BOOK of ABSTRACTS

XLV Max Born Symposium:

13th International Symposium

«OPTICS & ITS APPLICATIONS»

27 June – 1 July, 2025
Wroclaw, Poland

INTERNATIONAL YEAR OF
Quantum Science
and Technology

XLV Max Born Symposium:
13th International Symposium

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Symposium information & Book of abstracts

Edited by David Blaschke, Narine Gevorgyan and Lusine Tsarukyan

WROCLAW

2025

INTERNATIONAL YEAR OF
Quantum Science
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XLV Sympozjum Maxa Borna:
13. Międzynarodowe Sympozjum

« OPTYKA I JEJ ZASTOSOWANIA»

27 czerwca - 1 lipca 2025 r.
Wrocław, Polska

Informacje o sympozjum i księga streszczeń

Redakcja: David Blaschke, Narine Gevorgyan i Lusine Tsarukyan

WROCŁAW

2025

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The book includes the abstracts of reports submitted to the XLV Max Born Symposium: 13th International Symposium «Optics & its Applications» (OPTICS-2025). Abstracts printed as presented by authors.

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Program highlights

- ✓ *Public talks*
- ✓ *Plenary talks*
- ✓ *Invited talks*
- ✓ *Sectional presentations*
- ✓ *Poster presentations*
- ✓ *Student presentations (prize for the best talk)*
- ✓ *Lab tours*
- ✓ *Social events*

Topics

- ✓ *Quantum optics*
- ✓ *Quantum Information*
- ✓ *Biophotonics*
- ✓ *Optical properties of nanostructures*
- ✓ *X-ray optics and applications*
- ✓ *Beam optics*
- ✓ *Strong field optics*
- ✓ *Spectroscopy*
- ✓ *Nonlinear & ultrafast optics*
- ✓ *Fiber optics*
- ✓ *Integrated photonics*
- ✓ *Optical design*
- ✓ *Optical sensing*
- ✓ *2D materials*
- ✓ *Nanophotonics*
- ✓ *Laser dynamics*
- ✓ *Singular optics*
- ✓ *Mathematical methods in optics*

Symposium Venue

27 June

Rzewuski hall

Institute of Theoretical Physics,
Faculty of Physics and Astronomy
University of Wroclaw
pl. M. Borna 9, 50-204 Wroclaw, Poland

28 June

Oratorium Marianum

University of Wroclaw
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29 June

DSF hall

Institute of Theoretical Physics,
Faculty of Physics and Astronomy
University of Wroclaw
pl. M. Borna 9, 50-204 Wroclaw, Poland

30 June

Main Hall

Institute of Low Temperature and Structure Research of PAS
ul. Okolna 2, 50-422 Wroclaw, Poland

1 July

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Acknowledgement

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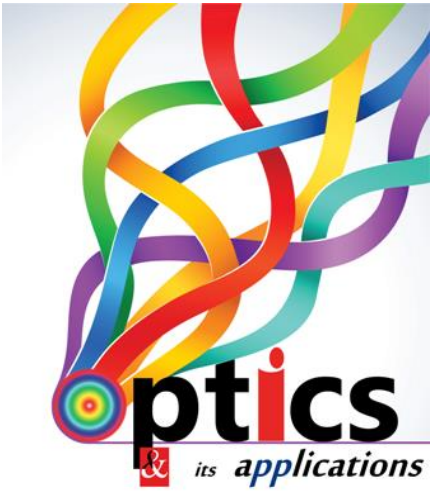
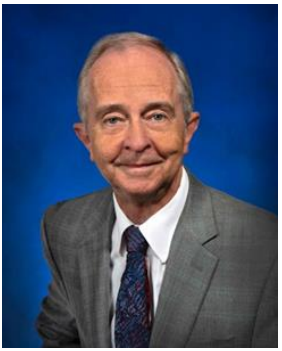
Public Lecturers





Berndt Mueller

Duke University, Durham, USA

The Quark-Gluon Plasma Story: From Speculation to Search, Discovery and Surprises

With the advent of multi-billion dollar research facilities in nuclear and particle physics the need arose for a compelling programmatic justification and research strategy. A critical analysis of the success of this strategy upon completion of the program can hold valuable lessons for future research projects of comparable scale. In my colloquium I will attempt such a comprehensive analysis of the research program of the Relativistic Heavy Ion Collider (RHIC), the first billion-dollar scale facility primarily dedicated to nuclear research. I will describe the original strategy and review where the proposed research program succeeded, where it fell short and where unsuspected discoveries contributed to its success. In the final part of my lecture I will discuss how the process has been formalized and applied to the Electron-Ion Collider, the next large-scale nuclear physics facility in the United States.

Constantino Tsallis

Brazilian Center for Physical Research,
Rio de Janeiro, Brazil

Entropy – Measuring the uncertainty

Energy has to do with the possibilities of the physical system, while entropy has to do with the probabilities of those possibilities. The former emerges in mechanics and electromagnetism, which are directly empirical sciences. The latter emerges in thermodynamics and statistical mechanics, which are more abstract sciences.

In this lecture, Constantino Tsallis will elaborate on these issues, and illustrate their usefulness in both simple and complex natural, artificial and social systems. For example, the algorithmic use of appropriate entropies can sensibly help increasing the number of true positives and decreasing the number of false positives in medical
diagnosis.

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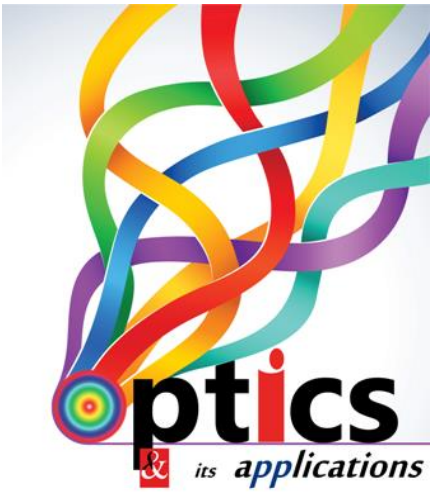
Plenary speakers



Ebrahim Karimi

Nexus for Quantum Technologies, University of Ottawa, Canada

National Research Council of Canada, Ottawa, ON, Canada

Institute for Quantum Studies, Chapman University, USA

Quantum Imaging from Bi-photon States Reconstruction to Object Recognition

Quantum entanglement lies at the heart of many foundational questions in quantum mechanics. It offers significant advantages in quantum technologies and plays a key role in achieving quantum supremacy. Structuring and precisely measuring high-dimensional entangled states, such as biphoton states, is essential for characterising the spatial properties of quantum sources. These states are essential in enhancing sensitivity for detecting small incoherent displacements in quantum imaging, preparing complex initial states for quantum simulators, and advancing quantum key distribution (QKD) protocols since they provide access to unbounded Hilbert space.

I will provide an overview of this exciting field, highlighting recent advancements and discoveries, including our recent work on quantum imaging of biphoton states and their use in quantum imaging and high-dimensional quantum information processing, which we achieved over the past several years.

Igor Meglinski

Aston Institute of Photonics Technologies, Aston University, Birmingham, UK

College of Engineering and Physical Sciences, Aston University, Birmingham, UK

Spinning Through Scattering: Wavefront Dynamics and Angular Momentum Conservation

Igor Meglinski[1,2], Ivan Lopushenko[3], Anton Sdobnov[3], Alexander Bykov[3]

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[2]College of Engineering and Physical Sciences, Aston University, Birmingham, UK
[3]Optoelectronics and Measurement Techniques, University of Oulu, Oulu, Finland

We explore the potential of structured vortex laser beams, also known as shaped light with orbital angular momentum (OAM), for the diagnosis of cells and cell cultures, as well as for the quantitative characterization of biological tissues. The structured vortex beams contain a spin contribution, conditioned by the polarization of the electromagnetic fields, and an orbital contribution, related to their spatial structure. When the shaped light propagates in a homogeneous transparent medium, both spin and orbital angular momenta are conserved. In order to study the conservation of spin and orbital angular momenta of the shaped light propagation in a homogeneous transparent medium, we have built a Mach-Zehnder-like interferometer featuring a spatial light modulator (SLM) for generating Laguerre-Gaussian (LG) light beams with different momenta. The LG beam passes through a tissue sample, and the interference with the reference plane wave is detected on the camera. We

demonstrate that when the LG beam propagates through normal and cancerous tissue samples, the OAM is preserved, accompanied by a noticeably different phase shift and twist of light. We also demonstrate that the twist of light is up to ~ 1000 times more sensitive to the refractive index changes within the tissue samples and, therefore, has a high potential to revolutionize the current practices of tissue diagnosis, e.g., histology examination. The results of our experimental studies are in good agreement with those obtained using the newly developed in-house Monte Carlo code [1-3]. In conclusion, the application of OAM in biomedical diagnostics offers promising opportunities for both innovative fundamental research and practical clinical applications.

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Tatiana Novikova

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Perspectives on using imaging Mueller polarimetry for biomedical applications

The screening, prevention, and treatment of serious health conditions - longstanding priorities in biophotonics research - have seen significant advancements in recent years, driven by population aging and the growing demand for accessible and reliable diagnostic technologies. One promising emerging approach consists of using multi-wavelength imaging Mueller polarimetry (IMP) as an optical diagnostic tool for tissue characterization and diagnosis [1].

Biological tissues possess three primary polarization-altering properties: diattenuation, birefringence, and depolarization, that yield valuable diagnostic insights. Each of these properties reveals specific aspects of tissue composition and structural organization. As tissue microstructure is frequently altered by pathological changes, polarimetric images typically demonstrate an enhanced contrast between healthy and diseased regions compared to unpolarized intensity images [2, 3].

Although IMP modality has already shown strong potential for accurate, non-contact, and cost-effective optical tissue diagnosis across a range of fields, including gastroenterology, gynecology, neurosurgery, and digital histology, several key challenges remain to be addressed. Ongoing research is focused on developing compact, user-friendly, and reliable polarimetric imaging systems, advancing next-generation IMP technologies capable of real-time imaging in clinical environments and improving

computational models for accurate diagnostic segmentation of polarimetric data [4].

Recent advancements and future perspectives for translating this technique into clinical practice will be discussed, along with its potential contributions to improved health risk management.

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Invited speakers

Optics & its applications

Humberto Cabrera

Mlab, STI, The Abdus Salam International Centre for Theoretical Physics, Trieste 34151, Italy

Ultrasensitive Photothermal Characterization of Thermoplasmonics Nanoparticles for Efficient Cancer Phototherapy

Humberto Cabrera[1], Ahmed Alsadig[2], Xuan Peng[2], Liliana R. Loureiro[2], Anja Feldmann[2], René Hübner[3],Manja Kubeil[1], Michael Bachmann[1], Larysa Baraban[1]

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In this work, we developed thermoplasmonic nanoconjugates consisting of 20 nm spherical gold nanoparticles (AuNPs) or gold nanostars (AuNSs) as nanocarriers, and (ii) surface-passivated antibody-based fibroblast activation protein (FAP)-targeting modules, used in adaptive chimeric antigen receptor T-cells immunotherapy [1]. The nanoconjugates demonstrated excellent stability and specific binding to FAP-expressing fibrosarcoma HT1080 genetically modified to express human FAP, as confirmed by fluorescence activated cell sorting, immunofluorescence, and surface plasmon resonance scattering imaging. Moreover, the nanocarriers showed significant photothermal conversion after visible and near-infrared irradiation. Quantitative thermal lens spectroscopy demonstrated the superior

photothermal capability of AuNSs, achieving up to 1.5-fold greater thermal enhancement than AuNPs under identical conditions [2]. This synergistic approach, combining targeted immunotherapy with the thermoplasmonic nanocarriers, not only streamlines nanoparticle delivery, increasing photothermal yield and therapeutic efficacy but also offers a comprehensive and potent strategy for cancer treatment with the potential for superior outcomes across multiple modalities.

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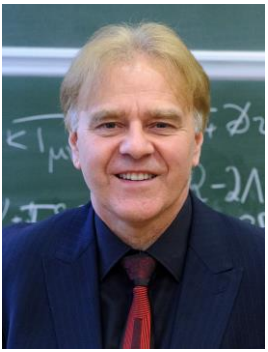

Mariusz P. Dąbrowski

Institute of Physics, University of Szczecin, Poland

Nonextensive Entropies as applied to Black Holes and Cosmology

A plethora of nonextensive entropies have been presented starting with famous Tsallis q-entropic statistics proposed around 35 years ago. All of them differ from the standard extensive and additive Boltzmann-Gibbs entropy and thermodynamics which does not take into account long-range interactions between the subsystems. Gravity is long-range and so it is expected to be nonextensive which makes nonextensive statistics being suitable to the description of black holes and the universe. The key achievement is the the Bekenstein-Hawking entropy which is nonextensive due to its scaling with the area and not with the volume.

During my talk I will review the properties of the nonextensive statistics (Tsallis, Tsallis-Cirto, Barrow, Renyi, Tsallis-Jensen, Sharma-Mittal, Kaniadakis) and show their application to black holes and their validity for the explanation of the dark energy phenomenon in the universe (holographic screens).

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Manuel Ferrer

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Bragging… a story of diffraction and unitary operations

Nicholas J. Sorensen[1], Michael. T. Weil[1], Arman Mansouri[1],
Manuel F. Ferrer Garcia[1], and J. S. Lundeen[1]

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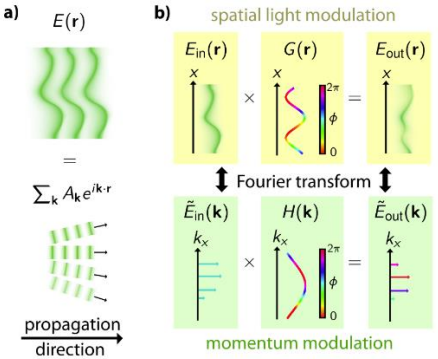
The ability to transform an optical field is fundamental to sensing, microscopy, telecommunication, and a myriad of other applications in optics. Typically, these transformations are performed by local optics elements, i.e. the output field at any position solely depends on the input field at the same position. Nevertheless, optical transformations using local optics are constrained to a subset of the generalized transformation. Here, we present the concept of momentum-space modulation as a platform to design and construct optical elements with nonlocal responses. In addition, we propose their implementation using superpositions of volume holographic gratings to realize arbitrary momentum-dependent transformations of light. We introduce an analytical framework for computing the spatially varying refractive index profile of a volume hologram from a target phase transformation. In addition, we introduce an experimental implementation for writing multiplexed volume holograms allowing us to generate non-local unitary operations.



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Rico Friedrich

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Designing Next Generation 2D Materials and Their Heterostructures

Two-dimensional (2D) materials and their heterostructures provide an extensive platform for realizing advanced electronic and magnetic functionalities at the nanoscale. While individual 2D systems are traditionally obtained from bulk layered compounds bonded by weak van der Waals (vdW) forces, the recent surprising experimental realization of semiconducting non-vdW 2D materials derived from non-layered crystals [1] opens up a new direction.

As outlined by our recent data-driven investigations employing autonomous ab initio calculations [2, 3], several dozens of new candidates showcase a wide range of appealing electronic, optical, and in particular magnetic properties owing to the (magnetic) cations at the active surfaces of the sheets. At the same time, chemical tuning by surface passivation provides a valuable handle to further control the electronic and magnetic properties of these next generation 2D compounds [4] (see Fig. 1). In addition, stacking these materials into non-vdW heterostructures leads to qualitatively new properties due to strong interfacial bonding [5]. As such, we observe hybrid interface bands, strong magnetic coupling, and significant variation of properties upon twisting the 2D components in the heterostructure. These features thus make non-vdW 2D materials and their heterostructures an attractive platform for fundamental as well as applied nanoscience.

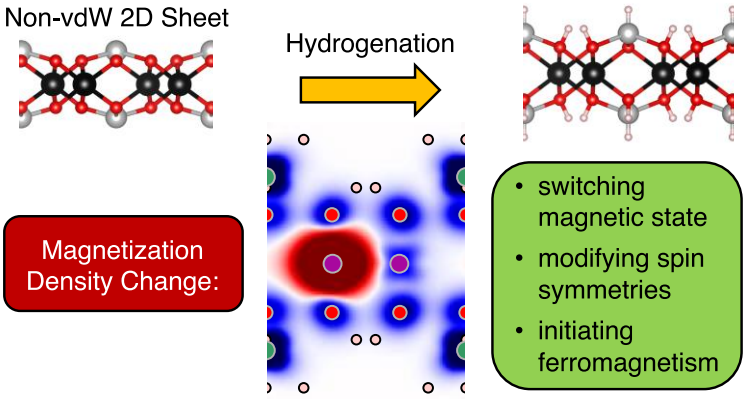

Figure 1: Overview of the surface passivation induced magnetic state control of non-vdW 2D materials due to hydrogenation.

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Florian Gahbauer

Laser Centre,
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University of Latvia,
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Creating and observing a hexadecapole moment in fluorescence in the Rb D1 system for magnetometry

Florian Gahbauer, Arturs Mozers, Daniela Jermacane, Marcis Auzinsh

University of Latvia, Faculty of Science and Technology, Laser Centre, Jelgavas Street 3, Riga, Latvia

Atomic vapour magnetometers can achieve exceptional magnetic field sensitivities near zero magnetic field by exploiting the Zeeman effect. However, for applications even in low magnetic field environments such as the earth's magnetic field, nonlinearities in the Zeeman effect can lead to heading errors [1]. The Rb D1 ground-state Zeeman sublevels whose z-component of the total angular momentum is $m_F=\pm2$ depend linearly on the magnetic field at all magnetic field values (see Fig. 1). Hence, coherences between these two states would be immune to the nonlinear Zeeman effect. However, creating such coherences is nontrivial, since one photon can create coherences between sublevels with $\Delta m=2$, which are related to the quadrupole polarization moment, but here $\Delta m=4$ coherences must be excited, which are related to the hexadecapole polarization moment. It has been shown that a hexadecapole moment can be created by exciting the atoms with short light pulses that are modulated at twice the Larmor frequency. This modulation creates both quadrupole and hexadecapole polarization moments. However, if after a period of pumping, the modulation is phase shifted by π, then, after an additional time of pumping, the quadrupole moment will suppressed, whereas

the hexadecapole moment continues to grow. The presence of a hexadecapole moment created in this way has been shown by polarization rotation measurements [1]. Here we investigate how the hexadecapole moment could be observed in fluorescence, which might be more sensitive or convenient in certain situations. We will present the results of theoretical calculations.

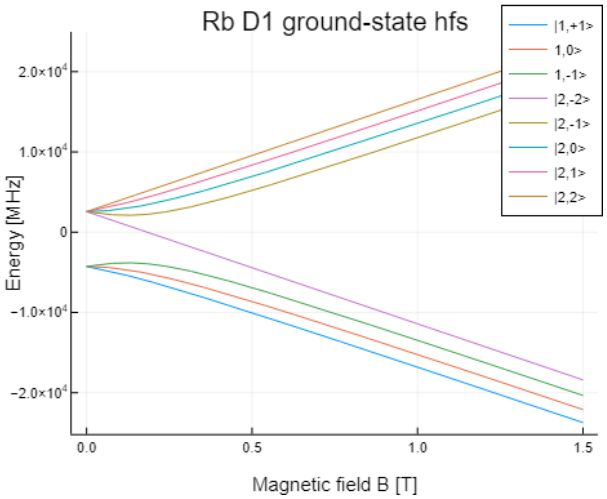

Figure 1. Zeeman splitting in the ground-state of Rubidium for F=1 and F=2.

We thank the Latvian Council of Science for support under Project No. Lzp-2023/1-0173 “Novel approach to improving accuracy and sensitivity of atomic Rb magnetometers.”

References

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Hermine Gharagulyan

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Institute of Physics, Yerevan State University, Armenia

Liquid Crystalline Nanosystems for Advanced Optoelectronics

Hermine Gharagulyan[1,2], Alexey Vasil'ev[1], Marina Zhezhu[1], Sara Gyozalyan[1], L. Avanesyan[1], V. Mehrabyan[1]

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[2]Institute of Physics, Yerevan State University, Armenia

Over the past decade, considerable effort has been directed toward the development and synthesis of two-dimensional (2D) hybrid and heterostructured materials, particularly those based on graphene-like materials and various 2D transition metal dichalcogenides [1, 2]. In this study, MoS_2–rGO nanostructures were synthesized using a hydrothermal and CVD methods. The chosen fabrication technique plays a crucial role in determining the electro-optical properties of MoS_2/rGO hybrids/heterostructures, providing valuable insights into their potential applications. These application prospects are further broadened by incorporating liquid crystals (LCs) or utilizing materials that form intrinsic LC phases. Notably, the integration of nematic LCs enhances the sensitivity and charge storage capabilities of the hybrid nanocomposites, as demonstrated based on chopped light voltammetry measurements. Additionally, the above-mentioned system reveals a photocurrent switching behavior induced by the nematic LC [3].

This work was supported by Grant No. 24LCG-2F027 of the RA MESCS Higher Education and Science Committee.

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Marek Gusowski

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Core-shell quantum dot nanostructures: How it's made?

A nanoparticle, a particle of the order of 1 to 100 nanometers (nm) in diameter, has found the applications in the last 20 years in a variety of fields of science, technology and medicine. A special group of nanoparticles is formed of semiconductor nanocrystals of a few nanometers' size, which is twice smaller than the exciton Bohr radius. They exhibit quantum confinement effects determining their electronic structure, making their optical and electronic properties fundamentally different from their bulk counterparts. Properties, like a size-dependent bandgap, surface-dictated charge quantum confinement effect in these nanometer-sized particles, which are usually referred to as quantum dots (QDs), allow for their application in the field of semiconductor optoelectronic devices, such as solar cells (SCs), photodetectors, light emitting diodes, field-effect transistors (FETs), and lasers. Among various colloidal QDs within infrared (IR) part of the radiation, PbS-based QDs are one of utmost importance due to their tunable IR bandgap in a wide range (800−3000 nm) as well as high photoluminescence efficiency in the range of telecom bands. Synthetic methods of PbS QDs have been well developed, and provide high quality samples with tunable optical properties. They become also commercially available with well-defined parameters. However, PbS QDs are very sensitive to the open air, which usually cause the degradation in properties and decrease of PL yields or even destruction of their optical properties. This unwanted feature can be remedied by protective cover of the nanoparticle by a suitably designed coat. The different approach to the coating methods and its effects will be presented on the example of PbS/CdS core-shell quantum dots.

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High Performance nanoscale Thermoelectric Single-Photon Detector

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Single photon detection plays a foundational role in a number of emerging applications, including quantum technologies, high-energy physics, astronomy, photonics, telecommunication systems, space communications, security, and medical devices. At present, superconducting nanowire single-photon detectors are utilized as a high-performance option in terms of efficiency, operation speed and bandwidth. However, such detectors require careful and deep cryogenic cooling, have complex architecture, and are expensive. At the same time, theoretical predictions and computer simulations indicate that thermoelectric detectors may offer single-photon detection with high performance.

In this study, we present the results of computer simulations on heat propagation processes within a multilayer detection pixel following single-photon absorption for different operating temperatures. Our findings indicate that a detection pixel consisting of a tungsten (W) absorber, a lanthanum-cerium hexaboride ($LaCeB_6$) thermoelectric sensor, and a molybdenum (Mo) heat sink can detect photons across a broad range of the electromagnetic spectrum, from near-infrared to near-ultraviolet - achieve a terahertz count rates (Figure 1), and generate a signal voltage on the order of microvolts.

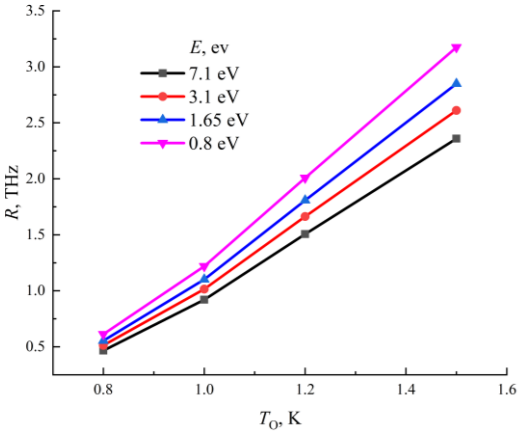

Figure 2. Count rate dependence on the detector's operating temperature

The advantages of thermoelectric single photon detector's detection pixel are its very simple design and absence of stringent requirements on the operating temperature. Such benefits pave the way for their potential use in large-scale cameras and optical chips. It can be argued that high-performance thermoelectric single-photon detectors may serve as an alternative to existing detectors.

This work was supported by the Higher Education and Science Committee of the Ministry of Education, Science, Culture, and Sport of the Republic of Armenia, in the frames of the research project №24WS-1C016 "Development of high performance and broadband nanoscale thermoelectric single-photon detector".

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Exploring the scattering of polarization-entangled photon pairs

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Non-invasive sensing and imaging techniques based on analysis of light intensity, phase, structure and correlations form the basis for modern optical biomedical diagnostics [1, 2]. Efficiency of the traditional solutions based on classical states of light is typically hindered by complex scattering processes and high optical losses. Modern studies leveraging quantum correlations attempt to overcome these obstacles. For example, non-classical states of light can provide improved sensitivity and enhanced accuracy of the measurement [3]. Our experiments unveil the potential of polarization-entangled states for quantitative characterization of scattering in tissue-mimicking phantoms [4]. Specifically, we study Bell state

$|\Psi^+\rangle = 1/\sqrt{2}(|H\rangle|V\rangle + |V\rangle|H\rangle)$ and propagation of one of its partner photons through a tissue-like medium. We investigate it experimentally using quantum state tomography [5] and describe it theoretically with a technique rooted in the iterative solution to the Bethe-Salpeter equation [6]. For the latter, we introduce a novel Monte Carlo model, which generalizes the well-acknowledged statistical description of light transfer through a scattering medium and expands it to follow the amplitude probability coefficients of constituent photonic states for all possible photon trajectories. We demonstrate that the developed approach allows to accurately predict the medium-affected photonic state (see Figure).

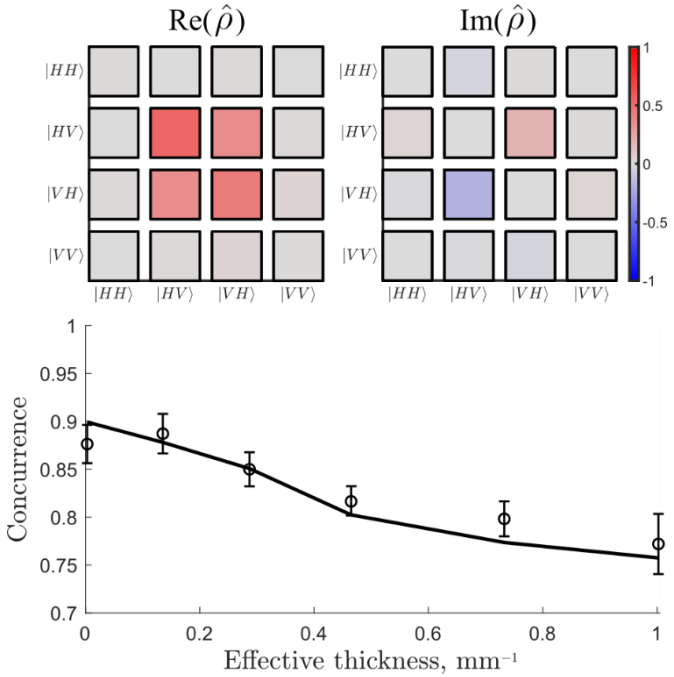

Figure: Real (Re) and imaginary (Im) components of the measured density matrix $\hat{\rho}$ for the phantom with unit effective thickness, followed by plot of simulated (line) and measured (circles) concurrence versus phantom effective thickness. Error estimation follows Ref. [5].

We studied a set of tissue-mimicking phantoms (300 μm thick) which exhibited different scattering properties characterized by the effective thickness (i.e. actual thickness divided by the transport mean free path) and

explored which properties of quantum states (e.g. concurrence) could be used for sensing purposes as monitoring parameters. The presented findings are expected to significantly enrich the fields of optical metrology and foster the enhancement of diagnostic technologies.

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Optical Vortices and Their Applications

Optical vortices belong to a family of optical singularities. The topic of optical singularities has become the subject of intensive research over the past 30 years. This lecture is intended as a brief introduction to the optics of optical vortices. I will begin by discussing their physical properties. In the second part, I will present methods for generating optical vortices, and in the third part, discuss their most important applications.

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Deep UV Raman Spectroscopy: Marked Vibrational Signatures in Chemicals and Biomolecules via Resonance

Resonance and Pre-resonance conditions in deep UV excitation enhance the Raman cross section of molecule vibrations and makes it possible to investigate the vibrational signals of the sample even in extreme dilution regime. Thanks to the marked increment of the detection limit due to the resonance enhancement and to the suppression of interfering fluorescence contributions, the Raman signals arising from both sample and solvent can be detected and analyzed. At the IUVS laboratory of Elettra Sincrotrone in Trieste, Italy, a range of advanced instrumental setups are dedicated to Resonance Raman spectroscopy, enabling the investigation of a wide array of complex systems. These include biomolecules such as viruses, proteins, and DNA; studies of the structural and dynamical properties of water; and the characterization of ionic liquids. The facility also supports interdisciplinary applications in both medical diagnostics and environmental monitoring. By leveraging the unique advantages of deep ultraviolet (DUV) excitation, these setups allow for enhanced sensitivity and specificity in detecting vibrational signatures, opening new avenues for molecular-level insights and practical innovations.

Ladislav Mista

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Angle and angular momentum - new twist for an old pair

Ladislav. Mišta, Jr., J. Řeháček, and Z. Hradil

Palacky University, Olomouc, Czech Republic

The talk will focus on building the theoretical foundations of quantum technologies using unorthodox pairs of complementary observables. Instead of the standard position and momentum or spin variables, we will consider angular momentum and the unitary shift operator in angular momentum of a quantum rotor. The development of the new theory involves proposing a new measure of uncertainty in the angular variable and unifying it with other measures based on an analogy with the moment of inertia, deriving appropriate uncertainty relations, finding the optimal simultaneous measurement of the complementary observables, and establishing the basis for a description of the rotator in phase space [1,2]. Finally, we also show that the new concepts can be practically used in optimal pulse shaping and detection at the quantum limit.

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Zhandos Moldabekov

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Linear-response time-dependent density functional theory approach to matter under extreme conditions

X-ray Thomson scattering (XRTS) measurements provides access to the dynamic structure factor (DSF) of electrons of materials in experiments. This methodology facilitates plasma diagnostics under extreme conditions characterized by high energy density and short temporal scales. Linear response time-dependent density functional theory (LR-TDDFT) serves as a vital ab initio method utilized for simulating the DSF [1,2].

This talk is focused on the application of LR-TDDFT in modeling XRTS, placing particular emphasis on the interpretation of experimental measurements and the prediction of novel features associated with the heating and/or compression of solids. We report thermally excited new signatures in isochorically heated solids, such as aluminum (Al) and silicon (Si) [3,4]. Additionally, we examine an alternative approach employing the Liouville-Lanczos technique for simulating the DSF [5,6]. This method eliminates the necessity for empty states, thereby enabling the assessment of the DSF at elevated momentum transfer values across a broad frequency range. To benchmark the Liouville-Lanczos approach against LR-TDDFT, we utilize exact path integral Monte Carlo results for the imaginary-time density-density correlation function.

The successful validation of the Liouville-Lanczos method constitutes a significant advancement within the realm of ab initio simulation techniques, thereby supporting experimental initiatives in the field of warm dense matter.

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Hadron production yields as a probe of the QCD phase boundary

We discuss the thermal origin of hadron production in heavy-ion collisions. We show that their yields are consistent with the QCD equation of state at the phase boundary. We consider specific properties of heavy-flavour hadron production and find new scaling properties of open-charm hadron yields in high-energy proton- and nucleus-collisions.

Mariusz Stefanski

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Effect of rare earth ion doping on the spectroscopic properties of three-dimensional inorganic halide perovskites obtained in powder form

Mariusz Stefanski[1], Bartosz Bondzior[1], Maciej Ptak[1], Adam Sieradzki[2], Eunika Zielony[2], Wieslaw Strek[1]

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Inorganic halide perovskites have been known in the literature for several decades. Nevertheless, they attracted real interest in 2015, when Kovalenko and co-workers reported the synthesis of nanocrystalline colloidal inorganic halide perovskites with the general formula $CsPbX_3$ (X = Cl, Br, I) [1]. Since then, the growth of scientific publications on these compounds has been tremendous. It is noteworthy that the vast majority of papers available in the literature consider nanocrystalline colloids obtained by various methods, studied from different aspects. Here, structural and spectroscopic results on larger analogs of inorganic perovskites characterized by micrometric grain size will be presented. In particular, the phase purity of materials obtained by the solid-state reaction method will be demonstrated, and the effect of doping on morphology and optical properties will be shown. Perovskites reveal a very broad and intense

absorption band, which, depending on the composition, ranges from the ultraviolet to 400 nm and 500 nm for chlorides and bromides, respectively. Excitation of the host with a laser diode operating in the UV range results in the generation of two luminescent centers in different spectral ranges. It was found that perovskites obtained using the dry chemistry technique exhibit much better-structured dopant emission bands and reduced luminescence quantum efficiency relative to their nanocrystalline colloidal analogs. The latter suggests that a different energy transfer mechanism is responsible for the observed optical effects in powdered inorganic halide perovskites.

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Dynamic control of spatial coherence via superposed vortex lattices

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Spatial coherence refers to the correlation between two points of the optical field and becomes an important feature to study interference, field propagation, or light-matter interactions. Thus, the ability to control the degree of spatial coherence becomes crucial for various applications, including optical trapping [1], imaging [2], or communication [3].

The most common method for controlling spatial coherence is to utilize a rotating ground-glass diffuser, which produces a series of speckle fields when spinning. The degree of coherence can therefore be adjusted by controlling parameters such as the beam's diameter at the diffuser and the diffuser's grit [4]. Another approach reduces the spatial coherence by increasing the number of spatial modes that come out from the degenerate cavity laser. Adjusting the cavity or implementing additional amplitude filters [5] changes the number of spatial modes, thus reducing the spatial coherence.

In this work, we present a new method that allows for dynamically adjusting spatial coherence without the modification of the experimental setup,

as the adjustment does not require moving mechanical parts of the setup. For that, we utilized a spatial light modulator and created holograms that consist of superposed lattices of phase singularities [6]. We adjust their parameters such as lattice density and level of disorder to control spatial coherence. Through that, we digitally mimicked the effect of rotating a ground glass diffuser.

We present fundamentals of the hologram design process, numerical simulations, as well as results of the experiment, showing the flexibility of the developed methods. With that, we aim to pave the way to treating spatial coherence as another degree of freedom in laser beam shaping.

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Application of Photovoltaic Tweezers for 2D Trapping of DNA Molecules

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We report a novel approach for trapping DNA molecules on the surface of a photorefractive Fe-doped lithium niobate (LN:Fe) crystal. Illumination of the crystal by a milliwatt power nondiffracting optical Bessel beam (λ = 532 nm, periodicity of light-rings 40 μm) exerts a Bessel-like nonuniform 2D photovoltaic (PV) field inside and near the surface of the crystal through the PV effect [1]. The inner PV field forms a long-living concentric-ring refractive lattice with ~40 μm period inside the crystal. The alternating evanescent PV fields near the crystal surface generate strong dielectrophoretic forces capable of manipulating and trapping the uncharged micro- and nanoscale objects on the crystal surface, acting as PV tweezers.

In the experiment, DNA molecules from the calf thymus suspended in a 10^{-3} M NaCl buffer with a DNA concentration of 0.58 mg/ml were deposited on the LN:Fe surface. Using an optical phase microscope operating in transmission mode, we simultaneously observed the Bessel-like refractive lattice and the trapped DNA molecules. The DNA is registered as refractive index nonuniformities on the background of a Bessel lattice. Experiments

showed that the folded DNA molecules are localized predominantly at the borderlines of the concentric rings (Fig. 1), indicating that the effective trapping of DNA takes place due to the repulsive dielectrophoretic forces induced by the PV field. The negatively charged DNA molecules can form neutral random coils through screening by Na^+ counterions due to the dissociation of NaCl in distilled water. These random coils exhibit a nearly globular shape with an average size of ~4 μm. A physical model of the local PV field distribution was developed to explain the observed trapping mechanis.

This work demonstrates the applicability of PV tweezers for the spatial manipulation and trapping of DNA molecules on a crystal surface. This approach in combination with phase-sensitive detection offers a label-free visualization of the folded DNA molecules. In general, chip-scale PV tweezers are a light-powered platform for micro/nano-manipulation, with potential applications in biophotonics, biotechnology, and microscopy.

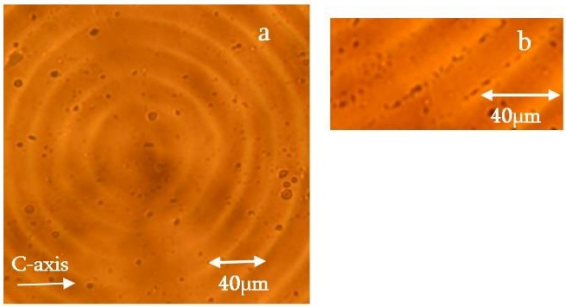

Fig. 1. Phase-contrast images of DNA on LN:Fe surface: (a) immediately after deposition, (b) 30 minutes later, showing trapping at Bessel ring borders.

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Exploring memory engram encoding through optical activation

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Recent decades have seen significant advancements in optical techniques for neuroscience investigation, achieving high temporal and spatial resolution, and cell specificity. Among them, Optogenetics enables cell excitation and inhibition by light, for precise manipulation of network activity in in-vivo and in-vitro systems [1]. We leveraged this technique to perform studies on memory formation and consolidation in the brain.

Traditional *in vivo* approaches in memory studies face the complexity of the brain, where millions of diverse cells interact, making it difficult to examine the specific contributions of individual cells or small circuits.

Conversely, *in vitro* techniques offer a highly controlled environment to investigate the fundamental mechanisms involved in the operation of the basic circuits involved in memory (*engrams*).

We developed a technique that combines digital light processing (DLP) with optogenetics to achieve precise control over neuronal activity. Selective excitation of neurons is achieved, with a precision ranging from cell ensembles down to dendritic spines. Leveraging this capability, we successfully generated small, distinct engram-like circuit modules [2]. This allowed us to directly investigate and emulate Hebb's postulate, the principle stating that synaptic connections between neurons are strengthened when those neurons are activated simultaneously [3]. By utilizing the Synactive labeling technique, we were able to identify, and track strengthened spines between active neurons combining Arc mRNA targeting elements with a protein tag for activity-dependent protein production in spines [4]. This enabled us to examine how a pattern of activity between neurons is established within the engram circuits, and to analyze the spatial arrangement of the potentiated synapses within the engram module. We are currently extending our work to perform *in-vitro* molecular analyses on memory consolidation mechanisms.

These methodologies hold significant promise for creating more accurate experimental models of memory storage and retrieval, opening the doors to a new understanding on the fundamental mechanisms driving the brain.

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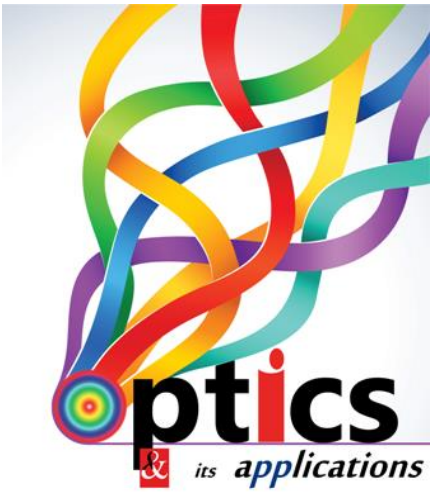

The green-emitting Eu^{2+} doped phosphates for application in white LEDs

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In recent years, white light-emitting diodes (WLED) have emerged as a one of the most important technologies in lighting applications, offering significant advantages over traditional lighting sources, such as lower energy consumption and longer lifespan. Common types of WLEDs include RGB, blue-light-excited, and UV-excited LEDs. Among these, UV-excited LEDs are particularly promising due to their potential advantages over traditional LED constructions [1]. Unlike blue-light-based WLEDs, UV-excited WLEDs typically exhibit higher color rendering index (CRI) and lower color temperatures (CCT). The goal is to achieve a high CRI of 100, for which the illuminated colors appear as they would under natural sunlight [1, 2]. Furthermore, UV-excited WLEDs do not produce intense blue light emission, which can disturb circadian rhythm and melatonin production [3].

The fundamental element of every WLED is a luminescent phosphor material doped with rare earth ions or transition metals. The development of new phosphor should consider factors such as excitation spectrum compatibility with LED sources, high quantum efficiency, thermal stability and short photoluminescence lifetimes to minimize saturation at high excitation intensities. Additionally, these materials should be easy to manufacture, non-toxic, and made from inexpensive, available precursors [1].

In this work, Eu^{2+} doped $Ca_2Sr(PO_4)_2$ phosphor is presented, which was synthesized via a simple solid-state technique. The material structure is representing a *R3cH* space group and no additional phases was detected as confirmed by powder XRD analysis. The Eu^{2+} ions can occupy four Ca^{2+} sites in the material, resulting in multiple overlapped emission peaks in the 400 nm up to 700 nm range. The maximum emission peak under 350 nm excitation is observed at around 505 nm. The highest quantum yield was achieved for the lowest 0.1% Eu^{2+} concentration, reaching 33%.

In conclusion, the spectroscopic properties of this material make it promising in WLEDs application.

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Bayesian Equation of State Inference using Data from Pulsar Observations with X-ray Optics

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Precise measurements of neutron star properties are essential for investigating ultra-dense nuclear matter present in the cores of compact stars. A crucial role in these astrophysical observations is played by X-ray optics, with instruments such as Chandra, XMM-Newton, and NICER enabling detailed studies of neutron star emission that were previously unattainable. Building on these observational advances, Bayesian inference techniques are employed to translate mass-radius measurements into probabilistic constraints on the neutron star EoS. In particular, we demonstrate an approach that enables the extraction of constraints on coupling constants in models of strongly interacting matter.

Subdiffraction imaging with highly-nonlinear photon avalanching nanoparticles

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Lanthanide ions doped inorganic nanoparticles (LnNP) are potential candidates and alternative labels to fluorescent molecules and quantum dots. Among the other, they display narrowband absorption and emission lines, multicolour emission, long luminescence lifetimes and are perfectly photostable. In sensitized configuration, they are also capable to efficiently convert NIR excitation to visible range (so called upconversion UC), thus avoiding background fluorescence and enhance signal to background ratio towards super-sensitive biosensing & imaging. They also display non-linearity of luminescence intensity versus pump intensity, which enables imaging beyond diffraction limit with simple, customized confocal setups.
Among upconversion processes leading to the anti-Stokes emission, the photon avalanche (PA) became an interesting research topic since 1979, when it was first observed in Pr^{3+} doped $LaCl_3$ [1]. There are several essential requirements necessary to enable observation of PA in a given system – these include (i) the presence of efficient ESA transition and negligible GSA at the pumping wavelength and (ii) the presence of efficient the cross-relaxation (CR) processes required to populate intermediate excited level. As a consequence, the luminescence intensity of PA increases by several, typically 2-3 orders of magnitude when exciting with power density slightly (e.g. twice) above the PA threshold. Only recently its PA emission was also demonstrated for $NaYF_4$ nanoparticles doped with Tm^{3+} at the room temperature under 1064 and 1450 nm photoexcitation and 800 nm emission [3].

In this lecture, short state-of-the-art on PA emission and the PA emission in nano, micro and bulk $LiYF_4$ crystals will be summarized aiming to show the wide application potential of PA (e.g. super-resolution imaging [3], biosensing [4], nano-thermometry [5] etc.). Special attention will be given to subdiffraction imaging using highly non-linear photon avalanching luminescent colloidal nanoparticles.

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Balancing self quenching and resonant energy transfer efficiency in highly Tm^{3+} doped upconverting nanoparticles for multicolour upconversion FRET sensing

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Upconverting nanoparticles (UCNPs) have emerged as promising alternative donors for Förster Resonant Energy Transfer (FRET)-based biosensing due to their efficient anti-Stokes emission under near-infrared excitation and narrow absorption and emission bands, resulting in the elimination of background signal and spectral cross-talk. Upconversion-FRET (UC-FRET) has found applications in pH or ion sensing and immunoassays.[1] However, it suffers from several limitations, including the weak susceptibility of donor lifetimes to acceptor presence, short Förster distance ~3 nm, and the relatively large size of UCNPs, which results in donor ions being distributed at varying distances from surface-bound acceptors. Although numerous chemical design strategies and modeling approaches have been proposed, the existing studies have only quantitatively clarified the influence of UCNP composition and architecture on luminescence energy transfer efficiency.[2][3] Moreover, rarely multicolour FRET is discussed. To address these challenges, we synthesized UCNPs with a core@shell structure consisting of a Yb^{3+}-doped core and a Yb^{3+},Tm^{3+}-doped shell with varying thulium concentrations. The nanoparticles were functionalized with organic ATTO dyes to enable FRET efficiency measurements. We found that a 4% Tm^{3+} concentration in the shell yielded the highest FRET efficiency among all tested compositions, indicating that increasing donor ion concentration can enhance energy transfer, even when overall nanoparticle brightness is not maximized. Moreover, Tm^{3+} ions offer a broader spectral gap (~480–650 nm) compared to Er^{3+} (~550–650 nm), making them more suitable for multiplexing, which we have demonstrated by distinguishing between different ATTO dyes based on their emissions at separate wavelengths. Our results offer a strategy for improving UC-FRET sensitivity through donor concentration tuning, providing new insights into the rational design of more efficient, multicolor biosensing platforms.

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Spectroscopic investigation of Cr valence effects on YAG ceramics structure and defects

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Chromium-doped transparent ceramics are of increasing interest in optical applications due to their potential in laser systems and luminescent devices. In particular, yttrium aluminum garnet (YAG, $Y_3Al_5O_{12}$) doped with Cr exhibits promising optical properties, which are strongly influenced by the valence state (III or IV) of the dopant and the structural quality of the host matrix. Point defects, including oxygen vacancies and lattice distortions, can significantly affect performance by introducing trap states that mediate non-radiative processes or enable persistent luminescence [1].

In current work, Cr-doped YAG ceramics containing chromium in different oxidation states were investigated to understand the interplay between structural modifications and trap dynamics. A comprehensive structural and defect analysis was conducted using Raman spectroscopy, Fourier-transform infrared spectroscopy (FTIR), and thermoluminescence (TL) techniques. Raman spectroscopy revealed distortions in the YAG lattice associated with changes in chromium valence, while FTIR analysis provided complementary information on the local bonding environment and defect-related vibrational modes.

Thermoluminescence measurements, performed after X-Ray and UV (266 nm) irradiation at varying doses and heating rates, enabled the identification of trap levels and their thermal stability. These results allowed us to correlate chromium-induced structural changes with trap formation and energy storage capacity in the material. The observed dependence of trap characteristics on chromium valence suggests mechanisms of electron capture and recombination relevant for both optical memory and long-persistence emission.

This work was supported by Polish National Science Centre, grant OPUS 23 Nr. UMO-2022/45/B/ST5/01487.

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Unraveling the Cr^{4+} Formation Process in Garnets Using Spectroscopy

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The demand for self-Q-switched lasers caused a growing interest in Cr^{4+}:YAG materials. However, the main problem of Cr^{4+}:YAG is an insufficient concentration of Cr^{4+} ions. This problem is complicated by the absence of the adequate model describing formation of Cr^{4+} ions. Analysis of the temperature dependence of Cr^{3+} luminescence in the Cr-doped YAG ceramics after different thermal treatments allows understanding the mechanism of Cr^{3+}-Cr^{4+} valence transformation. Two types of Cr^{3+} centers with different spectroscopic properties were revealed in the Cr,Ca-doped YAG ceramics, namely, single Cr^{3+} ions, and Cr^{3+}/$[Ca'_C \ldots V^{\bullet}_O]$ couples (Fig. 1). Using the obtained spectroscopic data, a model of formation of Cr^{4+} ions in YAG lattice was proposed [1]. This work was supported by the Polish National Science Center, grant: OPUS 23, UMO-2022/45/B/ST5/01487.

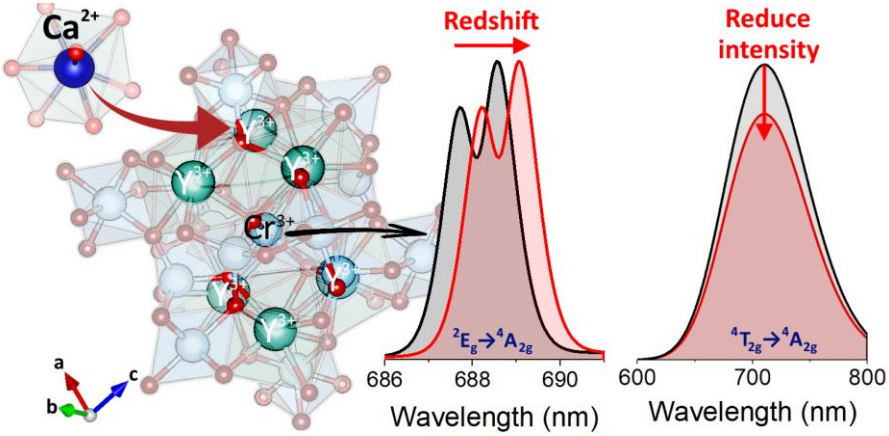

Fig. 1: Schematic illustration of the nephelauxetic effect. Substitution of Y^{3+} ions in NNN octahedral environment of $Cr^{3+}(Al^{3+})$ center (C_{3i}) by large Ca^{2+}

ions leads to enhancement of the nephelauxetic effect for $(CrO_6)^{9-}$ active center that red-shifts the R-lines.

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Quantum Phase Imaging via Diffraction of Correlated Bi-photon states

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High-dimensional biphoton states are promising resources for quantum applications, ranging from high-dimensional quantum communication to quantum imaging. A key challenge is fully characterizing these states, which is typically time-consuming and not scalable when using projective measurement approaches. Fortunately, advancements in camera technology allow for recording the position and time of arrival of photons with nanosecond resolution, enabling new techniques for reconstructing strongly correlated two-photon states [1,2]. This innovation significantly enhances both the efficiency and accuracy of quantum state tomography. By combining entangled state generation with these reconstruction techniques, we can characterize a quantum state as it propagates through a sample, allowing us to characterize the transmission function of the sample itself. Here, we demonstrate that, when a phase object is placed in the image plane of the source, diffraction through the sample can be extracted from the correlations between the two entangled photons. Moreover, by applying phase-retrieval algorithms, we achieve a twofold enhancement in phase reconstruction due to the two-photon nature of the source [3].

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Many-body effects in field emission from arrays of carbon nanotubes

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Field electron emission (FEE) from carbon nanotubes (CNTs) is a crucial tool in electron microscopy, offering stable, low-energy electron beams. Despite experimental advances, a theoretical framework describing low-energy field emission is currently unknown, primarily due to the unavoidable, correlated behavior of one-dimensional (1D) materials. This work aims to develop such a theoretical formalism.

We propose a theoretical formalism based on Tomonaga–Luttinger liquid (TLL) theory, which captures the collective behavior of electrons in 1D systems. We extend the Fowler–Nordheim theory to include TLL effects in local density of states (LDOS) and the tunneling amplitude, enabling the study of electron-electron interaction and temperature effects on FEE.

Furthermore, we present a model for calculating TLL parameters in multiwalled nanotubes (MWNTs), accounting for inter-shell interactions and the distribution of conductive channels among coaxial shells. These results provide a unified framework for understanding FEE from CNTs, with clear predictions that can be validated experimentally.

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Seeing Spins with Light: Optically Addressable NV Centers for Quantum Sensing

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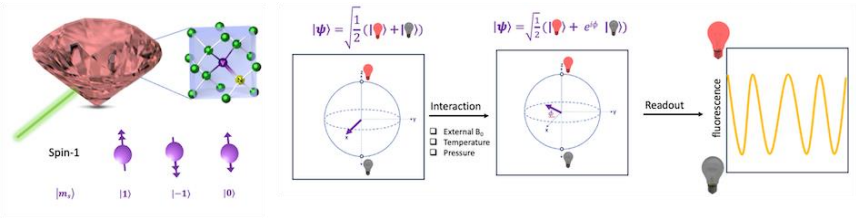
This talk presents our ongoing work on NV-diamond-based quantum sensing at the Center for Quantum and Topological Systems (CQTS) at NYU Abu Dhabi, with a focus on optical techniques for spin state readout and signal enhancement. Nitrogen-Vacancy (NV) centers in diamond are point defects that serve as atomic-scale quantum sensors, offering remarkable sensitivity to magnetic and electric fields, temperature, and strain [1,2]. These color centers exhibit spin-dependent fluorescence under green laser excitation, enabling optical initialization and readout of their quantum state even at room temperature.

At the core of our experimental approach is Optically Detected Magnetic Resonance (ODMR), a technique that uses changes in NV center fluorescence to measure shifts in spin transitions, revealing information about the surrounding environment [3]. We are currently building a custom NV-based sensing setup, which involves laser excitation at 532 nm, microwave control of spin transitions, and efficient fluorescence detection via optical filters and photodetectors.

Our work conducted in collaboration with Prof. Dominik Bucher at the Technical University of Munich (TUM) aims to optimize the optical alignment, fluorescence collection efficiency, and stability of the system for robust quantum sensing applications. We explore methods to enhance contrast in ODMR spectra, increase sensitivity, and suppress background noise, which are critical for real-time, high-resolution measurements. These efforts lay the foundation for emerging applications in nanoscale magnetometry, bioimaging, materials characterization, and lab-on-a-chip sensing technologies [4,5].

This presentation will give an overview of the NV center's optical properties, practical design considerations in setting up an ODMR experiment, and the broader role of photonics in quantum sensing. We will also discuss future directions toward integrating NV-based sensors into compact, scalable platforms for interdisciplinary applications in physics, biology, and engineering.



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Real-time luminescent thermometry of hybrid perovskites containing Cr^{3+} ion

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Metal-organic frameworks (MOFs) featuring perovskite-like architectures have emerged as promising materials due to their distinctive structural flexibility, lattice dynamics, and optical behavior [1]. Among these, a luminescence that varies with temperature is particularly interesting, especially in the rapidly developing field of luminescent thermometry [2].

In this work, we investigate the series of hybrid perovskites $[DMA]M^{II}_{1-x}Cr_x(HCOO)_3$, where $M^{II} = Zn^{2+}$, Mn^{2+}, or Mg^{2+} and x = 0, 0.01, 0.03, 0.05, as promising materials for use in highly sensitive optical thermometers. The incorporation of Cr^{3+} ions introduces distinct luminescent characteristics that are highly dependent on the composition of the host lattice. The dominant emission type of Cr^{3+} ions, narrow $^2E_g \rightarrow {}^4A_{2g}$ or broad $^4T_{2g} \rightarrow {}^4A_{2g}$ is governed by the crystal field strength (Dq/B). Due to the significantly higher contribution of the narrow emission from the ^2E_g level and following Stokes lines, the determination of the thermometric model has been performed by the ratiometric analysis of ^2E_g and one of the Stokes line intensities. The obtained results show the extraordinary potential of such an approach. The feasibility of fast acquisition and simplified processing makes these materials highly attractive for real-time thermal sensing.

The presentation will highlight the correlation between crystal structure, chemical composition, and luminescent performance in the $[DMA]M^{II}_{1-x}Cr_x(HCOO)_3$ system. Special attention will be given to the potential of these materials for application in real-time, luminescence-based temperature monitoring.

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Hybrid AI for Multimodal Analysis of Bioluminescence Imaging Using Local Language Models and Numerical Signal Processing

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Analyzing complex scientific datasets often requires fusing diverse modalities—such as raw image sequences and kinetic measurements—to uncover subtle patterns hidden within noise. We introduce a hybrid AI framework that integrates advanced numerical signal processing with local large language models (LLMs), enabling automated, context-aware interpretation of multimodal data. The system performs real-time tasks, including region segmentation, denoising, and temporal pattern recognition, while the LLM provides adaptive reasoning based on domain-specific context. Designed to operate entirely offline, the architecture ensures data privacy, low latency, and suitability for sensitive research environments. We demonstrate its effectiveness in preclinical studies using low-signal bioluminescence imaging, where combining imaging and kinetic data significantly improves interpretability and analytical throughput. This approach offers a scalable, intelligent solution for domain-driven analysis across biomedical and scientific applications.

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When Two (Infrared) Beams Are Better Than One: Controlling Emission in Thulium-Doped Upconversion Nanoparticles

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Upconversion nanoparticles (UCNPs) are luminescent materials capable of absorbing low-energy radiation (e.g., near-infrared) and emitting higher-energy photons in the visible range [1]. This process, known as *energy transfer upconversion* (ETU), involves photon absorption by sensitizer ions (Yb^{3+}), followed by energy transfer to activator ions such as Tm^{3+} or Er^{3+} [2].

Typically, a single excitation source is used—most often a 970–980 nm laser that excites the Yb^{3+} ions. In our work, we propose a dual-excitation strategy involving both indirect excitation (via Yb^{3+}) and direct excitation (via Tm^{3+}), using two beams: a 975 nm laser and a tunable beam in the 1050-1875 nm range.

Spectroscopic analysis identified two broad absorption bands for Tm^{3+} at 1213 nm and 1732 nm. Exciting these bands alongside the 975 nm source resulted in a dramatic enhancement of the 800 nm emission—up to a 1000% increase or the emergence of emission from near-zero levels. This nonlinear response, termed **surplus emission**, indicates strong photophysical synergy between the excitation channels.

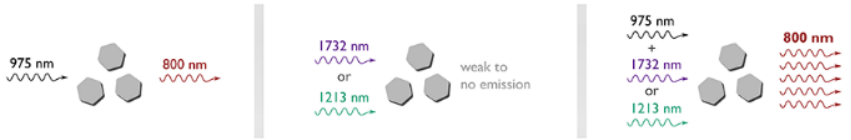

Fig. 1. Conceptual diagram of co-exciting Tm^{3+}-doped nanoparticles using a 975 nm beam and an additional NIR beam. The 975 nm laser alone produces

power-dependent emission at 800 nm. The selected NIR wavelengths alone yield no signal, but their combination results in a strong emission enhancement.

Crucially, this effect allowed us to visualize NIR radiation above 1700 nm—a range beyond the sensitivity of standard InGaAs detectors. Neither excitation source alone produced a measurable signal, but their combined use generated a distinct emission, confirming a **synergistic excitation mechanism**.

These findings highlight the potential of co-excitation for designing optical logic systems (e.g., AND gates) and light control. With optimized core-shell nanoparticle architectures and tailored wavelengths, co-excitation offers a powerful strategy for emission control in both scientific and technological contexts.

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Spatial-Mode Quantum Cryptography in a 545-Dimensional Hilbert Space

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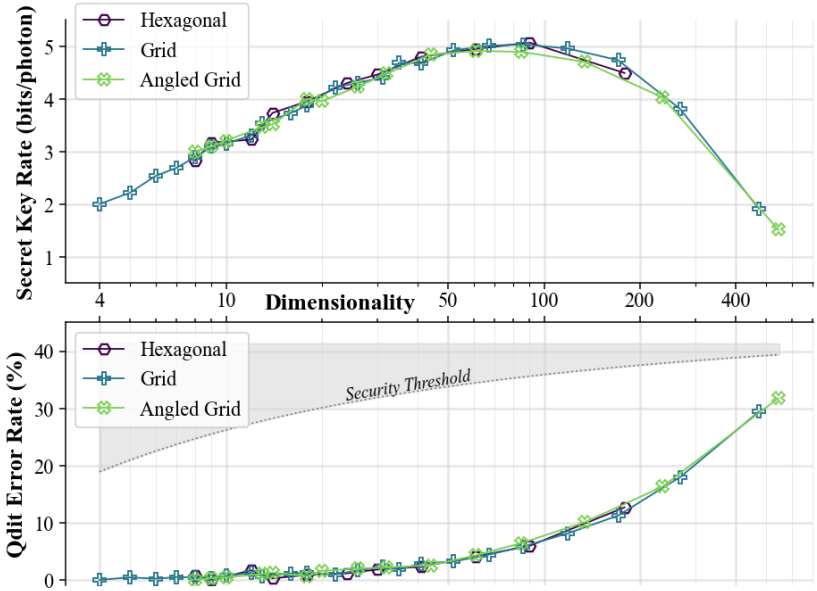
Quantum key distribution (QKD) enables information-theoretically secure communication, guaranteed by the fundamental principles of quantum mechanics. By leveraging quantum entanglement between two distant photons, QKD allows two parties to establish a shared secret key with provable resistance against both classical and quantum eavesdroppers. By going beyond a 2-dimensional encoding scheme, high-dimensional (HD) QKD protocols can allow for greater than one bit of information to be transmitted per photon even in noisy channels where 2-dimensional QKD would be impossible [1,2].

In this work [3], we report a QKD protocol operating in a 545-dimensional Hilbert space, the highest dimensionality yet achieved for spatial encoding in QKD. This experiment is also among the first to utilize position and momentum as complementary observables, exploiting their conjugate relationship to perform secure key exchange using mutually unbiased measurements. Our protocol combines features of both entanglement-based and prepare-and-measure approaches. Entangled photon pairs are generated via spontaneous parametric down-conversion (SPDC). Alice performs a passive projective measurement on her photon to remotely prepare the state of Bob's photon—streamlining state preparation. Detection is performed with time-tagging single-photon cameras, while the basis selection is implemented passively using beam splitters and lenses reducing the need for additional complex optical equipment.

We explore several spatial-mode configurations based on pixel sub-sampling and analyze performance across a range of dimensions in terms of both sifted key rate as well as the overall error rate, shown in the attached

Figure. In an optimized 90-dimensional configuration, we achieve an information density of 5.07 bits per photon. Even in the full 545-dimensional case, we observe a positive key rate despite increased crosstalk, demonstrating the scalability of our approach. By combining record high-dimensional encoding with the operational simplicity of projective measurement and passive detection, our work offers a practical path toward scalable, high-bandwidth quantum communication.



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Experimental Characterization of Multimode Quantum Correlations Using Universal Invariants

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Quantum universal invariants of general multi-beam Gaussian fields are investigated through the framework of intensity moments. A method is proposed that uniquely links these invariants—including global and marginal purities—to measurable intensity moments, offering a practical tool for characterizing quantum correlations. This approach enables the identification of Gaussian states and reformulates the Peres-Horodecki separability criterion in terms of quantum universal invariants, thus making it accessible via experimentally observable quantities. The method is experimentally demonstrated using photon-number-resolved measurements on noisy symmetric 3-beam Gaussian states generated via spontaneous parametric down-conversion. The 1-, 2-, and 3-beam purities are expressed in terms of intensity moments up to sixth order, and the corresponding quantum invariants are determined. These allow for quantitative analysis of quantum correlations, including the identification of bipartite and tripartite entanglement. In particular, the coexistence of bi- and tripartite entanglement, as well as genuine tripartite entanglement, is observed and characterized in the generated states. This framework provides an experimentally viable and theoretically robust method for entanglement detection and state characterization in multimode Gaussian systems.

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Applications of Optics and Optoelectronics in Electromagnetic Compatibility (EMC)

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Electromagnetic Compatibility (EMC) is a field of science and engineering dedicated to ensuring the proper operation of electrical and electronic devices within their intended electromagnetic environment.
Traditional methods for ensuring EMC, such as filtering, shielding, and proper grounding, are primarily based on metallic (conductive) components.

Fiber optic and optoelectronic technologies represent a breakthrough in the approach to designing and testing systems for EMC. Their fundamental advantage is the use of photons as the information carrier instead of electrons. The transmission medium, an optical fiber is a dielectric.

Key advantages of optical technologies in the context of EMC:
Complete immunity to interference (EMI/RFI) Optical fibers are non-conductive, making them completely immune to electromagnetic and radio-frequency interference. No stray currents are induced in them, and they do not act as receiving or transmitting antennas.
Perfect galvanic isolation. Optical transmission provides excellent electrical separation between connected systems. This eliminates problems related to ground loops, potential differences, and electrical surges, which are common causes of failure in systems connected by copper cables.
Optical fiber does not carry electric current, it is not a source of electromagnetic fields. Consequently, it does not introduce additional disturbances into the environment.

The measurement environment, such as an anechoic chamber, must be free of unwanted conductive elements that could distort the controlled electromagnetic field. Fiber optics are indispensable in this context.

Signal transmission to and from the Equipment Under Test (EUT). The use of optoelectronic converters allows for the transmission of control signals to the EUT and the reception of data from it without introducing metallic cables that would act as antennas.

E-field and H-field modern probes for measuring electric and magnetic field strength are powered and read via fiber optic links. This ensures that the probe itself and its cabling do not perturb the field being measured.

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Poster Presentations

Up-conversion and luminescent properties of Pr^{3+} ions in CaF_2 microcrystals

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Ultraviolet UV radiation is used to combat dangerous diseases, including pandemics and various antibiotic-resistant infections in medical institutions [1]. The development of self-sterilizing surfaces based on stable ultraviolet (UV) emitting materials excited by visible light is driven by the need for surface disinfection without the use of UV lamps. Pr3+ ion is an effective luminescent activator, emitting light in the UV region through up-conversion (UC) processes, converting lower-energy radiation into higher-energy UV light [2]. Therefore different materials doped with Pr3+ ions are a promising candidate for application to sustainable disinfection technologies, including light-activated antimicrobial surfaces [3]. The CaF_2 crystalline matrix can be used as a host for Pr^{3+} ions due to its low phonon energy.

In our work, CaF_2:Pr^{3+} (0.02-2% Pr^{3+} ions) microcrystals were synthesized by the precipitation method and annealed at 800°C. The structural (X-ray diffraction) and optical (absorption; photoluminescence excitation, emission spectra in visible spectral range and life times of luminescence; Up-conversion emission by laser excitation at 444 nm) properties were investigated.

The X-ray diffraction of the CaF^2:Pr^{3+} microcrystals showed the formation of a calcium fluoride pure phase. The measurement of UC emission spectra of CaF2:Pr3+ microcrystals showed that the emission in the main is located in the ultraviolet-C (220-280 nm) spectral region. The intensity of UC emission in the maximum (265 nm) of CaF2:Pr^{3+} microcrystals higher of intensity Y_2SiO_5:1%Pr^{3+} in 1.9-2.7 times. The most intense emission peaks in the photoluminescence spectra of CaF_2:Pr^{3+} microcrystals are correspond to the $^3P_0 \rightarrow {}^3H_4$ and $^3P_0 \rightarrow {}^3F_2$ transitions. Synthesized microcrystals and composites are of interest for the creation of self-disinfecting surfaces on their basis.

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Assessment of key factors affecting retroreflex-based detection of optical systems under sunlight

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Retroreflex-based optical detection, also known as the “cat’s eye effect,” relies on the return of light along its incoming path due to reflection from optical systems. Any system with a lens and focal-plane detector exhibits this property. Despite low absolute power, retroreflected light is highly directional and significantly brighter than diffuse background scatter, making it useful for detecting optical/electro-optical devices [1]. This approach is not only valuable for early detection of hidden optical threats but is also being explored as a basis for low-power, free-space optical communication between remote stations, enabling high-bandwidth data transfer without physical connections. Understanding how key parameters - such as aperture size, source power, and daylight background - affect detection is essential for practical application. Simulation and experiments help optimize system design for daylight use.

This study analyzes the key parameters influencing the guaranteed detection of optical systems using the retroreflex method under daylight conditions. The minimum required power of the laser detection system and the maximum detection distance were investigated. The dependencies of the critical detection parameters on the aperture diameter of the optical system to be detected were examined. The influence of daylight as a background illumination, which significantly reduces the guaranteed detection threshold, was analyzed. It was shown that the minimum required source power and the maximum detection distance are related by a fourth-power law. It was also derived and experimentally confirmed that the aperture diameter of the detection system appears in the overall equation raised to the sixth power. Quantitative estimates were made based on the ASTM G173-03 [2] reference daylight spectrum.

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Phase Imaging with Correlated Photon Diffraction through Turbulence

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Atmospheric turbulence severely affects the resolution and stability of optical imaging systems over free-space links, distorting phase fronts and degrading spatial fidelity. In this work, we investigate degenerate biphoton states generated via spontaneous parametric down-conversion (SPDC) as a potential solution for high-resolution imaging in turbulent environments. Unlike classical light, biphotons exhibit strong transverse spatial correlations, described in terms of separable centroid and relative coordinates with potential applications in enhanced phase imaging [1] and ghost imaging [2].

Turbulent and scattering media can, however, alter partially or completely these correlations [2]. We propose the use of 4D coincidence analysis [1,3] with correlation post-selection to isolate events that undergo minimal scattering and thus preserve sample phase and amplitude information. Moreover, the use of adaptive optics [4] can be included to compensate for turbulence effects and consequently improve the signal-to-noise ratio of the collected data.

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Wavefront Sensor Based on Phase Singularities

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In optical metrology, wavefront measurements are typically performed using two main types of devices. The first group relies on interferometric techniques [1], while the second group estimates local wavefront tilts. A widely used representative of the latter is the Shack-Hartmann sensor [2], which employs an array of microlenses to determine wavefront shape by tracking the displacement of focused spots relative to known reference positions. Precise spot localization is critical, as even small inaccuracies can introduce significant phase errors.

This study introduces a novel approach that redefines the probing beam geometry in a Shack-Hartmann-like system by using Laguerre-Gaussian (LG) beams [3]. These beams, characterized by inherent phase discontinuities, exhibit enhanced sensitivity to phase perturbations. Furthermore, they offer new localization methods by analyzing the positions of phase singularities.

Our method utilizes prior knowledge of the existence of these phase discontinuities to define a new localization approach, using a pseudo-complex amplitude technique. [4]. We evaluate its performance by comparing it with the conventional weighted centroid method [5] applied to standard Gaussian beams.

To validate the proposed approach, we perform both numerical simulations and experimental tests. The sensor's robustness is assessed in the presence of controlled shot noise, highlighting the potential of LG beams and the new localization technique to improve accuracy in wavefront sensing applications.

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Flexible Quantum-Dot Light-Emitting Diodes Using Embedded Silver Mesh Transparent Electrodes Manufactured by an Ultraprecise Deposition Method

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Flexible transparent conductive electrodes (TCEs) are essential components in organic light-emitting diodes (OLEDs), widely employed in both display and lighting technologies. The most commonly used material for such electrodes, indium tin oxide (ITO), has significant limitations for use in flexible electronics due to its inherent brittleness [1].

In this work, we introduce a new strategy for producing flexible, transparent, and conductive electrodes using a silver metal mesh, fabricated via an ultraprecise dispensing (UPD) of silver nanoparticles-based conductive ink. The resulting silver mesh demonstrates 80% optical transparency at 550 nm and a sheet resistance of 11 Ω/sq. To evaluate its practical application, the Ag mesh embedded in a polymer matrix was used as the anode in a quantum dot light-emitting diode (QLED). The device achieved a maximum external quantum efficiency (EQE) of 2%, a current efficiency of 6 cd/A, and a peak luminance of 3200 cd/m² at a current density of 100 mA/cm². This approach offers a rapid and straightforward method for fabricating optoelectronic components, eliminating the need for complex processing steps or specialized equipment [2].

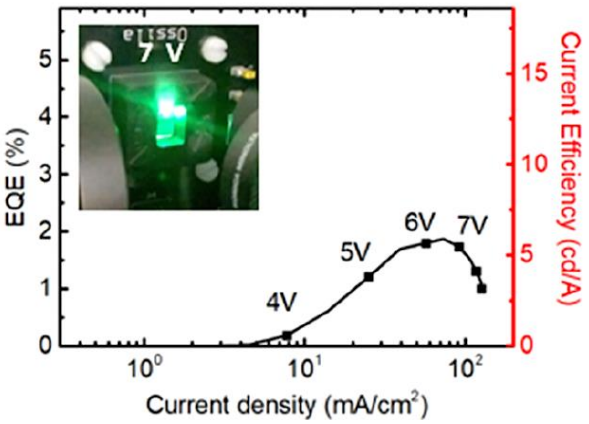

Fig. 1. EQE–*J*–CE characteristics of the QLED. The inset shows an image of a pixel area.

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Transdermal Therapy Using Optical Methods with Eggshell Nanoparticles

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Nanoparticle technology has revolutionized various fields, including medicine, cosmetics, and materials science, exhibiting unique properties due to their small size and large surface area.

Eggshell, an readily available waste product primarily composed of calcium carbonate (CaCO3) and an organic matrix, allows for the creation of biocompatible nanoparticles. we use nanoparticles measuring 50 nanometers.

The research aims to develop a simple method for obtaining nanoparticles from eggshells, confirm their size and presence through spectrophotometric analysis, and subsequently enhance their transdermal penetration using various optical tools.

By grinding washed eggshells we obtain eggshell powder with a size of 50 nm or less. The suspension, passed through deionized water, is filtered through 100-nanometer filter paper, and we obtain its spectroscopic image (190-600 nm), confirming that it contains eggshell nanoparticles. placing it in the mixing apparatus, we take samples of the solution located beneath the skin every 15 minutes and conduct spectrophotometric analysis.On one side, we have deionized water, and on the other, the obtained nanoparticle-containing solution. The method confirms that eggshell nanoparticles will penetrate the porcine skin and be found in the deionized water. Skin penetration has been increased with the help of glycerin.

There are various ways to enhance the penetration of eggshell nanoparticles into the body: Laser-Assisted Delivery (Laser Ablation/Poration), Photothermal/Photodynamic Therapy (Often Coupled with Nanoparticles), Optical Clearing Techniques

This experiment successfully demonstrated a simple and effective method for preparing nanoparticles and presented convincing evidence that these eggshell-derived nanoparticles can penetrate porcine skin.Most importantly, optical tools are the most powerful means to increase nanoparticle penetration into the body and treat diseases such as osteochondrosis, calcium deficiency, or even accelerate fracture healing. Further research is needed to

optimize penetration, assess cellular absorption, and evaluate potential biological effects and safety profiles in more complex biological systems.

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The Study of Optical Properties of LAS·2H2O and LAS Crystals

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The sulfates of amino-acids have been widely studied [1-3], particularly TGS crystal [2], which is used in various fields as an infrared receiver sensor, but the L-arginine sulfate hasn't been obtained.

The subjects of the present study are L-arginine sulfates (LAS·$2H_2O$ and LAS). The thermal properties, vibrational spectra, UV-Vis transmittance spectrum and second harmonic generation activity were experimental studied. The crystal and molecular structure of LAS and LAS·$2H_2O$ were determined by the single-crystal X-ray diffraction method. The crystals LAS·$2H_2O$ ((L-Arg^{2+})·(SO_4^{2-})·$2H_2O$) and LAS (L-Arg^{2+})·(SO_4^{2-}) crystallize in the monoclinic ($P2_1$) and orthorhombic ($P2_12_12$) systems, respectively. Unit cell parameters: a=8.0895(16)Å, b=7.0417(14)Å, c=12.146(2)Å, α=γ=90°, β=91.07(3)°, Z=2, D_c=1.480g/cm^3 for LAS·$2H_2O$ and a=10.5118(2)Å, b=21.1861(5)Å, c=10.1165(2)Å, α=β=γ=90°, Z=8, D_c=1.605g/cm^3 for LAS.

After a structural computational optimization procedure, we obtained the new lattice parameters a=7.60348(33)Å, b= 6.9690(30)Å, c=11.84296(2)Å for LAS·$2H_2O$, and a=10.33604 Å, b= 20.78662 Å, c=9.96028 Å for LAS. Thus, the optimized unit cell volume was reduced by 9.9% for LAS·$2H_2O$ and 5.02% for LAS crystals, respectively. As well as, theoretically obtained optical properties are consistent with the experimental ones. In particular, the absorption spectrum of LAS·$2H_2O$ decreases rapidly at low energy regions, which agrees well with the transmittance spectrum of LAS, suggesting a dielectric nature of both materials. Moreover, the bands originating from the orbital electrons of oxygen (O), nitrogen (N) and carbon (C) are responsible for the formation of energy gaps of about 4.2 eV for LAS·2H2O and 4.6 eV for LAS crystals highlighting their dielectric properties.

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