Conference on Advanced Topics in Photonics

CATP 2025 Sofia

BOOK OF ABSTRACTS

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National Recovery and Resilience Plan
OF THE REPUBLIC OF BULGARIA

Conference on Advanced Topics in Photonics (CATP 2025)

ABSTRACTS OF PLENARY, KEYNOTE, INVITED TALKS, AND POSTER PRESENTATIONS accepted to be presented on the Conference on Advanced Topics in Photonics - CATP'25

03 - 05 July 2025
Sofia, Bulgaria

Organizing committee:

- Dr. Lyubomir Stoyanov
- Dr. Maya Zhekova
- Prof. Alexander Dreischuh

Editors: *Maya Zhekova, Lyubomir Stoyanov*

Dear colleagues, friends and guests of CATP'25,

We are excited and honored to welcome you to the **second edition of the Conference on Advanced Topics in Photonics** – or simply **CATP'25**.

It is both a privilege and a pleasure to host you for three days of engaging discussions and presentations, spanning a wide range of topics in photonics, including **laser physics, nonlinear optics, spectroscopy, quantum optics, metamaterials and materials processing, singular optics** and many more.

We hope that the conference will foster a warm and friendly atmosphere, serving not only as a platform for sharing scientific results, but also as an opportunity to expand your network, connect with leading experts and explore the latest advancements in the field of photonics. We have prepared a rich social program, including **coffee breaks, lunches, official conference dinner** and **welcome cocktail**, combined with the **poster session**.

This year's program features **6 tutorial** and **9 keynote lectures** designed especially for **students and early-stage researchers**. In addition, the latest research findings will be showcased through **13 invited lectures**. Our **poster session**, with more than **26 poster presentations**, will provide an informal and cozy setting for young researchers and students to present their work and engage in discussion. The **three best posters** will be selected and awarded by the **Scientific Committee of CATP'25**.

On behalf of the **Organizing Committee**, I would like to wish you an enjoyable and inspiring time at **CATP'25** and a pleasant stay in the vibrant city of **Sofia**.

Welcome to CATP'25!

July 2025, Sofia, Bulgaria
Dr. Lyubomir Stoyanov

ACKNOWLEDGEMENTS

The Organizing Committee of CATP'25 would like to express its sincere gratitude to all those who contributed to making this event possible.

We gratefully acknowledge the financial support provided through the SUMMIT Project at Sofia University – Marking Momentum for Innovation and Technological Transfer.

We would also like to thank the Center of Excellence UNITe for generously providing the lecture hall and conference venue.

We extend our appreciation for the strong institutional support of Sofia University, the Faculty of Physics, the Faculty of Mathematics and Informatics, and the Union of Physicists in Bulgaria.

We are grateful to the Scientific Committee and reviewers for their valuable work in evaluating the submitted abstracts and shaping the scientific program.

Special thanks go to our **invited, keynote and plenary speakers, as well as to session chairs**, whose contributions are essential to the success of this conference.

We would also like to thank the members of the Organizing Committee and more precisely Dr. Maya Zhekova and Professor Alexander Dreischuh, as well as all the volunteers and local staff who worked tirelessly to ensure the smooth running of CATP'25.

Special personal thanks go to those who supported and contributed to the realization of this conference in countless ways:
Professor Georgi Rainovski, Assoc. Professor Trayana Nedeva, Professor Miroslav Abrashev, Professor Maya Stoyanova, Ms. Vladislava Krumova, Ms. Tzvetanka Zhivkova and Mr. Karamfil Hristov.

Finally, we extend our heartfelt thanks to all participants for their enthusiasm and for bringing their expertise to Sofia. We hope the conference will be both scientifically fruitful and personally enjoyable for everyone involved.

It takes a whole community to create a vortex of ideas.

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INVITED TALKS (20 mins)

POSTER PRESENTATIONS

Controllable Beam Splitting, Spectral Broadening and Coherent Beam Recombination by Vortex Lattices

L. I. Stoyanov[1], G. Maleshkov[1], Y. Zhang[2,3], I. Stefanov[1], G. G. Paulus[2,3], A. Dreischuh[1,4,5]
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The generation of ultrashort laser pulses and the exploration of extreme nonlinear phenomena such as high-harmonic generation represent dynamic and extensively studied frontiers in modern photonics. Since their inception, these areas have prompted intensive research efforts aimed at addressing key challenges, including spectral broadening, filamentation, pulse and beam characterization, amplification techniques, and coherent beam combining. In parallel, the field of singular optics has seen rapid progress, with a particular emphasis on the controlled shaping of laser beams by using phase singularities. A key application of special interest is the spectral broadening of intense femtosecond pulses, essential for their subsequent temporal compression. At high intensities, beams can become unstable (see e.g., [1]), a challenge that can be mitigated by controllably splitting the beam into sub-beams. However, this approach is only viable if there is a reliable method to coherently recombine the sub-beams after spectral broadening, allowing for pulse compression just before they enter the laser-matter interaction zone.
In this talk we will first give an overview of the concept of optical vortex lattices. We will discuss possible ways for experimental generation of such lattices of different symmetries [2]. Then we will show the available control parameters and how we can create ordered arrays of (Gaussian) peaks in the artificial far-field, i.e. focal plane of lens. Last, we will demonstrate experimental results for the controlled beam break-up, filamentation, and coherent recombination of intense femtosecond beams in nonlinear media – ambient air and a glass substrate – using custom designed square optical vortex lattices [3].

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[1] A. Braun, G. Korn, X. Liu, D. Du, J. Squier, G. Mourou, Opt. Lett. 20, 73-75 (1995).
[2] L. Stoyanov, et al., Scientific Reports 9, 9:2128 (2019).
[3] L. Stoyanov, et al., Opt. Express 32, 48758-48771 (2024).

Acknowledgements: We acknowledge funding by the Bulgarian National Science Fund (project КП-06-Н78/6). The work was also supported by the Bulgarian Ministry of Education and Science as a part of National Roadmap for Research Infrastructure, project ELI ERIC BG and by the European Regional Development Fund under "Research Innovation and Digitization for Smart Transformation" program 2021-2027 under the Project BG16RFPR002-1.014-0006 "National Centre of Excellence Mechatronics and Clean Technologies". L.S. would like to gratefully acknowledge the Return Grant awarded by the Alexander von Humboldt Foundation.

Scrutinizing Nonlinear Photoionization Using High-Harmonics

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Nonlinear optics have found broad usage in science and technology. Perhaps the most dramatic nonlinear effect is high-harmonic generation (HHG) of intense femtosecond laser pulses. HHG enables the generation coherent extreme ultraviolet (XUV) light and has given birth to attosecond science. The commercial availability of suitable driving lasers for HHG, makes bright XUV light accessible for use in spectroscopy, imaging and ultrafast experiments in university laboratories.

Despite this progress, experimental research into nonlinear processes driven by HHG light is still in its infancy. Such research, including all-XUV pump-probe experiments, has been possible almost exclusively at the small number of XUV free-electron laser facilities that exist worldwide. However, recent advances in laser technology and high-harmonic generation using visible drivers are lifting this restriction.

In my talk, I will give an introduction to strong-field physics, including HHG, an demonstrate how coincidence experiments allow us to track ultrafast electronic dynamics and unravel intricate laser-matter interactions. I will present experimental advances achieved in our laboratory, where we combine a high-power, high-repetition rate femtosecond fiber laser with a reaction microscope.

Using a recently developed HHG source, we perform coincidence measurements on nonlinear, two-photon double ionization of argon at 26.5 eV [1]. Our results reveal the imprint of electron correlations in the near-simultaneous emission of two electrons from the same atom. In further experiments, we add an intense visible laser pulse to observe the underlying autoionization dynamics in a time-resolved experiment. Our work represents the advent of lab-based, highly-differential measurements on nonlinear laser-matter interaction in the XUV.

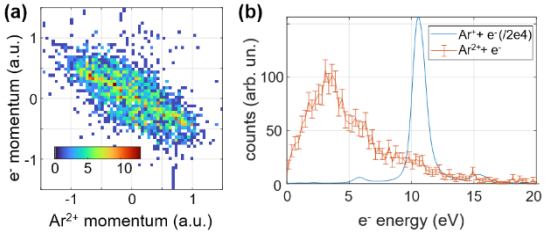

Figure 1: Photoeletron-photoion coincidence spectrum showing the correlations between the momentum components along the XUV polarization for photoelectron and Ar^{2+} ion. (b) Energy distributions for photoelectrons detected in coincidence with Ar^{+} (blue) and Ar^{2+}ions (red).

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[1] S. Hell, et al., *in press*, arXiv:2503.18913 (2025), https://doi.org/10.48550/arXiv.2503.18913

Advanced Optical Image Processing with Ultra-thin Optics

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Digital signal processing is crucial for many modern technologies, but it often faces limitations in terms of memory and speed. Recent advancements in metasurface design and fabrication have led to the emergence of optical analogue computing as a viable solution to complement or enhance digital signal processing. Optical analogue computing has shown promise in tasks such as image edge detection and image classification using patterned flat optical elements. However, the current operations are limited to the linear regime, which restricts the technology to linear Fourier systems. In this presentation, we introduce nonlinear operations to metasurface-based analogue optical processing, demonstrating that nonlinear optical phenomena in flat optics can be used to create image processing beyond linear Fourier optics (see Figure 1). This opens up possibilities for a wide range of new applications, including convolutions with arbitrary kernels and image differentiation. Our findings lay the groundwork for compact optical systems for pattern recognition and detecting fast-moving objects.

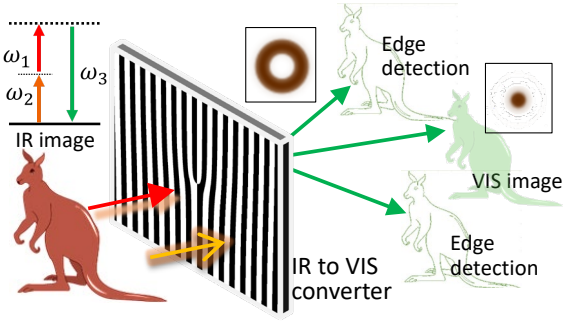

Figure 1: Concept of nonlinear image processing in a metasurface with phase dislocation. Direct and edge-detection images can be simultaneously observed.

References:

[1] L. Valencia Molina *et al.*, Adv. Mater. 36, 2402777 (2024).
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Time-Resolved Infrared Spectroscopy in Material Science

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Electronic and structural properties of materials are generally interdependent and the charge migration through the material induces a vibrational response in it. Femtosecond IR spectroscopy uses the local vibrational spectators to follow processes such as the redistribution of charge density on individual molecules or the formation and recombination of excitons and polarons in bulk materials. Moreover, the Drude-like response of free charges in semiconductors and dielectrics renders IR radiation especially responsive to their presence, making time-resolved IR spectroscopy a powerful technique for monitoring photoinduced charge carrier dynamics in emerging materials. We have applied this method to a range of energy conversion materials, including the following three examples: (i) Dynamics of charge transfer in molecules adsorbed on silver nanoparticles, where charge transfer occurs only upon resonant plasmon excitation and in the presence of adsorbed molecules [1]. We observed strong evidence that the transferred charge carriers are stabilized by solvation and polaron formation, leading to charge back-transfer times that exceed the traditionally expected sub-ps time scale.
(ii) In 3D perovskites, we observe a new IR-active mode linked to symmetry breaking and find that carrier localization decreases at low temperatures due to dynamic lattice disorder [2]. In contrast, 2D Ruddlesden–Popper perovskites show no such localization, suggesting a different stabilization mechanism for free carriers. Experiments on heterostructures reveal that holes are mainly responsible for the new IR mode.
(iii) In organic solar cells we used Fano resonances to track charge-transfer state (CTS) behavior [3]. We observed additional ps-scale dynamics in the small-molecule acceptor, which indicate morphology-dependent behavior. These findings suggest that the observed IR signals originate from CTS at the donor-acceptor interface, where both electron and hole polarons interact with the acceptor's vibrational modes.

References:
[1] D. Sandner et al. submitted (2025)
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Acknowledgements: We acknowledge the support from the DFG with the project EXC 2089/1 – 390776260 and by the European Union NextGenerationEU through the "National Recovery and Resilience Plan of the Republic of Bulgaria, project BG-RRP-2.004-0008-C01"

Nanoscale Cross-sectional Imaging Using High Harmonics

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I will discuss cross-sectional nanoscale imaging in the extreme ultraviolet (XUV) spectral region using high-harmonics produced by femtosecond laser radiation. The imaging technique is particularly easy to understand in time-domain: An attosecond pulse incident on a sample is reflected at the internal structures of the sample. As a consequence, a series of attosecond pulse replicas is generated. The delay between these pulse replicas is on the order of 100 to a few 100 as, corresponding to structures on the order of 10s to 100s nanometer.

Naturally, the pulse replicas differ in spectral amplitude and phase, depending through which and how much material they have propagated. In any case, their spectral interference can be measured by an XUV spectrometer and used to reconstruct the internal structure of the sample. In fact, it is possible to retrieve the phase of the XUV radiation reflected by the sample [1]. Accordingly, the field of the train of pulse replicas is known [2].

A particularly relevant application of XCT for the spectral range up to 100 eV are silicon-based samples. We have demonstrated depth resolutions of 20 nm and very high sensitivities. Buried oxide layers of a thickness of a few nanometers could be detected as well as buried monolayers of graphene [3]. Thanks to the ability to reconstruct the field, it is even possible to identify the material encapsulated in silicon and to determine also properties like layer roughness without destroying the sample [2]. Applications in the material sciences have also been found [4]. A unique perspective is ultrafast imaging.

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[4] Abel, J. J. *et al.,* Mater. Charact. **211**, 113894 (2024).

Attosecond-to-Zeptosecond X-ray Physics and Quantum Optics

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Ultrafast imaging and spectroscopies powered by coherent EUV-X-ray light, generated through the nonlinear process of high harmonic generation, are successfully addressing fundamental questions in complex molecular systems, plasmas, and advanced materials. The exquisite quantum control of the attosecond dynamics of the rescattering electrons in this extreme frequency upconversion enables unprecedented sculpting of the classical and quantum properties of the light, offering remarkable tunability in its spectral, spatial, temporal shape, as well as spin and orbital angular momentum state. The exceptional coherence of this unique light enables multidimensional imaging at the space-time extreme, delivering 4D resolution with nanometer and femtosecond precision, while also accessing an effective 5th dimension–the periodic table of elements–through X-ray absorption fingerprinting with elemental and chemical specificity. A myriad of ultrafast applications, typically performed only at large scale synchrotron or free electron laser facilities, are already possible in many university laboratories using these novel ultrafast discovery tools.
In this plenary talk, I will present the scaling of various regimes of X-ray generation under phase matching conditions using UV – VIS – IR laser fields, including the path forward to generating bright coherent soft and hard X-ray pulses at photon energies of 1-10 keV with unprecedented attosecond-to-zeptosecond pulse durations. Remarkably, merging the attosecond physics of the high harmonic process with quantum optics creates novel quantum regimes of coherent X-ray generation, where the design of the light properties can be dominated by the dynamics of strongly correlated electrons and record-fast attosecond Rabi oscillations. A fully spatially and temporally coherent successor of the Roentgen X-ray tube with quantum control of the properties of the X-ray light, may be possible, promising transformative spectroscopic and imaging modalities.

References:
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[2] Alba de las Heras, et al., “Attosecond Rabi Oscillations in High Harmonic Generation Resonantly Driven by Extreme Ultraviolet Laser Fields”, Phys. Rev. Research 7, L022067 (2025).

Acknowledgements: This work was supported by the ERC grant XSTREAM No716950, Alfred P. Sloan Research Foundation, UC Multicampus Research Programs and Initiatives, and University of California San Diego startup funds.

Strong Electron Correlations, Attosecond Rabi Oscillations, and Angular Momentum of X-rays

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We present two novel quantum regimes of coherent X-ray generation, where the design of the light properties is dominated by the dynamics of the entangled electrons in a simple He atomic system. Interestingly, the physics of these regimes extends beyond the well-established three-step high-harmonic generation model. In the first regime, driven by strong UV laser fields, the entangled electron dynamics yields a characteristic plateau in the X-ray spectral region, extending well beyond the conventional cutoff [1]. This is due to simultaneous double electron recombination where a single high-energy X-ray photon is emitted only in atomic systems with strongly correlated electrons. This low probability phenomenon paves the way to a sensitive attosecond spectroscopy as a probe of highly correlated interactions, *e.g.*, in phase transition materials and nanosystems of relevance to quantum computing and superconductivity. In the second extreme regime, using intense EUV driving fields tuned to a resonance frequency of He can result in a very bright harmonic emission in the X-ray regime [2]. Furthermore, record-fast attosecond Rabi oscillations are predicted to suppress the depletion of the ground state, which otherwise terminates the emission of X-ray photons. The physical description of this novel high harmonic process is not possible within the scope of the conventional three step model since two different pathways coexist: first, a two-level coupling, and second, a bound-continuum coupling. These new advances in quantum control over the coherent X-ray emission enable new insights into complex entangled electron dynamics and applications in nanoscience and quantum technology.

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[1] S. Wang, et al., Surprise in Highly Correlated Two-Electron System: Extended Secondary Plateau in X-ray High Harmonic Generation from Helium Due to Double Electron Recombination, CLEO Europe 2023 (*Optica Publishing Group*), Postdeadline PD_1_5, 2023.
[2] A. de las Heras, et al., Attosecond Rabi Oscillations in High Harmonic Generation Resonantly Driven by Extreme Ultraviolet Laser Fields, arXiv preprint, arxiv.org/abs/2404.04053, 2024.

Acknowledgements: S.C. gratefully acknowledges funding from the European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project № BG-RRP-2.004-0008-C01 and a Fulbright Scholarship, Grant Number 24-21-04. This work was supported by the ERC grant XSTREAM No716950, Alfred P. Sloan Research Foundation, and University of California San Diego startup funds.

Study of Chirped Pulse Amplification Performance of Yb:CALYGLO Laser Crystal

Lyuben S. Petrov[1,2], Dimitar Velkov[3], Iriney Vasilev[1], Kaloyan Georgiev[1,2], Anton Trifonov[2,3], Xiaodong Xu[4], Ivan Ch. Buchvarov[1,2]

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We investigate the amplification behavior of newly created Ytterbium doped $CaY_{0.9}Lu_{0.05}Gd_{0.05}AlO_4$ (CALYGLO) crystal as a part of a chirped pulse regenerative amplifier (CPA) system. The crystal is developed as an improvement in amplification bandwidth and thermal conductivity over the standard $CaYAlO_4$ (CALYO) crystals [1]. To investigate the performance of the Yb:CALYGLO, we have used our single crystal classical chirped pulse regenerative amplifier setup with the option to insert a birefringent plate filter module to shape the seed input spectrum, it is schematically shown in Figure 1 A).

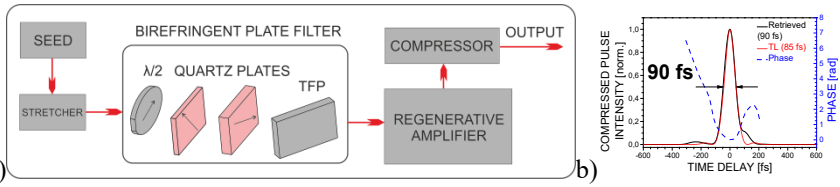

Figure 1: a) Scheme of the optical setup of the CPA system. b) Shortest pulse duration achieved at 1 kHz repetition rate, with 1.8 mJ output energy of the compressed pulse, retrieved intensity(black line) with phase (blue dashed line) and the transform limited duration (red line)

We compare the operation at 1 kHz as well as at 1 MHz, showing the excellent potential this newly developed crystal has for chirped pulse amplification. We also observe the impact seed spectral shaping has on the pulse duration, demonstrating up to 23% pulse shortening. For the 1 kHz we have achieved 1.8 mJ output power with 98 fs pulse duration. When we introduce a birefringent plate in the optical path between the stretcher and the amplifier we were able to shorten the pulse duration down to 90 fs, while maintaining the same output energy of 1.8 mJ. At 1 MHz we were able to achieve 8.6 W output power with 149 fs pulse duration, and 115 fs with 7.6 W output power when using seed spectral shaping.

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[1] Z. Wang, J. Liu, P. Chen, P. Liu, J. Ma, X. Xu, Y. Wei, K. Lebbou, and J. Xu, "Growth and Characterization of Yb: CALYGLO Crystal for Ultrashort Pulse Laser Applications," Crystals **14**(2), 120 (2024).

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Spontaneous Super-resolution Is Enabled In a Confocal Microscope by Super-linear Emitters

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Sub-diffraction (super-resolution, SR) microscopy has revolutionized bio-imaging. Yet, its broad uptake remains constrained by complex and costly setups, image reconstruction artifacts and need for high laser powers. Additionally, most methods are limited to 2D. To address these limitations, we introduce an alternative SR approach that achieves 3D super-resolution on standard confocal microscopes, available in most bio-labs, without the need for hardware alterations or image processing. Remarkably, the resolution improves when reducing the excitation power. We term the method Super-linear Excitation-Emission (SEE) microscopy, as it leverages fluorescent probes - specifically, upconversion nanoparticles - whose emission increases super-linearly with excitation intensity, contrasting standard fluorophores, which exhibit linear-to-sublinear emission response. We demonstrate the method in a 3D bio-sample at near-infrared wavelengths (980nm), where SR methods are sparse, yet often desired for reducing phototoxicity, avoiding autofluorescence, and increasing imaging depth. Overall, SEE microscopy democratizes sub-diffraction imaging, enabling SR for a broader scientific community. Furthermore, we will explore how such non-linear light-matter interactions yield exotic imaging effects, offering potential integration with other imaging techniques such as light-sheet microscopy-particularly for studying neural activity in brain and retinal tissue.

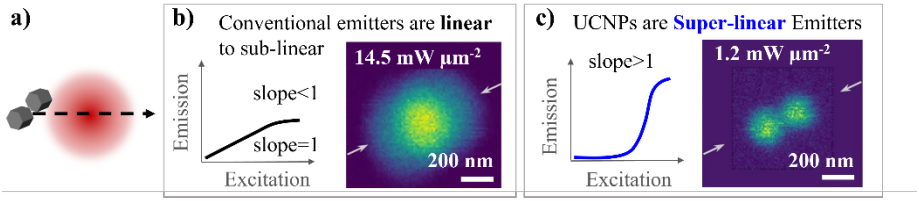

Figure.1 Confocal excitation is diffraction limited (a). Confocal imaging is diffraction limited for conventional emitters (a), while super-linear emitters enable spontaneous super-resolution imaging (b)

References:

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Quantum-enhanced Fluorescence Microscopy

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Fluorescence lifetime imaging microscopy (FLIM) and two-photon fluorescence (TPF) are extremely widespread work horses in chemistry, biology, and medicine. Several methods for FLIM and TPF are established, mainly based on pulsed illumination or phase modulation. These methods require a high technical effort, and can be connected the risk of photobleaching. Quantum light provides the opportunity to avoid this disadvantage: Because of the intrinsic time-frequency correlation of entangled photons, a minimal light intensity is sufficient for the determination of the fluorescence lifetime without the use of pulsed laser sources [1]; moreover, it was already shown that quantum light enables a higher temporal resolution than conventional FLIM methods [2, 3].
Additionally, it has been shown that Entangled two-photon fluorescence (eTPF), provides a linear scaling with the pump power as opposed to the quadratic scaling of TPF, thus providing a quantum advantage in the low photon flux regime [4]. Entangled light generated by spontaneous parametric down-conversion (SPDC) in nonlinear waveguides offers an additional benefit for both FLIM and eTPF: Entangled photons with narrow bandwidths and easily manageable center wavelengths. With this, spectral resolved investigations of fluorescence lifetimes without cost-intensive tunable light sources are possible [3].
We will review the state-of-the-art of quantum-enhanced fluorescence microscopy and identify bottlenecks and open questions, as well as highlight a possible roadmap towards applications.

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2D Materials toward Optoelectronic and Photonic Devices

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2D layered materials have attracted outstanding attention due to their strong in-plane covalent bonds and weak van der Waals bonds joining adjacent layers which provide extraordinary electron mobility, energy gap dependence and extremely high anisotropic optical response. Here, we report the detailed study of controlled synthesis and characterization of graphene and transition metal dichalcogenides (TMDC) and their integration in optoelectronic and photonic devices. As example, application of graphene and PtSe2 as transparent conductive electrode in display devices is demonstrated. Besides the excellent phase modulation repeatability over the large-scale area, graphene exhibits great potential for future ITO-free integrated photonics.
Next, we focus on TCO layers, that prove superior performance indicating a growing demand for the next generation technology, including advanced display devices and dynamic flat-panel functionalities. For example, they can play multifunctional role in Liquid Crystal Spatial Light Modulators configurations as transparent conductive layer and as alignment layer allowing vertical alignment in LC molecules. Besides excellent phase modulation repeatability over the large-scale area, TCO's exhibits great potential for future integrated photonic devices including flexible structures and bio-oriented technologies.

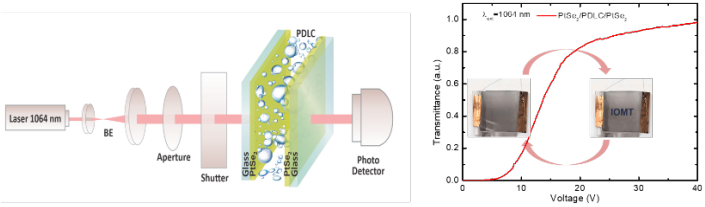

Figure 1: Schematic set-up and "off "and "on" states of PtSe2-based PDLC device

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Generation and Propagation of Nondiverging Beams by Using Specially Designed Diffractive Optical Elements

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The nondiverging (or "nondiffracting") beams are of special interest in optics because they preserve their transverse intensity profile with same dimensions and form along defined propagation interval. We propose a phase diffractive optical element and investigate it in the process of Fresnel diffraction of a Gaussian laser beam. It is a combination of an element with azimuthal cosine-profiled phase changes deposited on a plane base (cosine-profiled phase Siemens star (CPSS)) and a thin phase axicon; thus, we refer to this composed element as the cosine-profiled phase Siemens star axicon (CPSSA). The CPSSA is illuminated by a normally incident Gaussian beam, whose waist is in the plane of this combined element and its axis is passing through its center. The diffracted wave field consists of coaxial wave components: the zeroth-diffraction-order beam, described by the Bessel function of the first kind and zeroth order, and the ($\pm m$)-th higher-diffraction-order (HDO) beams (m=1,2,3,...), described by Bessel function of the first kind and order mp (p is the spatial frequency of the CPSS). These beams are nondiverging and have same propagation distances. When the bright axis, zeroth-diffraction-order beam is eliminated by choosing an appropriate value of the relief depth, then, the diffraction pattern has a central dark, non-vortex spot, surrounded by $2p$ bright spots arranged in a circular array; when it is not eliminated, then, a central bright spot, surrounded by alternating dark and bright rings is observed.

By making a photo-reduced drawing of the lines of the maximum phase values of the CPSSA on a transparent plate, and further applying the etching or bleaching technique, one can produce a binary phase grating, named as rosette gratings (because of their rose shapes). When they are illuminated by a Gaussian laser beam, the diffracted wave field is found as a sum of odd-diffraction-order coaxial, nondiverging (in defined intervals) beams. Each diffraction order consists of a zeroth-order Bessel beam (BB) and a sum of higher-order BBs. The bright axis of the zeroth-order BB in a given diffraction order can be eliminated by a specific choice of the grating relief depth. It is shown that the propagation distance of the s-th diffraction order decreases when the value of s increases. The rosette gratings can be applied as suitable replacement of the CPSSA in its application, in the interval along the propagation axis, where the first diffraction order exists separately, non-mixed with the higher diffraction orders.

A computer-generated element, whose transmission function corresponds to a linear combination of two helical axicons with same in value but opposite in sign topological charges, for generating Bessel beam with cosine amplitude profile, is also studied.

Applications of the nondiverging beams in optical trapping of very small particles, atom optics and optical communications are discussed.

All Optical Transistor Effect in Silicon Based Metasurface

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Conventional electronic transistors are the fundamental building blocks of modern elelctronic circuits and devices. These transistors use an electric current or gate voltage to control a stronger output current or voltage, enabling amplification or switching based on a lower-power input signa In the optical domain, analogous devices—optical transistors—allow weaker input signals to control stronger output signals, either proportionally (amplifier mode) or digitally (switching mode), and can operate in optical chips or computing systems, especially within telecommunications networks where optical signals work independently or alongside electronic ones.
In this work, we experimentally demonstrate and characterize, for the first time, this effect using a meta-optical nanostructure in the form of an optically dichroic metasurface mirror (ODMM)—a two-dimensional resonant nanostructure incorporating at least one silicon nanoscale layer, capable of generating a "step-like" spectral profile in reflection or transmission, defined by a specific cutoff wavelength (λs) [1]. When the ODMM is light up with a gating wavelength (λgate) within Si absorption band, a spectral blue-shift of the cutoff wavelength (λs) of the step-like profile is induced. The shift (Δλ) is proportional to the intensity of the gating signal (λgate). This enables modulation of an incident and directed signal wavelength (λ_L) in two operational modes: a transition from minimal to maximal reflection for wavelengths shorter than the cutoff (λs) within the range λs − Δλ, or a transition from minimal to maximal transmission for wavelengths also below λs in the same interval, with a switching time 10-120 ps.

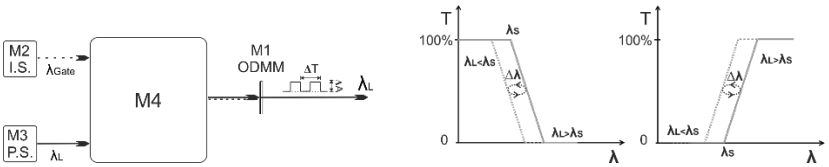

Figure 1. Optical Transistor: Conceptual layout and Operating Principle.

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Optics of Broadband Laser Pulses, Polarization Forces and New Regime of Tunnel Ionization

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The typical spectrally limited laser pulse in the near infrared region is narrowband up to 30-40 femtosecond (fs). Its spectral width Δk is much smaller than the carrying wave number k_0 ($\Delta k \ll k_0$). For such kind of pulses, on distance of few diffraction lengths, the diffraction is Fresnel's one and their evolution can be described correctly in the frame of the well-known paraxial evolution equation. The established in 1985 technology of amplification through chirping of laser pulses gave the opportunity of fast progress and construction of femtosecond laser pulses up to 5-6 fs which are broad-band ones ($\Delta k \sim k0$). The spectra of fs pulses can be enlarged to broadband by different nonlinear mechanisms and by synthesis of frequency bands also. The linear [1] and nonlinear [2] propagation dynamics of broad-band pulses is quite different from narrow-band ones. On the other hand, the longitudinal polarization force is inversely proportional to the pulse duration and becomes significant in the femtosecond region. This leads to confinement the neutral particles into the pulse envelope [3, 4]. The optical frequency of the trapped into the pulse envelope particles is proportional to the carrier to envelope ones (GHz in gases), the Keldysh parameter γ become very small ($\gamma << 1$) and an ionization with intensities, significantly below of the Keldysh's threshold is observed in the experiments.

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High-Speed/High-Density Reversible Optical Data Storage in Azopolymer Materials Based on Digital Polarization Holography

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An important potential application of polarization holography is reversible optical data storage [1]. As known, azodyes and azopolymer are one of the most efficient photoanisotropic materials [2]. Furthermore, they have very short response time, of the order of pico- or femtoseconds, and very small molecule size in the nanometers scale. This reveals an unprecedented potential for ultrafast, high-density, high-capacity, reversible optical data storage. However, there are numerous technical issues related with time stability, light stability, polarization encryption and data encoding with low bit-error ratio, etc., that hampered their application for commercial devices so far.

We present a comprehensive summary of the developments within the field of 2D and volumetric optical data storage in different media, and in particular in polarization-addressable materials. More importantly, we suggest strategies based on digital polarization holography [3-5], aimed to overcome the above-mentioned challenges and achieve the many years craved dream of practical high-capacity, high-speed data storage in azopolymer and azopolymer-based nanocomposite materials [6].

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Laser Induced Reverse Transfer for Fabrication of Metal Oxide Structures for Sensor Applications

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In this work the method of laser induced reverse transfer is applied for a stabile implantation of ZnO and SnO nanoparticles into glass substrate. The method is based on laser ablation of Zn and Sn targets covered by soda-lime glass. The experiments are performed using nanosecond laser pulses at wavelength of 1064 nm. The illumination of the target through the glass side results in ablation and embedding of the ablated material into the glass. At certain conditions the implantation process is highly efficient as multiple washing of the substrate with water and even a wiping do not remove the deposited material. Detailed analyses of the processed area are performed in order to clarify the morphology, composition and the structure of the material. The mechanisms of nanoparticle formation and their embedding is discussed on a basis of heat diffusion model describing the evolution of the temperature during laser interaction. Application of the formed structures in resistive gas sensor is demonstrated.

Acknowledgements: The authors acknowledge the financial support of project KP-06-N87/8 “Development of sensor elements based on composite metal-oxide thin films and nanostructures” under the “Competition for financial support of basic research projects – 2024” Program of the Bulgarian National Science Fund.

Double-minimum Potential Energy Curves from Spectroscopic Point of View

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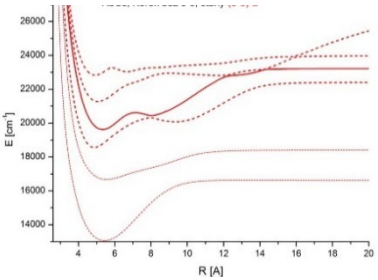
Electronic states of diatomic molecules with exotic shapes of their potential curves (PECs) are challenging both for spectroscopic observation and description of their energy structure. They arise due to avoided crossing of diabatic PECs of the same symmetry and often are characterized with multiple potential minima, "shelf" regions and other shapes which are very different from the regular Morse-like appearance.

From a spectroscopic point of view, it is difficult to observe transitions to all energy levels of such states. The reasons are usually the unfavorable Frank-Condon factors or the sharp change of the transition dipole moment as a function of the internuclear distance. Even when it is possible to register good spectra often it is difficult to analyze them, because of the irregular structure of the vibrational progressions.



Examples of $^1\Sigma^+$ states with exotic PECs in RbCs

The description of such electronic states within the Born-Oppenheimer approximation via molecular constants is not possible, since they are applicable only to states with regular shapes of their potential curves. If the avoided crossing is sufficiently strong and the adiabatic approximation is valid, the energy levels of the exotic states may be described directly with the potential energy curve by solving the so called inverse spectroscopic problem. There are numerous cases, however, when neither the diabatic nor the adiabatic approximations are valid. Then, one should treat the observed energy structure as a system of several coupled electronic states (diabatic or adiabatic). The talk will present the present status of the research in this area of laser spectroscopy.

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Physical Vapor Deposition (PVD) of Antibacterial and Biocompatible Thin Films and Coatings

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In recent years, physical vapor deposition (PVD) techniques have undergone rapid advancement, becoming the preferred method for depositing a broad range of industrially significant coatings. This growth has been driven by the increasing demand for high-performance functional thin films across a variety of sectors. PVD methods often deliver comparable or even superior functionality to much thicker coatings produced by traditional surface engineering techniques, while offering greater precision and efficiency. As a result, PVD methods have a substantial impact in areas such as wear resistance, friction reduction, and corrosion protection. More recently, its application in biomedicine has shown great promise, particularly for developing thin films and coatings with antibacterial and biocompatible properties to meet modern healthcare requirements.

This talk presents recent research on the deposition of advanced coatings with tailored biological functionality. The influence of deposition parameters on film structure is systematically investigated, with particular attention to how phase composition and microstructure affect antibacterial performance and biocompatibility. The findings highlight the potential of PVD as a versatile platform for next-generation biomedical coatings.

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Gouy Phase of Structured Laser Beams

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It is well established that a focused Gaussian laser beam undergoes an axial phase shift relative to a reference plane wave as it propagates through the focal region. This phase shift, known as the Gouy phase shift, is given by Φ_G=atan(z/L_D), where L_D denotes the Rayleigh range and z is the longitudinal coordinate. The phenomenon was first described by Gouy in his investigation of focused wave propagation [1].
The Gouy phase plays a pivotal role in the understanding and engineering of light-matter interactions, particularly in the field of nonlinear optics. Its spatially varying nature introduces an additional phase shift along the propagation axis with respect to a plane wave, which can significantly affect the efficiency of nonlinear processes such as second-harmonic generation, four-wave mixing, and parametric amplification. In tightly focused beams, where the Gouy phase varies rapidly near the focus, it can lead to a change of conventional phase-matching conditions, thereby limiting interaction lengths or altering the spectral and spatial characteristics of the generated signals. Moreover, in structured light fields and ultrafast optics, the Gouy phase is intimately linked to mode structure and pulse shaping, making it a crucial factor in the design of high-resolution and high-efficiency nonlinear optical systems.
In this talk, we provide an overview of our analytical, numerical, and experimental investigations into the determination and control of the Gouy phase in various types of singular (structured) beams. Specifically, we explore the Gouy phase behavior in Bessel-Gaussian beams and in laser modes with distinct transverse symmetries such as Hermite-Gaussian and Laguerre-Gaussian modes. Finally, we present results for the particularly intriguing case of necklace-like arrangements of singly charged optical vortices possessing identical topological charges, highlighting their Gouy phase evolution.

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3D Visualization of Inverted Domains in Nonlinear Photonic Crystals by Cherenkov Second Harmonic Generation Microscopy

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Nonlinear photonic crystals (NPC) are a class of metamaterials with constant refractive index, but spatially modulated 2nd order nonlinear susceptibility. Their development has revolutionized the field of nonlinear optics, because they offer not only a versatile way to realize efficient nonlinear optical interactions, but also allow the exploration of novel classes of light-matter interactions. While conventional fabrication techniques - such as photolithography combined with electric field poling - have been rather effective, emerging all-optical poling methods offer greater flexibility and enable the realization of complex 3D NPC architectures. A critical barrier to further advancement in this field is the difficulty of visualizing ferroelectric domain structures, especially within the bulk of the material.

In this presentation, I will introduce Cherenkov Second Harmonic Generation Microscopy, a novel imaging technique we developed to address this challenge. By exploiting the strong emission of Cherenkov SH signal when a Ti:Sa laser is tightly focused on a ferroelectric domains boundary, the method enables high-resolution, three-dimensional mapping of domain patterns with submicron accuracy. I will discuss how this technique provides new insights into domain structure formation and stability, and how it can support the design and optimization of next-generation nonlinear photonic crystals.

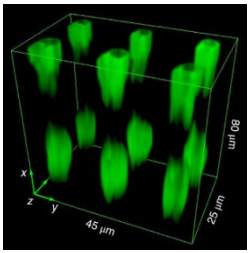

Figure 1: Cherenkov SHG Microscopy image of the 3D ferroelectric domain pattern, fabricated in ferroelectric BCT crystal by focused infrared femtosecond pulses polling.

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Correlative Fluorescence and Soft X-Ray Microscopy in the Water Window Region in an Integrated Lab-based Setup

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We present a correlative fluorescence and water window (WW) microscope in an integrated lab-based setup [1]. The WW spectral range between the carbon and oxygen absorption edges (280-530 eV) is particularly suited for biological samples as the strong absorption in carbon and the high transmission in oxygen create a natural structural contrast. Combined with the functional contrast provided by fluorescence microscopy, this enables a holistic view of the sample.

The wide-field zoneplate microscope operates with a laser plasma source, while the fluorescence microscope uses a wide-field epi-illumination configuration. By mounting both the zoneplate and the fluorescence objective on a shared stage, switching between imaging modes is possible without altering or moving the sample.
The WW microscope achieves a resolution of 50nm half pitch, determined using a Siemens star test target. We will present correlative imaging results from various specimens, ranging from simple test targets like fluorescent nanobeads to biological samples, including cyanobacteria, critical-point dried NIH-3T3, and COS7 cells.

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Metalenses for SWIR Imaging in Space Applications

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Devices based on meta-optical materials have significant advantages compared to standard bulk optics. They are very compact, lightweight, and can be engineered to meet the needs of specific applications, making them particularly suitable for space applications. In this work, we present the first results from the optical characterization and space environment stress testing of novel meta-optics lenses designed for NIR-SWIR wavelengths, aimed at potential applications in future space missions – e.g., as components of remote sensing and/or optical communication space platforms' sub-systems and payloads.

First, state-of-the-art physics-based design and simulation tools were developed in-house, allowing the new advanced custom photonics elements in a proprietary 'silicon on sapphire' fabrication process flow, employing electron-beam lithography (EBL) and plasma etch steps. Lenses operating at each specific wavelength (808, 940, 1064, 1550 [nm]) were designed and fabricated. Next, optical characterization of the fabricated lenses is executed to identify the correlation between their design and the finally achieved properties. The initial results reveal good accuracy of 'preserving' the designed optical functionality when executing the entire custom development flow: design→ fabrication→ functional verification. In the next step, a design of experiment is developed based on the ECSS-Q-ST-70-17C standard (Durability testing of coatings) in order to verify the space environment stress robustness of the meta-surface optical components. Exposure to atomic oxygen stress, total ionization dose radiation, and vibration stress, including their combination, is executed at pre-defined levels corresponding to LEO space missions. The current preliminary post-stress optical performance characterization of the structures shows virtually negligible impact of the defined stress factors on the optical properties of the metal lenses.

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Synthesis and Application of 2D Mo-Based Chalcogenides

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Monolayer and few-layer MoS_2, $MoSe_2$ and $MoTe_2$ were synthesized by chemical vapor deposition (CVD) and thermally assisted conversion (TAC) methods. Nanosheets with lateral dimensions up to several microns were obtained. To explore direct integration, $MoSe_2$ was grown in situ on both graphene and carbon-fiber substrates, forming clean 2D/2D and 2D/1D interfaces without transfer steps.

All samples were examined by Raman spectroscopy: characteristic E_{2g} and A_{1g} modes confirmed layer count and phase, and for $MoTe_2$ distinct spectra revealed both the 1T (metallic) and 2H (semiconducting) phases under varied growth conditions. Atomic force microscopy on MoS_2 showed uniform terraces of one to three layers. Transmission electron microscopy and X-ray photoelectron spectroscopy on MoS_2 and $MoSe_2$ demonstrated high crystallinity and correct stoichiometry. Scanning electron microscopy with energy-dispersive X-ray mapping verified conformal $MoSe_2$ coverage on sapphire substrate.

These results demonstrate the effectiveness of our synthesis approaches in producing high-quality two-dimensional Mo-based chalcogenides. Ongoing work will aim to refine growth protocols and further investigate the material properties under various conditions.

Acknowledgements: This work was supported by the Bulgarian Science Fund under the grant number КП- 06-COST/15 under the COST CA 20116 Action “European Network for Innovative and Advanced Epitaxy” (OPERA). Financial support from the Research equipment of distributed research infrastructure INFRAMAT (part of Bulgarian National roadmap for research infrastructures) supported by Bulgarian Ministry of Education and Science is also acknowledged. Research equipment of the project № BG16RFPR002-1.014-0006 "National Centre of Excellence Mechatronics and Clean Technologies" was used for experimental work financially supported by European Regional Development Fund under "Research Innovation and Digitization for Smart Transformation" program 2021-2027.

Periods of Energy Exchange under the Mutual Effects of Four-Wave Mixing, Self-Phase Modulation and Cross-Phase Modulation

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In the present work the periods of energy exchange between the pump, signal and idler waves, under the influence of the process of four-wave mixing (FWM), with consideration in addition of the effects of self-phase modulation (SPM) and cross-phase modulation (XPM) are presented. A comparison between the obtained results has been made. It is shown that the effects of SPM and XPM increase the period of energy exchange.

The current study is a continuation of developments published in our previous articles [1-3], in which the amplification and periodic energy exchange between the three optical waves in CW regime of propagation (short-cut equations) were successfully described. Exact analytical solutions for the intensities of the waves, characterizing their periodic changes were found and expressed by Jacobi elliptic functions. The period of the energy exchange between the waves can be presented by elliptic integral of the first kind.

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Study of Laser Polarization Dependent Photoexcitation and High Harmonic Generation in Semiconductors

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We investigate theoretically and experimentally the dependence of high harmonic generation (HHG) in semiconductors on the crystal orientation relative to the laser polarization direction of mid-infrared femtosecond drive laser pulse. The orientation dependence of the harmonics arises from the anisotropic electronic band structures and spatial symmetry properties of the materials. It is shown that in addition to the signature of the specific electronic energy bands, the symmetry of the lattice strongly affects HHG in semiconductors.

In silicon, the efficiency of HHG varies with the alignment of the laser polarization relative to the crystal axes. Alignments along high-symmetry directions such as [100] and [111] have been shown to enhance harmonic yields.
The hexagonal symmetry of ZnO leads to distinct patterns in HHG spectra. For instance, the generated even-order harmonics exhibit two-fold symmetry, while odd-order harmonics display six-fold symmetry when the polarization is rotated in the (0001) crystallographic plane of zinc oxide (ZnO) with wurtzite crystal structure. The generated harmonics exhibit specific dependence on the circular and elliptical polarization of the driving light.

We have made calculations of the polarization dependent harmonic spectrum in the chosen semiconductors employing a quantum mechanical description of solid-state HHG [1] with the same laser parameters as the ones used in the experiments.

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Quantum Teleportation of Arbitrary Two-qubit States Along Linear Chain Clusters

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We report experimental results on the teleportation of a two-qubit entangled Bell state across a six-qubit entangled system on ibm_sherbrooke. The teleportation protocol begins with the generation of a four-qubit cluster state on Bob's subsystem and the preparation of a two-qubit Bell state on Alice's subsystem. The entangled state is then teleported to the last two qubits of Bob's cluster state through a series of controlled-NOT (CNOT) gates.
To maximize the fidelity of the protocol, we implemented targeted optimizations within IBM's transpiler, enabling precise control over gate placement and error mitigation. These modifications were critical in achieving a protocol fidelity of 90%, which represents the upper limit for IBM's quantum hardware.
Our findings demonstrate the feasibility of reliably teleporting entangled states across distributed quantum systems and highlight the importance of hardware-aware optimization strategies in achieving high-fidelity quantum information processing. This work serves as a step forward in scaling entanglement distribution protocols, with implications for quantum communication and distributed quantum computing.

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Machine Learning with Insufficient Data for Edible Oil Mixtures Classification by Means of LIF Spectra

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In recent years, the algorithms of artificial intelligence (AI) are being developed extensively and they attract increasing attention of scientists since they open doors to efficient solutions of many problems that otherwise require a lot of time, effort, expenses and often inspiration. A main challenge to their wider application in biophotonics is the lack of ample amount of diverse and representative data for training. Therefore, we present here the application of Neural Network (NN) algorithms trained with insufficient data for solving a task related to the classification of mixtures of food oils (sunflower and extra-virgin olive oil) with different concentrations for verification of food quality. The task will be approached both as a classification and as a fitting task. The cases of training with raw data and with diagnostic parameters with biochemical meaning, and also when extending the insufficient datasets with and without adding noise will be reported. The outputs of different approaches for treating the insufficient data problem will be compared.

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Towards Optimized LIPSS Designs of Solar Panel Glass for Creating Self-cleaning, Anti-fouling Surfaces with Improved Efficiency

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According to the current regulatory documents and the main strategic frameworks for the development of the EU (Regulation (EU) 2020/852), 6 main environmental objectives have been defined. The activities in the current study are directly aimed at two of them, mainly pollution prevention and control and sustainable use and protection of water. Surface cleaning remains essential for the sustainable operation of high-performance solar collectors. Self-cleaning of such surfaces has become a must due to the reduction of cleaning costs, waste of resources such as clean water, and minimization of the complexity of embedded mechanical systems. The self-cleaning process of surfaces is associated with low adhesion between the surface and foreign dust particles. In solar thermal energy harvesting applications, glass/polymer or composite materials are used, where surface texturing remains a challenge in terms of cost and precision when using conventional chemical treatment methods that do not provide a long-lasting effect and can even induce side effects, due to the interaction of the substance with the surface material. Ultra-short laser-based surface texturing on the other hand possesses numerous advantages over other modification techniques. The contactless technique is characterized by high precision and tunability of the laser radiation parameters, and it provides a possibility for diverse micro and nano surface designs, resembling an effective and green alternative to the developed chemical methods. An example of bio-inspired micro- and nanostructures that significantly reduce dust and dirt contamination on glass surfaces is the lotus leaf effect, which demonstrates selective self-cleaning action, with dust particles being removed from the water droplet due to the presence of specific nanostructured shapes on the leaf surface. Superhydrophobic surfaces prevent dust particles attachment and are the basis of self-cleaning anti-fouling effect. The future aim of this preliminary research is femtosecond laser structuring and creating water-repellent, anti-fouling and self-cleaning surfaces of solar panels, through ultra-short laser processing, using laser-induced periodic surface structures (LIPSS) and hierarchical (micro-, nano-) morphologies, with the aim of reducing their maintenance costs and increasing their productivity. The interplay between wettability and surface roughness is the basis of achieving this goal. In this study, preliminary results of precise control of surface wettability and roughness of glass slides are demonstrated. It is identified that the morphology and wettability of laser-induced surface structures created can be efficiently tuned by adapting the laser processing parameters to create structures, which could possess antifouling qualities, that could find a successful application for creating a sustainable solar panel glass design with improved energy efficiency and self-cleaning properties.

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Synthesis of Metal Oxide Nanocomposites by Atmospheric PLD

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Developing high-performance gas sensors is crucial for real-time monitoring of harmful and toxic gases in the industrial, environmental, and medical fields. Semiconductor gas sensors are the most successful commercially applied sensors due to their easy fabrication, simplicity of use, low costs, long life, and ability to detect different gases. The gas-sensitive material is the main part of the semiconductor gas sensor. Various materials have been prepared for gas sensors; among them are TiO_2, WO_3, SnO_2, ZnO, etc. In contrast to sensors composed of one of those metal oxides, in this work, we seek to improve the sensitivity and selectivity to the gases through investigating composite materials based on the TiO_2-WO_3 pair.

We present a synthesis of nanocomposites based on TiO_2 and WO_3 metal oxides by pulsed laser deposition (PLD) performed at atmospheric pressure, the so-called atmospheric PLD. We focused our attention on the samples' structure, composition, morphology, and physical properties while varying the TiO_2/WO_3 ratio in the target used for ablation. It was found that composite TiO_2-WO_3 samples were deposited with a predominant TiO_2 or WO_3 crystal phase as their composition depends on the TiO_2/WO_3 ratio in the target. Further, no phases of mixed Ti-W oxides were detected. The predominant metal oxide determines the samples' morphology, representing a porous nanostructure formed by nanoparticles of different sizes.

Porous semiconductor metal-oxide structures composed of high surface-to-volume ratio "building blocks", such as nanoparticles, are a prerequisite for excellent gas-sensing performance. Further, the electrical properties of all samples are sensitive to light irradiation, which makes them a suitable candidate for fabrication of light-sensitive gas sensor elements.

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Choice Between Diabatic or Adiabatic Approximation by Double-well Potentials

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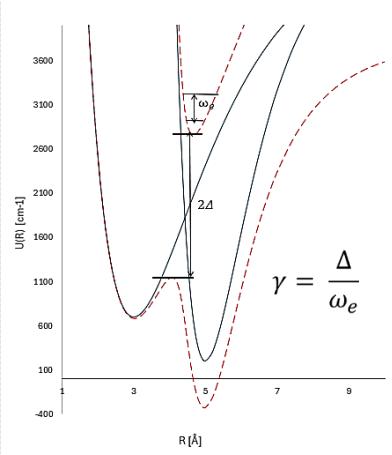
To obtain a solution of the time-independent Schrödinger equation for a diatomic molecule, the interactions between states of the same symmetry must be considered. The problem can be solved using either adiabatic or diabatic approximation. They are equivalent, but each is more appropriate depending on the strength of the interactions.

When the electrostatic interaction between the diabatic states is negligible, the diabatic approximation is usually used. Then states of the same symmetry may cross (see Figure 1). When the interaction is significant, then it is better to consider the adiabatic approximation. The states of the same symmetry cannot cross anymore and this gives rise to adiabatic electronic states with multiple minima or other exotic shapes. In the adiabatic approximation the states are coupled by the kinetic energy operator of the nuclei – the so called non-adiabatic coupling.



In 1985 Dressler introduced a criterion γ to distinguish which approximation is more appropriate (see the Figure).
Δ is two times the magnitude of the electrostatic interaction and omega e is the vibrational constant of the upper electronic state. When γ <<1 the diabatic approximation should be preferred, when γ >> 1 – the adiabatic is better. In this contribution we try to give a more quantitative estimation on the accuracy of both approximations, which may be achieved depending on the adiabaticity criterion.

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Vortex Structures in Linear Optical Fibers with a Step-index Profile

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Modern singular optics is one of the fastest growing areas of modern photonics. In recent years, the study of laser vortex structures with amplitude type singularity, which are often found in the literature as polarization vortices, has become relevant. Their specific feature is that they can be observed only in the components of the amplitude function of the optical pulse.

In present work, the linear regime of propagation of ultra-short laser pulses in isotropic dispersive media, such as optical fibers with a step-index profile and the possibility of generating laser vortex structures with amplitude type singularity are considered. This was done on the basis of the vector linear amplitude equation. New exact analytical solutions of this equation have been found, describing amplitude type vortices in the components of the vector amplitude function of laser pulses.

The peculiarities of their dynamics reveal new perspectives in the improvement of a number of modern devices, such as quantum data transfer and information encryption, high-resolution laser microscopy, precision optical tweezers, and many others.

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Assessment of Fluorescence Contrast for Distinguishing Ex Vivo Tissue Slides in Collagen-related Degenerative Skin Diseases

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Histopathological analysis is fundamental in clinical diagnostics, providing critical insights into disease identification and progression. However, traditional methods can be time-consuming and labor-intensive. To improve diagnostic efficiency and accuracy, optical techniques are being explored as potential alternatives or complementary tools. One promising approach involves leveraging the autofluorescence of unstained tissue slides to distinguish between various pathologies.

In our study, we investigated the diagnostic potential of autofluorescence to differentiate collagen-related skin conditions such as psoriasis, lupus erythematosus, scleroderma, and Raynaud's syndrome. By employing two distinct optical techniques – fluorescence microscopy combined with colorimetric analysis and synchronous fluorescence spectroscopy – we analyzed the unique spectral characteristics of affected tissues. These methods allowed us to identify disease-specific fluorescence patterns, providing a non-invasive and label-free approach to histopathological assessment.

Our analysis evaluated potential classification parameters that could enhance disease differentiation. The findings suggest that autofluorescence-based techniques may serve as valuable tools for improving diagnostic workflows, reducing reliance on traditional staining methods, and facilitating faster, more precise disease identification. By refining and standardizing these methods, we can work toward more efficient, accurate, and accessible diagnostic solutions for collagen-related skin diseases.

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Laser Beam Splitter/Coupler (at 1.55 μm Wavelength) with Nanostructured Plates of Ion-implanted PMMA

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We report the results of a study on the transmissive and reflective properties of thin plane-parallel plates of ion-implanted polymethyl methacrylate (PMMA) irradiated with laser light at the telecommunications wavelength of 1.55 μm (Fig. 1). Bulk PMMA was examined, subjected to low-energy (50 keV) silicon ion (Si^+) implantation at various ion fluences in the range from 10^{14} to 10^{17} ions/cm^2. The modification of the subsurface region of PMMA by ion implantation leads to the formation of a nano-clustered structure with optical properties different from those of pristine PMMA. The ion-produced subsurface organic nanolayer and its interface can be of importance when considering the advanced applications of ion-implanted optically-transparent polymeric nanolayers in photonics, biophotonics, integrated optics and optical communications.

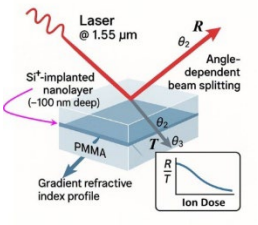

Figure. 1: Transmissive and reflective properties of thin plane-parallel plates of ion-implanted polymethyl methacrylate (PMMA) irradiated with laser light at the telecommunications wavelength of 1.55 μm.

Due to the ion-produced modification of PMMA, the formed ultrathin near-surface ion-implanted layer of a thickness of about 100 nm, buried in a depth of ~100 nm, can be used to split (or combine) laser beams at 1.55 μm with a low absorption loss. This feature of Si^+-implanted PMMA at the wavelength of 1.55 μm was investigated as a function of both the angle of incidence on the probed interface and the ion fluence used for implantation of the polymer PMMA. The obtained results were correlated to the structure formed in the studied ion-implanted nanolayers. The functional dependence of the change in the reflection-to-transmission ratio of Si^+-implanted PMMA at 1.55 μm was explained by taking into account the Si^+ ion-produced gradient refractive-index in-depth profile of the subsurface (buried) ion-implanted organic-carbonaceous nanolayer.

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Partially Coherent Anti-Stokes Raman Scattering (pCARS) in Transparent Molecular Liquids by Nanosecond Laser Pulses (Numerical Modeling)

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We present a numerical modeling of the key characteristics of the so-called 'partially coherent anti-Stokes Raman scattering' (pCARS) – a coherent nonlinear optical (NLO) process in condensed matter, demonstrated in 1990 – 1997 by using nanosecond (ns) laser pulses [1,2], but so far unexplained. Through our model, the physical nature of this NLO effect has been elucidated.

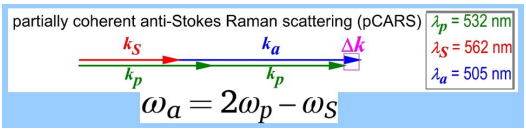

Figure 1. Optical configuration of pCARS.

Experimental data obtained by pCARS are modeled with an analytical expression derived from the classical description of four-wave optical mixing at Raman resonance. In this way, pCARS data can be analyzed and interpreted, in addition to or instead of the complex fluctuation models of molecular physics.

The results obtained through the proposed model show that pCARS is based on a parametric-stimulated mechanism for generation/amplification of a coherent optical signal [3]. The application of the proposed model can provide spectroscopic information about Raman-active condensed media and micro-interfaces, complex molecular liquids, solutions, inhomogeneous media, fluid hybrid and composite materials studied by ns pCARS.

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Real Time Characterization of Stokes Polarization Parameters Using Rotating Quarter-wave Retarder

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Since polarization is one of the fundamental properties of light [1, 2] the ability to manipulate and monitor it is required for many practical applications. The most convenient and widely used way to describe the polarization state of light is by the use of Jones Vectors. It consists of two complex amplitudes in X and Y orthogonal directions and for convenience it can be normalized to length of 1. If the light passes through some optically active element, like polarizer, or a waveplate, we can use a Jones matrix of the element to describe the effect of the material on the incident light, and the output polarization state can be calculated by multiplying the Jones vector of the incident light with the Jones matrix, or so called transfer function, of the corresponding element. To model the effect of many elements we can just multiply the Jones matrices for all the elements. Even though the Jones matrix are an extremely practical and useful way for description of polarized light, in practice it is hard to measure electric field. What we usually measure is the intensity and here is where the Stokes vector and the Mueller matrix come of use. In contrast to Jones vector, Stokes vectors consist of four parameters S0 to S3 and each of these parameters can be experimentally measured. Moreover, these quantities are time averaged, so even randomly polarized light will give a well-defined result, which is not the case with the Jones vector. All these measurements are not practically challenging, but they are time-consuming and can not be done manually in real time, which is important for applications like ellipsometry, or polarization resolved spectroscopy, where the polarization state of light is constantly changing.
In this work, we propose a novel polarization analyzer for real time measurement of the Stokes parameters (S0 to S3), based on rotating quarter waveplate method. It consists of a photodetector, which in our case is a simple large area photodiode, a linear polarizer and quarter waveplate in front of it, mounted in a special design mechanical setup that can rotate constantly. The intensity of the light passing through the analyzer is then being measured and a specially developed applications analyze the data and calculate the Stokes parameters of the incident light in real time.

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Squaraine Dyes for Sensitization of TiO_2/GO Photocatalytic Nanocomposites

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Squaraines intense absorption properties are suitable for applications related to the photosensitization phenomenon [1]. Sensitizing a TiO_2 semiconductor with squaraine may produce a highly effective photocatalytic system due to the electron transfer from the excited dye to the titania conduction band or pre-adsorbed molecular oxygen. Effective photocatalytic decomposition of different types of pollutants through dye-sensitized TiO_2 systems is due to a simultaneous effect of both semiconductor and dye [2]. Synergistic effect of coupling a squaraine dye (SQ) as a photosensitizer with a composite containing titania and reduced graphene oxide (TiO_2/rGO) has been investigated. A three-component TiO_2/rGO/SQ catalyst was synthesized and its ability to improve Methylene Blue discoloration in aqueous solution under visible light irradiation has been tested. XRD, SEM, TEM, and VIS spectroscopy were employed for sample characterization. A squaraine dye excited by visible light is capable of transferring electrons to TiO_2/rGO material, which contributes to increasing the apparent discoloration rate constant up to 0.028 mol/l.s., which is 18 times higher than that of bare titania.

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Laser Light Diffraction by Dynamic Periodic Patterns Field-induced in Anisotropic Media

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We describe the application of a laser diffraction technique to the study of electroconvection in smectics C and nematics with short range smectic C order at obliquely incident coherent laser light. We have used laser diffraction as a method for the direct quantitative determination of the amplitudes of the director field. The basic characteristics of the diffraction grating effect at obliquely illumination, namely, the much more intense fringes obtained from a weakly distorted layer, compared with those formed in the normal incidence case, the asymmetry of the fringes, and the equal importance of the even-and odd-order fringes are revealed, which is very useful for the electrohydrodynamic instability analysis at conditions slightly above the threshold. An important result of our analysis is that an obliquely illuminated liquid crystal grating is a much more sensitive diffraction tool, because a distortion angle of a few degrees is adequate for the formation of intense fringes.

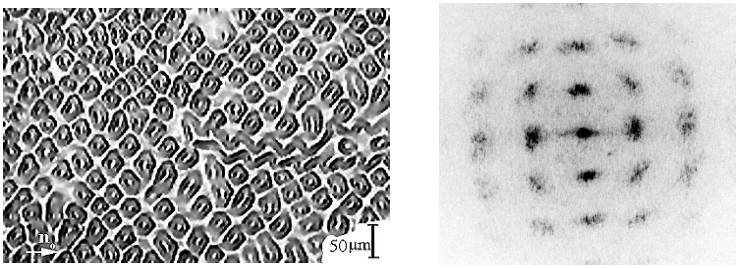

Figure 1: The electroconvective pattern (cell-domains) and the corresponding 2D diffraction pattern.

Determination and Controlling of the Gouy Phase of Laser Beams Carrying Vortex Necklace-like Structures

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It is assumed to be well understood that a focused Gaussian laser beam experiences an axial phase shift with respect to a reference plane wave when passing through its focus. This phase shift Φ_G=atan(z/L_D) is named after Gouy, who first investigated it. Here L_D and z are the Rayleigh diffraction length and the longitudinal coordinate, respectively. For a higher-order laser modes, e.g. for Laguerre-Gaussian (LG) modes with mode indices (m,p) the Gouy phase of the Gaussian beam Φ_G=atan(z/L_D) is multiplied by a factor of (1+$|m|$+2p) [1,2]. Here, $|m|$ accounts for the fact that the azimuthal mode index m (positive or negative integer number) represents the on-axis topological charge (TC) of the point-phase dislocation carried by optical vortices (OVs). The factor 2p is related to the radial mode index p of the LG beam.

Of particular interest, (especially in nonlinear optics), is the possibility to control the Gouy phase while the laser beam retains its clearly pronounced and dominant central peak. In this work, we report numerical simulations and experimental data indicating the possibility to determine and control the Gouy phase, and particularly its rate of change, by creating necklace-like structures of singly-charged OVs with the same signs of the TCs. Of importance here is that a pair of vortices with identical topological charges, formed to be symmetrically offset from the axis of the background laser beam, interact by repelling each other (if they are close enough) and rotating around the axis of the background beam [3]. This rotation should affect the Gouy phase, which is defined along the beams' axis. Having this in mind, we demonstrated that Φ_G can be either controlled by the radius of the vortex necklace structure or by the number of the OVs.

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2D-nanolayers of WSe_2 and their Heterostructures for Photonics Applications

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Two-dimensional (2D) materials, such as tungsten diselenide (WSe_2), have attracted considerable attention in the field of photonics due to their direct bandgap in the monolayer form, strong excitonic effects, and robust light-matter interaction [1,2]. In this work, we explore the synthesis, structure and optical properties of monolayer and few-layer WSe_2 and focuse on their integration with other 2D layers. Using optical and Raman spectroscopy, atomic force microscopy, and photoluminescence measurements, we investigate how the layer number and interface engineering influence the system's optical response and interlayer interactions. We further examine the potential emergence of interlayer excitons and the possible modulation of valley polarization. Additionally, we study vertical heterostructures based on WSe_2 and $PtSe_2$ (Platinum diselenide), prepared by direct polarization. The obtained results support the potential of WSe_2-based 2D system for compact photonic devices, including light emitters, modulators, and photodetectors operating in the visible and near-infrared spectral range.

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Power Superbroadening with Two Tunable Pulse Families and Delos-Thorson Equivalence Under Time-Dependent Phase Modulation

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This study introduces two novel pulse families—quadratic and even-power—that generate "power superbroadening" by amplifying non-adiabatic edges, enabling more sensitive interactions in EIT, quantum tomography, and nonlinear optics. These pulse shaping strategies were tested on IBM Quantum processors, demonstrating new tools for quantum state manipulation, broader interaction frequency spectrum, and improved spectroscopy techniques.

The second part of this work establishes the equivalence between phase modulation and detuning control: detuning is the time derivative of a complex phase on the coupling, allowing different quantum control models to be replicated via Rabi frequency phase modulation. By applying three different coupling–detuning combinations (LMSZ, AEH, and hAEH) on IBM Quantum processors, the study illustrates that multiple coupling–detuning pairs can produce identical transition probability landscapes, confirming the Delos-Thorson equivalence principle.

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Polarization Mapping of Birefringent Elements Generating Singular Beams

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Polarization mapping refers to the process of measuring and visualizing the spatial distribution of the polarization state across a light beam. It reveals how the polarization varies from point to point in space showing, e.g., regions with radial, azimuthal, or elliptical polarization [1-3]. Polarization mapping is essential in analyzing vector beams, structured light, and beams with spatially varying polarization such as those produced by q-plates or metasurfaces. It typically involves elements like rotating polarizers, wave plates, and imaging detectors to reconstruct the Stokes parameters or polarization ellipses across the beam profile.

In this work, however, we report a method for parallel determination (mapping) of the polarization change introduced by an unknown optical element using arrays of linearly polarized Gaussian beams. More precisely, we present an experimental technique for polarization mapping of birefringent elements generating polarization vortices, such as vortex retarders. The approach is applicable also for clear determination of the polarization response of spatial light modulators. Experimental data will be presented and discussed, focusing on benefits and the limitations of the demonstrated approach.

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Acknowledgements: We acknowledge funding of the Bulgarian National Science Fund (project КП-06-Н78/6). The work was also supported by the Bulgarian Ministry of Education and Science as a part of National Roadmap for Research Infrastructure, project ELI ERIC BG and by the European Regional Development Fund under "Research Innovation and Digitization for Smart Transformation" program 2021-2027 under the Project BG16RFPR002-1.014-0006 "National Centre of Excellence Mechatronics and Clean Technologies". L.S. and A.D. were also supported by the European Union NextGenerationEU through the "National Recovery and Resilience Plan of the Republic of Bulgaria, project BG-RRP-2.004-0008-C01". L.S. would like to gratefully acknowledge the Return Grant awarded by the Alexander von Humboldt Foundation.

Photoswitchable Photochromic Spirooxazines for Optical Sensing

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Spirooxazines (SOs) are an important class of photochromic dyes having intense photocoloration, high coloration contrast, reversibility, and good photo fatigue resistance. Nowadays, SO derivatives and modifications have advanced application for optical sensing. The optical sensing by such photochromic molecular switches can be extended by proper substituents in their chemical structure. Thus, sensitive fluorescent nanoprobes photoswitchable upon UV and visible light, were developed [1].

Here we report novel SOs bearing different substituents in their naphthoxazine and indoline ring molecular systems. The key property of SOs is their photoswitching ability: upon UV light their closed form transforms into an open merocyanine form having very different optical properties, and vise-versa by visible light. We studied the effects of both the molecular structure of the synthesized SOs and their solvation in various solvents) on the optical absorption properties and photoswitching of the SOs, as well as on their fluorescence induced by UV light. The obtained results on the photo-physical characteristics and photo-transformations of the synthesized SOs are useful since they can be applied in the highly sensitive and selective analytic techniques for optical sensing and imaging.

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This work was supported by European Regional Development Fund under "Research Innovation and Digitization for Smart Transformation" program 2021-2027 under the Project BG16RFPR002-1.014-0006 "National Centre of Excellence Mechatronics and Clean Technologies" and by National Science Fund of Bulgaria (NSFB) according to the research project No KP-06-M89/4.

Optical Stretchers for 1 µm Lasers – Challenges and Specific Designs

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We examine the key challenge of phase control during chirped pulse amplification (CPA), when the system is operating at a central wavelength around 1 µm. It is well established that utilizing a conjugated Martinez stretcher and Treacy compressor, the dispersive effects can theoretically be fully compensated. However, when the material dispersion of the amplifier is added this becomes impossible, as the higher-order dispersion terms of the stretcher and compressor are significantly higher than the ones introduced by the materials, leading to uncompensated higher orders of dispersion. This effect increases with longer wavelengths, larger material dispersion and a smaller grating constant (higher line density). To somewhat mitigate this effect, we can use gratings with a small line density (Figure 1. A)), but this leads to a larger system footprint. Alternatively, we can use mismatched gratings to achieve better pulse compression (Figure 1. B)) [1] and reduce the footprint.
An even better, more robust and compact solution is to employ a specially manufactured fiber Bragg grating, acting as a "lower line density grating" stretcher, which can ideally compensate the group delay dispersion, third-order dispersion, and fourth-order dispersion of the compressor and material in the amplifier.

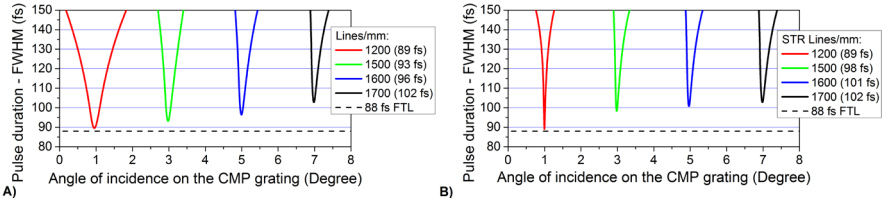

Figure 1: Numerical evaluations of pulse compression in an Yb CPA system with 50 passes in the regenerative amplifier, when using A) conjugate stretcher and compressor and B) when using a mismatched stretcher and 1700 lines/mm diffraction grating compressor.

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M^2–factors and Gouy phases of Annihilated Vortex Beams

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It is known that any focused light beam experiences an axial phase shift with respect to a reference plane wave when passing through its focus. This phase anomaly was first studied by Gouy and is named after him. An important feature of any laser beam is the so-called M squared factor. The M^2 factor (M squared factor), also called beam quality factor is a common measure of the beam quality of a laser beam.
Special class of laser beams are the optical vortices (OVs) – intriguing phenomena in nature that attract much attention in many areas of physics. OVs are associated with the presence of a spiral phase dislocation in the wavefront of a light beam that also determines the intensity structure of the beam – the characteristic doughnut-shape intensity profile [1]. Characteristic feature of the OV is their topological charge (TC) l, which corresponds to the total phase change $2\pi l$ over the azimuthal coordinate φ. Intriguingly, when two OVs of opposite TCs are annihilated and subsequently Fourier transformed (focused by a thin lens), the Gaussian form of the background beam is retrieved [2].

In this work, we show a thorough experimental verification and determination of the beam quality factor (M^2) of a laser beam obtained after annihilating OVs with TCs ranging from 1 to 6. Moreover, using the single-lens interferometer [3], we also measured and estimated the Gouy phase of these beams (see Fig. 1). Detailed experimental data, as well as the used experimental setup will be presented and discussed.

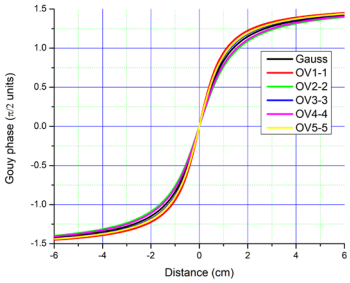

Fig. 1. Comparison of the Gouy phase of a Gaussian beam with the Gouy phase of annihilated vortex beams

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Quasi-Phase Matching & Crystal Segmentation for Robust Optical Parametric Amplification

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We propose a novel optical parametric amplification scheme that combines quasi-phase-matching with a composite pulse approach that involves crystal segments of specific lengths. The presented scheme highly increases the robustness of the frequency conversion against variations of the nonlinear coupling and of the pump, idler, or signal wavelengths, and has therefore the potential to enhance high amplification and broadband operation. Simulation examples applied to LiNbO are given.

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Thermal Measurements and Characterization of Novel Yb:CALYGLO Crystals for High-Performance Ultrafast Lasers

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Recently, it has been demonstrated that the use of the Yb-doped disordered crystal family $CaLnAlO_4$ (Ln = Y or Gd) enables the generation of sub-100 fs pulses in conventional chirped pulse amplification (CPA) lasers. Comprehensive thermal characterization of this newly developed material is a critical prerequisite for its integration into practical laser architectures. Here we present a study of the thermal conductivity of the newly developed $Yb:CaY_{0.9}Lu_{0.05}Gd_{0.05}AlO_4$ crystal utilizing long-wavelength infrared (LWIR) thermography combined with finite element analysis (FEA) [1]. The crystal was designed as an improvement on $Yb:CaYAlO_4$ (CALYO) to broaden the emission cross section [2] and improve its thermal conductivity. Thermal imaging for 21 W absorbed pump power, and cross sections corresponding to each crystal axis are shown in Figure 1.

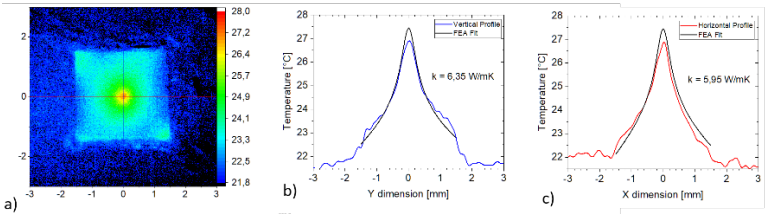

Figure 1: **(a)** Color map temperature profile obtained with LWIR thermography. **(b)** Vertical (Y axis, along crystal a-direction) section, blue line: experimental data, black line: numerical data. **(c)** Horizontal (X axis, along crystal c-direction) section, red line: experimental data, black line: numerical data.

The thermal conductivites measured for a-cut 1.3 at. % Yb:CALYGLO were $k_a = 6.4\,W/mK$ and $k_c = 6\,W/mK$. These results improve on the thermal conductivies of Yb:CALYO [1], and show promise for implementation in high repetition rate systems, where undesireable thermal effects, such as thermal lensing, are prevalent.

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European Union-NextGenerationEU, through the National Recovery and Resilience Plan of the Republic of Bulgaria, project № BG-RRP-2.004-0008-C01

Laser Spectroscopy of Highly-Luminescent Europium Complexes Upon Excitation with Femtosecond Pulses

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The luminescence of coordination complexes of trivalent europium ion (Eu(III)), particularly those containing thenoyltrifluoroacetonate ligands (EuTTA), in dilute aqueous solutions, was probed upon single- and two-photon preresonant excitation (almost off-resonance) with high-intensity ($\sim 10^{14}$ W/cm^2 in the focal volume) ultra-short femtosecond (fs) laser pulses. Particularly, diamine-liganded Eu(III)$(TTA)_3$ complexes was examined aiming their applications as luminescent labels for sensing and imaging of biological molecules.

As a laser source was employed Quantronix Ti-Light broadband mode-locked Ti:sapphire laser generator and Integra-C ultrafast regenerative/multi-pass Ti:sapphire amplifier. This compact laser system operates at a repetition rate of 1 kHz, producing 40 fs (fwhm) pulses with an energy of 3.5 mJ/pulse. The fundamental radiation band is centered on 800 nm (spectral bandwidth ~60 nm fwhm).

Our experimental studies reveal that even under pre-resonance conditions, the excitation of these compounds using high-intensity, broadband light of frequency-doubled Ti:sapphire fs laser – centered around a wavelength of 400 nm – leads to a remarkably efficient luminescent response of the investigated Eu complexes. This pronounced luminescence makes the proposed method of excitation of the Eu compounds understudy highly promising for use in biomedical diagnostics, bioanalytical techniques, and a wide range of other fluorometric applications, highlighting their potential for advanced photonic and life science technologies.

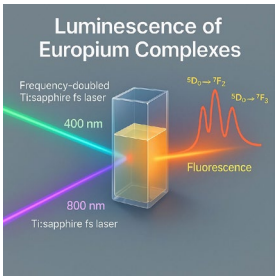

Fig. 1 Luminescence of Europium complexes

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Hyperfine Structure and Line Intensities of Selected ($B^1\Pi$-$c^3\Sigma^+$)→$a^3\Sigma^+$ Fluorescence in KRb, NaK and NaRb

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In a series of previous experiments laser induced fluorescence from the mixed $B^1\Pi$-$c^3\Sigma^+$ states in alkali metal dimers was used to study their lowest triplet state $a^3\Sigma^+$ [1-3]. The fluorescence lines show structure which was attributed mainly to the hyperfine splitting of the $a^3\Sigma^+$ levels. Only in KRb [1] the recorded spectra demonstrated that the hyperfine structure of the $B^1\Pi$-$c^3\Sigma^+$ levels is noticeable. In this study we used experimental data on the structure of $B^1\Pi$-$c^3\Sigma^+$ levels available in the literature for NaK, NaRb and KRb [4-6] and performed calculations on the profiles of the spectral lines to the $a^3\Sigma^+$ state. It was shown that it is not the hyperfine structure of (B-c) levels which makes the KRb case different from the other alkali metal molecules in those studies, but it is a coincidence of molecular structure and Doppler broadening, which lead to nonuniform population of the hyperfine components of the (B-c) levels. This effect becomes stronger when the hyperfine splitting approaches and even exceeds the Doppler width of the exciting X→(B−c) transitions. At lower instrumental resolution, however, the effect could be washed out and this may be the reason why it was not reported in all fluorescence studies of the $a^3\Sigma^+$ states through the complex of $B^1\Pi$-$c^3\Sigma^+$ states.

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Exploring Alternative Mechanisms for Non-Sequential Double Ionization with Silicon Ions

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We present a strong-field ionization study of silicon ions using a novel liquid metal ion source (LMIS) combined with high-repetition-rate (100 kHz), elliptically polarized laser pulses centered at 1030 nm. The experiment consists of two measurements, one with Si^+, the other with Si^{2+} as precursor and Si^{3+} being the final charge state.

The LMIS generates ion beams through field ionization of a molten Au-Si eutectic alloy, with selected charge states interacting with the laser focus. Fragment ions are detected using a position-dependent time-of-flight spectrometer with 3D momentum resolution. Elliptical polarization suppresses the recollision pathway, potentially revealing alternative NSDI mechanisms.

Semiclassical simulations based on rate equations assuming purely sequential ionization were performed. By comparing the yields and the momentum distributions obtained from the simulations and measurements we can identify potential NSDI contributions in the $Si^+ \rightarrow Si^{3+}$ process. The high repetition rate enables measurements with high statistics, while the LMIS approach opens new possibilities for expanding strong-field studies across the periodic table.

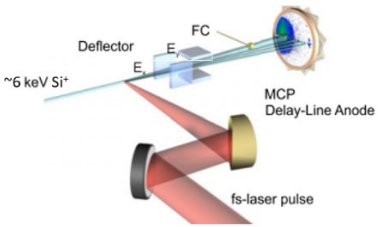

Figure 1: Sketch of experimental setup [1]

References:
[1] B. Ying, *et al.*, *J. Phys. B* **54**, 174002 (2021)

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Simple Spectral Shaper for Sub 100 Fs Yb Based Chirped Pulse Amplifiers

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Currently Yb doped laser systems have established themselves as the most popular solid-state lasers, due to their high energy, high average power and low cost. While Yb active media have a slew of advantages, the biggest problem is the manufacturing of short pulses, especially shorter than 100 fs. The other major factor limiting the spectrum of the amplified pulses is the well-known gain narrowing effect. There are a number of approaches proposed to overcome the gain narrowing, the technique that we use can be described as seed spectral shaping. To modulate the spectrum, we have decided to use a couple of birefringent quartz plates, a λ/2 waveplate and a polarizer (fig.1). With this approach we have flexibility on the depth and the shape of the modulation of our seed spectrum. For determining the plates' parameters, a python script was written using the Jones matrix formalism [1]. Utilizing our birefringent filter with two quartz plates, a zero order half-wave plate, and a polarizer we were able to shorten our pulses down to 91 fs, while maintaining a pulse energy of 1.7 mJ at 1 kHz.

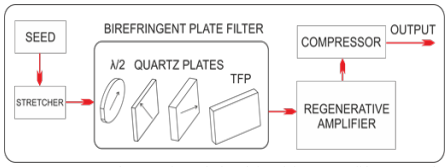

Figure 1: Schematic of the birefringent filter used.

Utilizing our birefringent filter with two quartz plates, a zero order half-wave plate, and a polarizer we were able to shorten our pulses down to **91 fs**, while maintaining a pulse energy of **1.7 mJ** at **1 kHz**.

References:

[1] Preuss DR, Gole JL. Three-stage birefringent filter tuning smoothly over the visible region: theoretical treatment and experimental design. Appl Opt. 1980 Mar 1;19(5):702-10

Nonstationary Optical Forces and Collision-Driven Ionization Beyond Traditional Keldysh Regimes

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We explore a new ionization regime emerging under intense femtosecond laser fields, where neutral particles are trapped and accelerated by nonstationary optical forces. This mechanism leads to collision-induced ionization, without relying on multiphoton or tunneling absorption. The model extends beyond Keldysh theory by introducing radiative capture and acceleration primary steps, validated through analytical solutions. Therefore, a new type of collision ionization can be observed in conditions of powerful femtosecond pulse propagation in air. The main difference of this new type of collision ionization from the multi-photon and tunnel ionizations, that all processes are included in the pulse width. Thus, the new ionization regime will realize one conical emission of charged particles, due to the collisions between trapped particles and free ones. [1] It is shown in [2] that nonlinear optical mechanisms can compress accelerated neutral atoms to distances up to several times the electron orbitals' size around the nuclei. This insight led us to develop a method and construct a device to separate nuclei from electrons while preserving their kinetic energy at several GeV.

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Synchronous Fluorescence Spectroscopy for Quantitative Analysis of Essential Oils

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Synchronous fluorescence spectroscopy (SFS) has emerged as a powerful analytical tool for the qualitative characterization and quantitative detection of essential oils (EOs. By scanning excitation and emission wavelengths simultaneously at a fixed offset ($\Delta\lambda$), SFS generates simplified, high-resolution spectra—ideal for analyzing complex EO mixtures without prior separation.

SFS enables rapid identification of essential oils through their unique fluorescence fingerprints. Studies show that oils from different botanical sources or brands can be clearly distinguished using SFS combined with chemometric methods such as Principal Component Analysis (PCA). Even minor adulteration, such as blending oils or adding non-fluorescent carriers, causes noticeable spectral changes, making SFS a reliable tool for quality control.

Synchronous fluorescence spectroscopy can also be calibrated for the quantification of essential oils in various formulations. Recent work is focused on demonstrated accurate measurement of EO using SFS. Synchronous fluorescence spectroscopy is rapid, non-destructive, and requires no chromatographic separation. SFS is also environmentally friendly and cost-effective compared to conventional techniques like GC-MS. Its ability to analyze multiple fluorescent components simultaneously and deliver high repeatability makes it suitable for both research and industrial quality control. With continued advances in instrumentation and data processing, SFS is poised to play a growing role in EO research and industrial applications.

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Engineered Micro/Nano-Hierarchical Polymer Surfaces for Advanced Self-Cleaning Solar Panels

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Maintaining clean surfaces is crucial for ensuring the efficient and sustainable performance of high-efficiency solar panels. Recent advancements in femtosecond (fs) laser processing have enabled the creation of micro- and nano-scale structures on polymer surfaces, significantly enhancing their self-cleaning and anti-reflective properties. This approach also helps conserve water and eliminates the need for complex mechanical cleaning systems. Polymers such as polyethylene terephthalate (PET), polydimethylsiloxane (PDMS), and polycarbonate (PC) are particularly well suited for these applications due to their natural hydrophobicity and optical transparency.

The self-cleaning functionality is based on reducing the adhesion of dust, water, and other contaminants to the surface. In solar thermal systems, polymers and polymer-based composites are favored for their versatility and cost-effectiveness. However, traditional chemical surface treatments often fall short due to limited durability and the potential for adverse interactions with the polymer material.

Ultra-short pulsed laser processing, such as femtosecond laser texturing, has emerged as a promising alternative for modifying polymer surfaces. This method offers precise control over processing parameters and enables the generation of complex surface morphologies. The resulting hierarchical structures at the micro- and nano-scale dramatically reduce surface adhesion, making the treated polymers highly resistant to fouling by dust, oils, and ice. In some cases, these surfaces also achieve low sliding angles (<10°), allowing contaminants to be removed easily by rain or minimal water flow.

This research aims to develop durable, self-cleaning polymer surfaces for solar energy systems using femtosecond laser structuring. By engineering surface textures at multiple scales, the goal is to reduce maintenance requirements and enhance the long-term energy output of solar collectors. These laser-treated polymer surfaces show great potential as coatings for photovoltaic panels, solar thermal devices, and other outdoor components. Their ability to minimize surface reflection, resist contamination, and maintain optical performance under real-world conditions positions them as a valuable material innovation for future solar energy technologies.

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Plasmonic Hot Spots in Conductive Ag Nanowire Meshes

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Surface plasmons propagating in metal nanowires scatter at wire intersections and form a hot spot [1] suitable for enhancing Raman scattering and localized fluorescence.
We present a simple method for constructing metal nanowire meshes by spin coating multiple layers of poly(methyl methacrylate) suspension containing silver nanowires and etching the supporting structure with acetone. After removal of the polymer the nanowires settle on the substrate and form a mesh. By varying the number of layers, we have precise control over the density of the resultant mesh.
When illuminated the mesh exhibits hot spots due to plasmon scattering in intersecting nanowires. The intensity of the hot spots shows slight dependance on the polarization of the incident light.

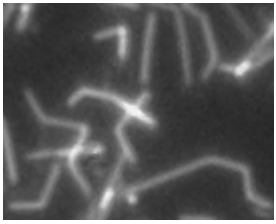

Figure 1: Hot spots in intersections of the nanowire mesh.

References:
[1] Zhuanfang Bi, Mu Yang, Yang Shang, Optics Communications, 429(2018)

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