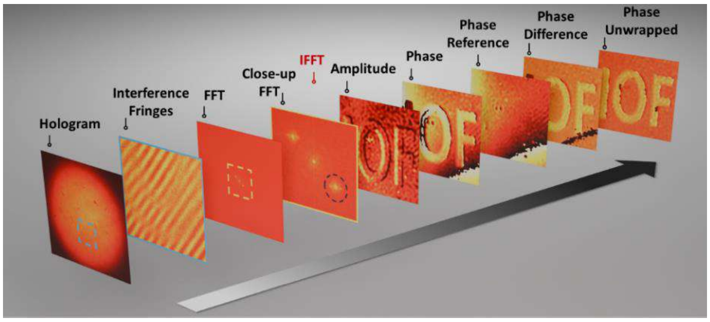

Fig. 1 Image reconstruction process, a sequence of steps used in Fourier off-axis holography are implemented together with the undetected photons scheme to reconstruct phase and amplitude information.

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Photoswitchable opto-Lab-on-a-Chip for real-time and label-free cell analysis via classical and quantum holographic imaging

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Abstract. Microfluidic lab-on-a-chip (LoC) devices, combined with 3D printing, hold significant potential for advancing the study of biophysical and biomedical processes, particularly by harnessing biophotonic technologies. These systems offer a breakthrough approach to investigate the inner workings of living cells in health and pathology such as in neurodegenerative diseases. In this context, we aim to develop a LoC device by comparing a novel quantum and a classical holographic microscope for real-time, label-free monitoring of cells by reconstructing their spatial shape. The chip prototype is fabricated using stereolithography for precise microchannel design and a molding replication process for scalability and reproducibility. Dimethacrylated Perfluoropolyethers (PFPEs-DMA), a class of UV-curable polymers with excellent antifouling properties, is used for the chip scaffold, helping to minimize non-specific biomolecule adsorption [1,2]. After a sealing step with high-refractive substrates (gold and/or silver), the PFPE-based device performance will also be compared with polydimethylsiloxane (PDMS)-based devices. The chip incorporates a reversible open chamber for cell culture compartmentalization, integrated with a dynamic perfusion system to ensure nutrient supply. The open channel configuration should guarantee easier access for future microscope coupling and cell imaging. Photoresponsive (sub)-microstructures [3] will also be integrated for effective cell compartmentalization, manipulation, and microfluidic operation. After assessing cell adhesion and viability, these cells will be characterized by the classical interferometric phase measurements exploiting the benchtop setup, foreseeing a potential miniaturization.

Our multifunctional microfluidic device was designed towards the stringent requirements of quantum imaging systems and will be coupled with a holographic quantum microscope in the framework of the BioQantSense project. A comparison between classical and quantum holographic imaging will give us the opportunity for the direct observation of limitations in the classical approach [3].

Quantum approaches can image without direct detection of the photons interacting with the cells and can eliminate the need for a well-characterized reference beam, thereby enhancing the measurement sensitivity and the robustness of holography [4]. As a proof of principle, we foresee the use of fibroblasts and, later, astrocytes, as a primary in vitro culture model of brain-derived cells. Here, we aim to report on the project progress and discuss future perspectives. We envision the development of a downstream detection module that can track secretome biomarkers released by cells, paving the way to gain insights into the brain-periphery network.

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Modelling of THz quantum cascade laser dynamics

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Abstract. We report on our recent progress in modelling THz frequency quantum cascade laser [1] (QCL) dynamics, where we have considered regimes of passive mode locking using distributed saturable absorber [2] and configuration for laser feedback interferometry [3]. Carrier transport simulations are used for the extraction of parameters for the dynamical simulations. Localized wavefunctions are calculated by solving the Schrödinger-Poisson equation system using the first neighbour and tight binding approximations, together with the infinite period QCL consideration. The transport of electrons through the quantum well heterostructure is modelled by a density matrix approach [4] where all the relevant scattering mechanisms are described as perturbations with the Fermi-golden rule, using the wavefunctions and material parameters as inputs. In order to model passive mode locking we then solve Maxwell-Bloch equations using two approaches: (i) a full wave model and (ii) a model which has reduced numerical complexity by employing rotating wave approximation (RWA) and slowly varying envelope approximation (SVEA). Graphene saturable absorber interacts with the optical field via an intensity-dependent loss. For modelling laser dynamics under optical feedback we use effective semiconductor Maxwell-Bloch equations.

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Neutral-atom arrays for quantum computing and cavity QED

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Abstract. Arrays of individually trapped neutral atoms are arising as a new tool for applications ranging from quantum computing to precision spectroscopy. Using Rydberg interactions, high-fidelity quantum gates can be realized in such systems. I will discuss first steps towards quantum computation with error detection and correction, i.e. a transition to first circuits with logical qubits. I will also report on experiments where arrays of atoms are coupled to high-finesse optical cavities, enabling fast state detection, adaptive measurements and control, and the real-time observation of individual atomic-collisions events.

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Advancing the next generation of photonic systems using machine learning

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Abstract. The 2024 Nobel Prize in Physics underscores the growing influence of machine learning in diverse areas of physical science. In the field of photonics, machine learning is proving invaluable for tasks such as optimizing and designing fiber-optical communication systems, optical amplifiers, noise characterization of frequency combs, inverse design of photonic components, and quantum-noise-limited signal detection. In this talk, I will review notable applications of machine learning in photonics and explore future directions in this emerging field. Specifically, I will highlight its role in phase noise characterization of optical frequency combs, end-to-end learning for fiber-optic communication, and realization of programmable ultra-wideband Raman amplifiers. Lastly, I will introduce an exciting new application of machine learning: controlling nonlinear interactions in highly nonlinear waveguides.

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