19th International Young Scientist Conference **"Developments in Optics and Communications 2023"**

ABSTRACT BOOK

Optical Materials and Phenomena

Laser Physics and Spectroscopy

Communications

Biophotonics

Vision Science

DEVELOPMENTS in Optics and Communications 2023

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81st International Scientific Conference of the University of Latvia 2023

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Welcome

Dear participants of **DOC 2023**,

This year we are happy to have a hybrid format where some of You are joining us physically on-site in Riga and some virtually on-line. The purpose of this conference is to bring together students and young scientists to discuss latest scientific results and upcoming trends in the fields of optics and photonics.

"*For the things we have to learn before we can do them, we learn by doing them.*" – Aristotle

Learning by doing means learning from your own experiences. Experience gained by watching, reading, and listening is greatly complemented by the direct experience of doing. We wish You to learn at least one small thing by doing during this conference, whether it is preparing the presentation, giving a talk, asking a question or socializing with other young scientists.

Best regards,
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Contents

Invited Speakers

Talks

Laser Physics and Spectroscopy

Poster Session 1

Part I
Invited Speakers

SPIE. STUDENT CHAPTER UNIVERSITY OF LATVIA

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81st International Scientific Conference of the University of Latvia 2023

The study of low and high-order nonlinear optics phenomena in the Lab. of Nonlinear Optics

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Interactions of intense laser light fields with matter form the subject of study in nonlinear optics (NLO). It involves various phenomena, mainly characterized by the multiphoton nature of all interactions. The main measuring scale is the intensity of the laser field, with increasing intensity optics moves from domains of linear optics to low-order and high-order nonlinear optical phenomena.

NLO is essential in the generation of coherent extreme ultraviolet radiation sources, nonlinear spectroscopy methods, the development of broad-bandwidth light sources, and other areas of photonics and optoelectronics. The NLO experiments require the application of short laser pulses with sufficiently high intensity. The picosecond and femtosecond laser systems are common in the study of nonlinear properties of materials. The nonlinear optical response can be additionally enhanced using the synthesized small-sized multi-atomic ensembles – nanoparticles and quantum dots.

In this presentation, some recent studies of NLO properties of small and large molecules, quantum dots, and nanoparticles of different materials carried out at the University of Latvia and the Institute of Solid State Physics are described [1-9]. A short introduction to the physics of low and high-order nonlinear optical phenomena is presented. Among the topics of presentation are the effects of self-focusing and defocusing expressed in a variation of the nonlinear refraction, nonlinear absorption of spectrally tunable femtosecond pulses in carbon disulfide, HgTe quantum dot films, exfoliated Bi_2Te_3 nanoparticle films, and mercury sulfide quantum dots, high-order harmonics generation (HHG) in connection with the characterization of laser-induced plasma plumes (LIP) in chromium, indium, and tin plasmas, etc. Also the study of HHG with two-color orthogonal pumping scheme and chirped pulses to control and tune HHG in carbide-containing LIPs, with SiC, B_4C, and Cr_3C_2 nanoparticles are presented.

Acknowledgments.
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Development of X-ray sensitive hybrid organic-inorganic systems utilizing tungstate nanoparticles for radiation detection applications

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The active field of research currently involves the development of new radiation detectors using nanomaterials. Hybrid materials, which consist of an organic matrix combined with high-Z nanoparticles, are highly promising for radiation detection applications.

This study focuses on the development of X-ray sensitive hybrid organic-inorganic systems utilizing tungstate nanoparticles (AWO_4, where A= Ca, Zn, Sr, Cd) and a P3HT:PCBM blend. The nanoparticles were synthesized using the hydrothermal method and analyzed using X-ray diffraction and scanning electron microscopy. The X-ray detectors were composed of five layers (ITO/PEDOT:PSS/NPs:P3HT:PCBM/BPhen/Al) and operated without a bias voltage. The detectors were tested using synchrotron radiation, and the addition of high-Z element nanoparticles improved the detectors' X-ray attenuation efficiency. The high dynamic range of the fabricated detectors allowed for recording X-ray absorption spectra and performing imaging experiments.

These hybrid detectors with different tungstate nanoparticles offer a cost-effective X-ray detection solution that can be optimized for a particular energy range by selecting the A-cation element.

Acknowledgments

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Novel family of 2D nanomaterials - MXene towards biomedical application

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MXene is a new family of 2D nanomaterials that shows great potential for biomedical applications. MXenes are synthesized through selective etching of the A layer from MAX phases, a family of ternary carbides and nitrides. MXenes have high surface areas, excellent conductivity, and tunable surface chemistry, making them ideal for a range of applications. The biocompatibility and low toxicity of MXenes make them promising candidates for various biomedical applications. MXenes can be used in drug delivery, bioimaging, biosensing, and tissue engineering due to their high surface area and biocompatibility. MXenes have shown to be effective in drug delivery as they can encapsulate various drugs and release them at a controlled rate. MXenes can also be used in biosensing by detecting biological molecules such as glucose, DNA, and proteins. In addition, MXenes can also be used in bioimaging as they have excellent light-scattering properties. MXenes also have the potential to be used in tissue engineering due to their tunable surface chemistry, high surface area, and ability to promote cell growth. This lecture will pay special attention on MXene application in conductive tissues regeneration and anticancer therapy. In tissue regeneration, MXenes have been shown to promote cell adhesion and proliferation, as well as enhance the differentiation of stem cells into specific cell types. This makes them useful for creating scaffolds for tissue engineering, which can aid in the repair of damaged or diseased tissues. MXenes have also been investigated for their potential in promoting nerve regeneration and wound healing. In anticancer treatment, MXenes have shown promise as drug delivery vehicles due to their high surface area and ability to bind to drugs. Additionally, their electrical conductivity has been shown to enhance the efficacy of certain cancer treatments, such as photodynamic therapy. MXenes have also been investigated for their potential as imaging agents for cancer diagnosis and monitoring.

Overall, the unique properties of MXenes make them attractive candidates for a wide range of biomedical applications, including tissue regeneration and anticancer treatment. Ongoing research in this field is expected to uncover new and innovative ways in which these materials can be used to improve human health.

Fundamentals of the laser beam shaping

Szatkowski Mateusz

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The ability to control light's parameters, such as amplitude, phase, and polarization, has not only paved the way for many modern applications but has also increased scientific society's interest in laser beam shaping. This term refers to all kinds of light tailoring performed for various purposes. Recently, digital holography has become one of the most important techniques for laser beam shaping. This technique follows classic holographic principles but is enhanced with modern devices such as spatial light modulators or digital micromirror devices, which offer precision, speed, and a user-friendly experience.

In this talk, I delve into the fundamentals of laser beam shaping through a step-by-step approach, focusing on its most practical aspects. I show how it can be implemented into daily laboratory tasks, starting with simple aberration corrections, through beam quality examination, and finally getting to advanced research tasks.

The talk is designed to be understandable by everyone who has pursued any class related to wave optics, although a short introduction of the used terms will also be given."

Acknowledgements

Mateusz Szatkowski serves as an OPTICA Ambassador.

Design and implementation of optical imaging systems for the human eye

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My current research revolves around the design and implementation of non-invasive optical systems to study optical and structural properties of the human eye. This is knowledge is applied to the study of biomarkers of the visual system and early detection of ocular diseases. Vision science is a multidisciplinary field including optical physics, biology, optometry, and ophthalmology.

Advanced optic systems are crucial for the detection and characterization of ocular diseases. Therefore, I am currently building an adaptive optics system including 3 different imaging techniques that work together to provide high speed and high lateral- and axial-resolution 3D images in both the anterior and posterior human eye for different applications. On one hand, the main purpose of this suite is to characterize retinal blood flow in small capillaries to study diabetic retinopathy. On the other, it is used for the characterization of changes in the microstructure of the main outflow pathway that can cause high intraocular pressure and, possibly, glaucoma.

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Alessandra is a Postdoctoral Fellow, and OPTICA Ambassador 2022.

Career planning as Olympic weightlifting

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If I had the opportunity to meet my younger self, I'd tell him...". One of the most important lessons I have learned is to learn from the mistakes of others and be open to following their guidance. This piece of advice remains valid for both personal and professional life. Fortunately, the latter is not so hard to master, especially if you are at the beginning of the professional route.

In my presentation, I draw parallels between a career in academia and Olympic weightlifting, revealing similar underlying principles. From laying a strong foundation and strengthening the core to executing the lift by activating key muscles, I will share effective strategies and insights for managing each stage. Although my talk primarily targets academia, many of these techniques can be adapted for success in the industry as well.

Acknowledgements
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Part II
Talks

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The Non Linear Optical Properties of the Quaternized Ammonium Salt and their Dependence on Lengths of Molecular Aliphatic Chains

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Today new liquid crystal systems with improved electro-optical properties are being actively created. One of the promising areas is ferroelectric liquid crystals. Recently we have studied structural and vibrational property of the quaternized ammonium salt (N_4OYBDHA molecule) – perspective object for liquid crystal systems []. Equilibrium structure of the N_4OYBDHA molecule (I), which contains atoms, presented on Fig. 1.

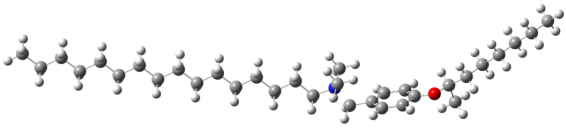

Figure 1: Equilibrium configuration of the N_4OYBDHA molecule calculated at the B_3LYP/cc-pVTZ level of theory.

It was interesting to find how electric and nonlinear properties of this molecule depend on lengths of long and short aliphatic chains. For now we have optimized three additional structure obtained from the N_4OYBDHA molecule by removing of the long or/and short aliphatic chains. These three new molecules are represented on Fig. 2.

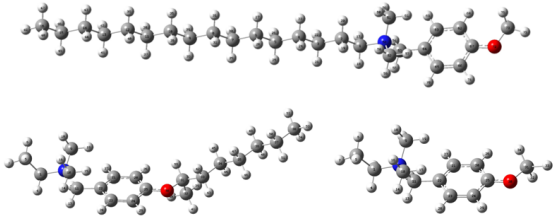

Figure 2: Equilibrium configurations of the N_4OYBDHA molecule in which: (II) short aliphatic chain removed (top molecule), (III) long chain removed (lower left molecule) and (IV) both chains removed (lower left molecule) calculated at the B3LYP/cc-pVTZ level of theory.

Values of the dipole moment and its components of the I-IV molecules calculated calculated at the B_3LYP/cc-pVTZ level of theory are collected in Tabl. 1. Values of the polarizability tensor components and its invariants calculated using various basis sets are given in Tabl. 2.

Table 1: Dipole moment and its components of the I-IV molecules calculated at the B $_3$ LYP/cc-pVTZ level of theory. All data are presented in Debye.

Molecule	m	m $_x$	m $_y$	m $_z$
I	12.92	12.64	-2.68	-0.22
II	26.63	0.00	0.00	26.63
III	19.42	-19.23	2.55	-0.91
IV	7.53	0.00	0.00	7.53

Table 2: Polarizability tensor components and tensor's invariants of the I-IV molecules calculated at the B $_3$ LYP/cc-pVTZ level of theory. All data are presented in Atomic Units.

Molecule	a	b	a_{xx}	a_{xy}	a_{xz}	a_{yy}	a_{yz}	a_{zz}
I	425.4	279.0	336.8	6.9	10.3	347.4	70.3	592.1
II	332.1	225.3	264.5	7.8	-3.7	250.0	4.3	481.6
III	244.2	154.3	200.3	-9.2	5.5	187.1	-11.4	345.2
IV	163.5	113.4	142.3	2.0	-22.1	119.8	2.2	228.6

The data on fisrt hyperpolarizabilities for studied molecules are available as well.

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Varying magnetic field measurements using NV centers in diamond

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In this study NV centers in diamond are used for varying magnetic field measurements based on the Zeeman effect of the ground state energy levels (See Fig.1) in combination with the method of ODMR [1] for developing a high DC current stabilization prototype device.

A bias magnetic field is aligned along one of the 4 possible directions in the diamond crystal lattice giving a linear response in the change of the ODMR frequencies depending on the measured magnetic field.

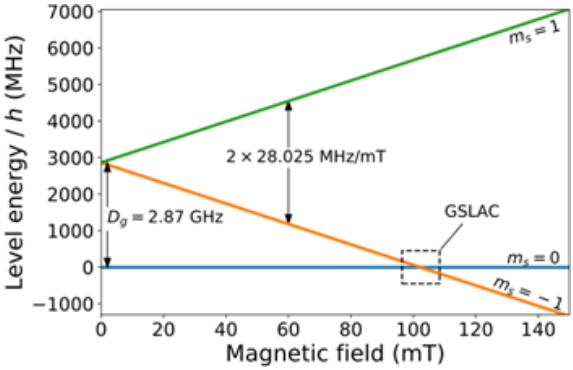

Figure 1: Levels of the NV centers' electron-spin magnetic sublevels in the ground state [1].

A dual resonance modulation technique is used to enhance the stability (including mitigation of temperature caused drift sand exciting laser power fluctuations) and sensitivity of the magnetic field measurements [2].

Measurements of a varying magnetic field generated by a direct current flowing through a wire will be used as an input for a PID algorithm to stabilize a DC current.

Acknowledgements
We acknowledge the support from the Latvian Council of Science, project No. lzp-2021/1-0379: "A novel solution for high magnetic field and high electric current stabilization using color centers in diamond".

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Investigation of energy transfer and light amplification properties of Alq3:DCM derivatives in thin films

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Red laser dye 6-(tert-butyl)-4H-pyran-4-ylidene malononitrile (DCM) has applications in small and compact light emission devices such as OLED, organic solid-state lasers, organic solar cells. The downside of DCM molecule is that it has large intermolecular interaction which reduce photoluminescence. DCM photoluminescence properties can be improved by Forster resonance energy transfer (FRET), or the molecule can be modified by adding different electron groups. For FRET to work two molecules are needed – one as the acceptor and other as the donor. Donor and acceptor molecules are made in host-guest systems, where the energy from donor is transferred to the acceptor in non-radiative way. The acceptor is DCM molecule and organic semiconductor tris(8-hydroxyquinolinato)aluminum (Alq3) can be used as the donor.

In this work 8 host-guest systems were made from 4 DCM derivatives and 2 Alq3 derivatives. These systems were made in thin films by the spin-coating method. Absorption, luminescence spectra, photoluminescence quantum yield and amplified spontaneous emission (ASE) of the samples were measured.

The measured absorption and luminescence spectra show that acceptor absorption overlaps with donor emission, therefore effective FRET can happen. Amplified spontaneous emission was successfully observed for all samples. ASE excitation energy thresholds of host-guest systems are compared with the previously obtained ASE thresholds of DCM derivatives in thin films without the host. Results show that ASE threshold energies are much lower for host-guest systems than pure DCM derivatives in thin films. Obtained host-guest systems show potential in application solid-state lasers as the gain medium.

Controlling Possibilities of Functionalized Graphene Oxide Liquid Crystalline Microdroplets

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Graphene oxide (GO) is the most widely used graphene derivative with significant properties, functionalization capability, and large surface area [1]. GO is of great interest for the formation of liquid crystalline (LC) phases that are applicable in the design of various types of small and thin devices with tunable parameters. This is possible due to combination of self-assembling properties of LCs and strong mechanical properties of GO [2]. The structural ordering could be remarkably enhanced by enriching GOLC structures with nanoparticles. Besides, functionalization of these materials with organic molecules could reveal additional peculiarities for cutting-edge applications. In this work, we focus on the electrochemical exfoliation of GO and LC phase formation of the synthesized material. Improvement of structural, electrochemical, and electro-optical features of GOLC materials was done by the addition of aromatic and non-aromatic amino acids (AA). The decoration of AA-functionalized GO flake suspensions with magnetic nanoparticles was implemented. Moreover, the orientation of the GOLC microdroplets was manipulated by a magnetic field and mechanical deformation which significantly broaden their functionality and hence the application possibilities. The crystallographic structure, chemical compound analysis, bond types/hybridizations, optical characterization, purity, absorbing properties, liquid crystalline phase, morphology, chemical composition, mass loss, and particle size distribution of GO were investigated by XRD, FTIR-ATR, Raman, PL, ICP-MS, UV-Vis spectroscopes, POM, SEM microscopes, TGA, and Particle size analyzer.

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Multimodal Nanoscale Upconverters for Optical Imaging, MRI, And Temperature Sensing

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There is a growing interest in developing multifunctional materials that can be used for both bioimaging and drug delivery. Rare-earth doped upconverting nanoparticles (UCNPs) have attracted significant attention due to their unique optical properties, such as low-energy excitation, high signal-to-noise ratio, absence of blinking and have high potential to be applied in theranostics as effective bioimaging probes etc [1]. However, several issues need to be addressed before UCNPs can be used widely for biomedical purposes. One of the primary concerns is the extensive heating of samples caused by 980 nm lasers. To address this issue, researchers have co-doped the UCNPs matrix with Yb^{3+} and Nd^{3+} pair to shift the near-infrared (NIR) excitation to 808 nm, which falls within the first biological window [2]. This approach allows 808 nm laser radiation to penetrate deeper into biological tissues compared to the commonly used 980 nm wavelength laser radiation, as water absorbance is approximately 90-95% lower in the first biological window [3].

In this study, we describe the synthesis of well-defined UCNPs with a complex core-shell composition that can be excited using both 808 and 980 nm laser radiation. We evaluate the optical and temperature-sensing properties of these UCNPs in detail and investigate their colloidal stability in aqueous and biological media. We also examine the viability of human kidney cells (HEK 293t) by XTT cell viability assay after exposure to UCNPs' solutions of different concentrations. Finally, we explore the potential use of these materials as MRI contrast agents.

Acknowledgements

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Incorporation of carbon in C+ ion-implanted silica glass

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The presence of carbon impurities in high-purity silica glass can occur during the synthesis process from silicon-organic precursors or from the melting environment. While silicon oxycarbide glasses have been extensively studied [1], the effects of low-concentration carbon dopants and the incorporation of single carbon atom in the SiO2 glass is still not well-understood. In this work, the properties of carbon atoms introduced into silica through C+ ion implantation at various doses (1×1015 – 3×1016 ions/cm 2) were examined. Samples implanted with equivalent doses of Ne+ ions were used to seperate chemical effects and radiation damage. Optical absorption and photoluminescence spectra of all samples indicate the creation of the usual bands due to NBOHC's and SiODC's: divalent Si and oxygen dangling bonds for C-implanted samples. In all samples, a signal of intrinsic defects, "E'-centers" – silicon dangling bonds or oxygen vacancies are present in EPR spectra. An additional broader signal is present in C-implanted glass; its intensity increases with irradiation dose due to the C impurities in the SiO2 structure previously reported as carbon-related surface radicals [2]. IR absorption spectra revealed the appearance of interstitial CO2 and CO molecules in C-implanted samples at higher doses indicating that C acts as a reducer in SiO2 structure. Additionally, the ultraviolet photoluminescence band at 3.7 eV region observed in the C+ implanted silica allows the identification of the formation of possible C impurities – naphthalene molecules previously identified in sol-gel silica glasses [3].

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Controlled synthesis of Al doped ZnO nanoparticles for optical biosensing applications

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The development of sensing technologies that offer high sensitivity and selectivity is crucial. Localized Surface Plasmon Resonance is one of the optical sensing mechanisms being explored for its efficient sensing properties [1]. Metal-oxides, which are active plasmonic materials in the long-wavelength infrared regions, are being considered for their potential in sensing applications. In this study, we have synthesized Al-doped Zinc oxide nanoparticles, a controlled growth process, supported by numerical models of the many-particle systems of doped metal oxides [2]. Our results indicate that metal-oxides have the advantage of being able to tune the plasmon resonance peak from the near to mid-IR region by altering the geometry and doping levels of the nanoparticles. The plasmonic properties of the Al-doped ZnO nanoparticles synthesized by the reflux method were investigated using FT IR, UV-Vis spectroscopic methods and compared to the experimental results obtained from the sol-gel and combustion synthesis. We found that the most efficient doping could be achieved by the reflux synthesis technique, which provides a higher control over the nanoparticle growth parameters, and has been previously reported in the literature as well [2]. In addition, our experimental results showed that the maximum intensity in the plasmonic absorption peak was not necessarily exhibited for the samples with the highest doping concentration value. This finding suggests that a careful balance of doping concentration may be required to achieve plasmonic properties in metal oxide nanoparticles for sensing applications. Our study demonstrates the potential of metal-oxide nanoparticles as a base element for optical biosensing and highlights the importance of using computational models to better understand the behavior of nanostructures in sensing applications.

Acknowledgments

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Rare skin disease assessment through multispectral imaging

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In the European Union, a disease is classified as rare if its prevalence is less than 1 in 2000 people. However, there are more than 6000 diseases that can be classified as such [1]. Due to their large number, for many of the diseases there have not been sufficient study into possible diagnostic and therapeutic methods.

Multispectral imaging has been studied for a wide variety of biomedical applications including dermatological disease imaging [2]. Depending on the wavelengths that have been chosen in the imaging device design, different skin chromophores can be targeted depending on their optical properties [3]. A combination of 405, 526, 663 and 964 nm has been shown to be sensitive to increased pigmentation of the skin associated with malignant processes [4]. This method combines autofluorescence imaging induced with 405 nm illumination and diffuse reflectance imaging that uses 526, 663 and 964 nm illumination. The device captures RGB images using a CMOS camera. Analysis of multispectral images was conducted using MATLAB and Python programming languages.

Preliminary results show that Neurofibromatosis Type 1 lesions café -au-lait macules exhibit an increased diffuse reflectance signal under 526 nm illumination compared to more common types of lesions of similar characteristics. They also have an increased p' parameter, which is a parameter that combines the proportions between the skin and the lesion under 526, 663 and 964 nm illumination. Similar observations were done with neurofibromas, however, the difference was much less pronounced.

For Fabry disease preliminary results show the difference in signal is more pronounced under 663 nm and 964 nm illumination but is heavily dependent on the severity of the disease for that specific patient.

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Chitosan-PLA electrospun nanofibrous membranes loaded with silver nanoparticles for biomedical application

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Introduction. Polylactic acid (PLA) and chitosan (CH) are two biodegradable polymers that possess high biocompatibility and biodegradability [1]. PLA is a leading candidate intended for medical applications due to its chemical, mechanical, and biological properties. PLA nanofibers are similar to the extracellular matrix (ECM) and possess a large specific surface area and high porosity with small pore size and appropriate mechanical properties, that are highly attractive for applications in the medical area [2]. The electrospun CH-PLA nanofibers loaded with silver nanoparticles are found to release ions Ag+ at a concentration level providing mandatory antimicrobial efficacy [3]. To summarize, the effective combination of biocompatible polymers with antibacterial materials (silver nanoparticles, AgNPs) can allow to produce of highly-effective scaffolds using electrospinning for tissue regeneration. The goal is the evaluation of the antibacterial properties and cytotoxicity of Ch-PLA-AgNPs nanofibrous electrospinning membranes depending on the concentration of incorporated AgNPs.

Materials and methods. Ch-PLA-AgNPs nanofibrous electrospinning membranes were produced by electrospinning with the addition of different concentrations AgNPs (400, 200, 100, 50 µg/ml). Determining the colony count was carried out using the streak plate technique at different time intervals of incubation (2, 4, 6, 8 and 24 h) in the suspension of *S. aureus* and *E. coli* (final density of 1x105 colony forming units (CFUs)/mL) after ultrasonication of the samples.

Results. The membranes Ch-PLA-AgNPs (400, 200 µg/ml) inhibited the growth of both microorganisms at 2, 4, 6 h point of the test. However, Ch-PLA-AgNPs (100 µg/ml) showed a potent antibacterial effect on *E. coli* at 2, 4, 6 h point of the test. Noticeably, Ch-PLA-AgNPs (100, 50 µg/ml) possessed lower antibacterial potential than Ch-PLA-AgNPs (400, 200 µg/ml) against *S. aureus*.

Conclusion. The higher AgNP content in the solution improved the antibacterial properties of membranes. Generally, Ch-PLA-AgNPs electrospun membranes' antimicrobial properties against both microorganisms make them applicable as an antimicrobial remedy.

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Simultaneous ternary message-passing protocol based on optical vortices – hologram generation and information encoding

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Using the optical controlled-swap gate, the simultaneous message-passing protocol aims to determine the overlap between two signals, without revealing their content. The overlap is determined through the output power, detected by the power meter after passing through the polarization Mach-Zehnder interferometer.

The message is encoded as the phase shift of the Laguerre-Gaussian mode (optical vortex), which is generated by the Digital Micromirror Device through amplitude modulation. As ternary basis requires three possible states, therefore, the phase shift of an optical vortex is divided into three possible values.

Therefore, the crucial component refers to beam shaping, where the message has to be efficiently encoded. In this work we show the core of the encoding procedure, starting from the hologram design that even if based on amplitude modulation, enables complex amplitude shaping. Then, the real experimental scenario will be discussed, where we compared a set of images, through the overlap of their hash sequences. The work covers the whole signal preparation starting from an idea and going step by step through the whole process finalized by the successful data transmission.

Average fixation duration and the number of fixations in children with and without reading difficulties

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Approximately 90% of total reading time is devoted to eye fixations [1]. The development of the reading circuit occurs rapidly, typically by age [2]. Therefore, reading difficulties may significantly impact a child's future learning success [3]. Studies investigating the relationship between fixation eye movements and reading fluency have shown different correlation assessments between increased average fixation duration, the number of eye fixations, and reading speed [4]. The aim of our study is to determine the correlation between reading eye movement parameters and *Acadience*™ test parameters for school-aged children in grades 1-6, both with and without reading difficulties.

The study included 378 participants from different schools, ranging in age from 6 to 13 years. They were divided into two groups: those with normal reading ability and those with reading difficulties. Certified speech therapists used the *Acadience*™ (DIBELS Next) test to determine each participant's group. Fixation eye movements were recorded using the *Tobii Pro Fusion* eye movement recording device at a frequency of 250 Hz and analysed using the I2MC (*Identification by Two-Means Clustering*) algorithm, which is available in MATLAB.

We analysed fixation duration values in 63 second-grade children for statistical analysis, using the Two Sample t-test. We found a statistically significant difference ($p = 0.004$) in the average fixation duration between those with and without reading difficulties. There was a statistically significant difference ($p = 0.18$) in the number of fixations between those with and without reading difficulties. For second-grade children, we found that the correlation of the literacy coefficient with the fixation duration was stronger than with the number of fixations.

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Evaluation of Saccadic Eye Movements of School-age Children With the Video Oculography and the NSUCO Method

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Introduction. Undiagnosed oculomotor disorders can impede the identification of other developmental and perceptual disorders, particularly in school-age children [1]. Various tests have been developed to evaluate the oculomotor system, such as the subjective Northeastern State University College of Optometry (*NSUCO*) [2], and the objective, non-invasive video oculography method. However, relationship between eye movement recording and the *NSUCO* method is not well understood, and no studies have investigated the association between eye movement disorders and reading difficulties as evaluated by the Acadience reading assessment test. The aim of this study is to describe saccadic eye movements in children with and without reading disorders using the *NSUCO* test and the video oculography.

Method. A total of 378 children, aged 6 to 13 years, from four Latvian schools participated in this study. Prior to testing, all participants underwent a visual function screening which included visual acuity assessment (using contact lenses, or spectacles if necessary) at of 65 cm distance, as well as an evaluation of a dominant eye, stereovision, phoria, and convergence). Saccadic eye movements were evaluated by the *NSUCO* test. Reading skills were assessed by school speech-therapists using the Acadience reading assessment test.

Results. 98 children (26%) were found to have reading difficulties based on the Acadience reading assessment test. The results of the *NSUCO* test demonstrated that 156 children (41%) had saccadic problems based on one parameter failure and 43 children (11%) had saccadic problems based on two parameter failure. Only 11 children (3%) were found to have both - reading difficulties and saccadic disorders. The chi-square test showed no statistically significant difference in the proportion of saccadic disorders between children with and without reading difficulties (χ^2=0.0059; $p = 0.94$).

Conclusions. Our study demonstrates that reading difficulties assessed by the Acadience reading assessment test are not only due to saccadic disorders evaluated by the *NSUCO* test in school-age children.

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Blinking Patterns During Vision Training

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Eye blinking or the quick momentary closure of the eyelid is one of the most common human behavioural activities occurring 12-15 times per minute on average (Doughty and Naase, 2006). Mean blinking rate (MBR) was found to be affected by the degree of required attention (Baumstimler and Parrot, 1971). The aim of this study was to evaluate blinking habits during vision relaxation exercises. A total of 42 healthy volunteers were enrolled in the study. Vision relaxation contained horizontal, vertical, diagonal, and rotatory eye movements, and far-near exercise. There were three experimental conditions: 1 – natural looking straight ahead; 2 – manual vision relaxation exercises; 3 – vision relaxation exercises with EyeRoll device. Participant's eyes were filmed during all conditions. The videos were analysed to count blinking frequency. Data analyses demonstrated that there was significant decrease of total number of blinks during vision relaxation exercises compared to condition 1. Largest changes were observed in full blinks. Changes in total blinking frequency did not corresponded to the subjective feeling after training. The subjective feeling was not affected by the way (manually or with the device) the training was performed. In conclusion, blinking rate decreases during vision relaxation exercises as in other attention-demanding tasks. Therefore, blinking breaks are suggested during vision relaxation exercises both for manual and performed with Eye Roll device.

Keywords: blinking, blink frequency, vision relaxation training, Eye Roll.

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Development of near visual functions selection algorithm for computerized screening

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Introduction. In recent years, technological advances have led to the introduction of computerized screening equipment and programmes in eye care practices, allowing a wider range of visual functions to be investigated in the shortest possible time. These programmes include not only distance visual acuity testing, but also near visual function screening to identify accommodation and vergence disorders [1]. It is important to identify accommodation and vergence disorders as they can negatively impact the physiological or perceptual processes of vision, academic performance and behaviour in children [2], cause a decrease in labor productivity, worsen the emotional state, and interfere with daily activities in adults [3].

Purpose. The study aimes to analyze expected values of the screening tests and create an accommodation and vergence dysfunction selection algorithm for computerized vision screening.

Method. 75 subjects (aged 22 +/- 5 years) participated in the study. Each participant was tested with the computerized vision screening device and manually using standard optometric methods. We analyzed and compared near vision functions data obtained in both examinations: binocular accommodative facility, vergence facility, positive and negative fusional vergence amplitudes, heterophoria, and AC/A value.

Results. The sensitivity and specificity of each test included in computer vision screening were determined. The best results showed binocular accommodative facility tests (sensitivity 86%, specificity 84%). It is important to note that this test was very similar to the standard optometric test, which could be the reason for such high values. The worst result showed positive fusional vergence test (sensitivity 20%, specificity 90%).

Conclusion. Since computerized screening tests are modified and differ in methodology from standard optometric tests, they should apply expected normal values other than those currently developed.

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Part III
Poster Session 1

SPIE. STUDENT CHAPTER UNIVERSITY OF LATVIA

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Preparation of functional Ga_2S_3 and Ga_2Se_3 shells around Ga_2O_3 nanowires via sulfurization or selenization

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Combining defect semiconductors Ga2S3 and Ga2Se3 in Ga2O3-based heterostructured nanowires (NWs) have potential in photonics and optoelectronics applications due to the materials appealing optical properties. In this work, we have developed and studied Ga2O3–Ga2S3 and, for the first time, Ga2O3–Ga2Se3 core-shell NWs. Ga2S3 and Ga2Se3 shell was obtained during the hightemperature sulfurization and selenization process of pure Ga2O3 NWs, respectively, in a chemical vapour transport reactor. As-grown nanostructures were characterized with scanning and transmission electron microscopy, X-ray diffraction, X-ray photoelectron spectroscopy and photoluminescence measurements. Single-nanowire photodetector devices were fabricated in order to demonstrate their electric and photoconductive properties. Such novel core-shell NW heterostructures could potentially be used in next-generation nanoscale electronic and optoelectronic devices.

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X-Ray Luminescence of AlN:Mn^{2+} ceramics

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AlN is a promising material for biomedical applications due to its low toxicity and accessibility as nanosized particles. When doped with Mn^{2+} , AlN:Mn^{2+} emits 600 nm luminescence, which fits the beginning of the first NIR window. Besides, luminescence possesses long-lasting (PersL) properties. The X-ray-excited luminescence of AlN:Mn^{2+} ceramics (Cer) was studied at room temperature and compared with the photoluminescence using 263 nm excitation [1] to propose differences and similarities. Furthermore, long-lasting PersL AlN:Mn^{2+} Cer caused by X-ray excitation was examined to compare with UV-excited long-lasting PersL. It was observed that both the X-ray-excited luminescence spectrum and photoluminescence spectrum of AlN:Mn^{2+} consist of the same sub-bands. They are the Mn-caused band at 600 nm and the oxygen-related defect bands at 400/480 nm. The ratio of luminescence intensities in these bands depends on the used excitation. Properties of X-ray excited $MnMn^{2+}$ PersL were examined and found to be consistent with those observed at UV-excitation. The results observed allow the proposal of the X-ray excited PersL mechanisms for AlN:Mn^{2+}, which makes this material prospective for application in biomedicine.

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Site-dependent luminescence of Cr^{3+} in $CaAl_{12}O_{19}$

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Phosphors containing multiple luminescence centres are promising candidates for application in temperature sensors based on fluorescence intensity ratio or luminescence lifetime. Structure-sensitive luminescence centres exhibiting different response to temperature changes can greatly improve the sensitivity and precision of temperature measurement [1]. Optical properties of transition metal Cr^{3+} ions are sensitive to local structure due to it 3d3 electron structure. Multi-centre luminescence of Cr^{3+} has been reported in matrices with multiple octahedral crystallographic sites [2]. Calcium hexaaluminate ($CaAl_{12}O_{19}$) exhibits magnetoplumbite-type structure with 3 distinct octahedral sites suitable for Cr^{3+} substitution [3] and is a perspective candidate to obtain a phosphor with multiple Cr^{3+} luminescence centres.

In this study, a series of Cr^{3+}-activated $CaAl_{12}O_{19}$ phosphors was synthesized by the solid-state reaction method. Electron paramagnetic resonance spectroscopy was employed to confirm the incorporation of Cr^{3+} in the material. Luminescence properties of $CaAl_{12}O_{19}$:Cr were investigated using steady-state and time-resolved photoluminescence spectroscopy techniques.

Our results indicate the presence of three Cr^{3+} paramagnetic centres with different local structure parameters. Photoluminescence spectra consist of three spectral components – red narrow-band emission with maxima at 689 and 700 nm attributed to the spin-forbidden $^2E \rightarrow A_2$ transition and broadband infrared emission with maximum at 785 nm originating from the $^4T_2 \rightarrow {}^4A_2$ spin-allowed transition. The excitation spectra and decay kinetics of corresponding emission bands have revealed the existence of three luminescence centres in $CaAl_{12}O_{19}$:Cr.

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By visualizing the deformation with mechanoluminescent particles, additive manufacturing offers a practical alternative to stress and strain simulation

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The use of stress-strain analysis in structural design or mechanical components is critical for avoiding or investigating structural failures. Mathematical full-field stress simulation yields unreliable results for complex designs. The usage of currently available strain gauges makes experimental analysis difficult and impossible when it comes to moving elements. Mechanoluminescent (ML) materials transform mechanical energy into visible light and can replace strain gauges to monitor strain/stress. In terms of additive manufacturing, 3D printing has improved significantly. In this research, we describe a method to produce an ML 3D print. The produced samples satisfy the need for quick and non-destructible spatial stress analysis and are precise and adaptable. A 3D printed photopolymer sample with SrAl2O4: Eu, Dy particle addition only to the final layers was tested and the number of layers was optimized. It was shown that between 10 and 20 layers is the optimal amount of layers for easy detection. It opens the possibility for real-time evaluation of complex uneven forces on complex parts, therefore, having a good potential for commercialization.

PEDOT:PSS and PEO composite material for transparent and flexible electronics

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For the manufacturing of transparent electronic devices, appropriate materials are needed. The materials must possess such properties as high durability, electrical conductivity, flexibility, and transparency. One of the most researched organic materials is Poly(3,4-ethylene-dioxythiophene) polystyrene sulfonate (PEDOT:PSS). It is an electrically conductive polymer, and its properties can be modified by additives and treatment methods.

In this work a PEDOT:PSS and polyethylene oxide (PEO) composite material has been made. The impact of polymer proportions on electrical properties was determined. For the most conductive sample, additional dimethyl sulfoxide (DMSO) was added. Thermal treatment and its effect on the material have been studied. Light transmission measurements were carried out to determine the transparency of the material.

Results show that the addition of PEO, DMSO and thermal treatment has a great impact on the material properties. The specific electrical conductivity relative to pristine PEDOT:PSS was increased from 0.3 S/cm to 750 S/cm after modifying the material. The specific electrical conductivity was determined with the 4-point probe method.

Acknowledgements

The financial support of the European Regional Development Fund (ERDF) Project No. 1.1.1.1/20/A/060 is greatly acknowledged.

Tracking the Phase Composition during Zinc Peroxide Decomposition: A High-Temperature X-ray Absorption Spectroscopy Study

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X-ray absorption spectroscopy (XAS) is a powerful tool for *in situ* investigations of the local environment in materials with varying degrees of crystallinity and disorder. In this study, we performed a high-temperature Zn K-edge XAS study of two zinc oxide phases (ZnO and ZnO_2) to probe their temperature-dependent local structure and lattice dynamics and elucidate the mechanism of ZnO_2-to-ZnO decomposition.

X-ray absorption spectra were collected at the Balder beamline [1] of the Max IV synchrotron in the temperature range of 20–900°C. We used principal component analysis (PCA) and linear combination analysis (LCA) to determine the type and amount of phases present at each temperature. Reverse Monte Carlo (RMC) simulations [2] were then used to extract detailed structural information from the extended X-ray absorption fine structure (EXAFS) spectra.

Our results [3] show that only the ZnO_2 phase was present up to 180 °C, while only the nanocrystalline ZnO phase occurred above 250 °C. A broadening of Zn–O and Zn–Zn pair distribution functions (PDFs) and related mean-square relative displacements indicated a significant increase in disorder as the decomposition temperature was approached. Further heating up to 900°C promotes the growth of ZnO crystallites.

This study provides insights into the local atomic structure evolution of zinc oxide phases upon heating, which may have practical implications, such as in the development of inks based on zinc oxide nanoparticles with the potential application in printed optoelectronic devices.

Acknowledgments
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Solvent premixing deposition method to improve light emission layer preparation repeatability for OLED

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Organic light-emitting diodes (OLEDs) are highly efficient devices that generate light from electricity. The device consists of several layers: electron and hole transport, electron and hole injection, and the emission layer. All the layers are necessary to achieve charge carrier balance in the system and to decrease the turn-on voltage. However, all the layers would be meaningless without a high-efficient emitter layer. To increase efficiency host-guest films are used. The host is used to transfer energy to the emitter (guest). In addition, the host separates the guest molecules to reduce the interaction between the emitters and increase the photoluminescence efficiency. The emissive layer of the systems consists of approximately 3 - 10 wt %. Such systems are classically made by the thermal evaporation method, where the compounds are simultaneously sublimated from 2 separate sources. This method does not allow to create the samples of exact concentrations, and their repeatability is limited. Therefore, a solvent premixing deposition method is introduced, which allows manufacturing host-guest systems using a single evaporation source. To compare the methods, OLEDs with structure ITO/ MoO3/ CBP/ CBP:Ir(ppy)3(5, 8, 11 wt %)/ TPBi/ LiF/ Al were made. The presentation will show a comparison of these methods in terms of repeatability, material consumption and OLED efficiency.

Third-harmonic generation in DMABI and PMMA host-guest thin films

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The demands of modern communication systems have stimulated a great interest in the development of all-optical signal processing devices. To create such devices, we can use nonlinear optical effects, for example, third-harmonic generation (THG) where an optical signal is generated with three times shorter wavelength than the pumping radiation. The main challenge is the selection of suitable materials, which is why organic materials are often used in such studies due to their large nonlinear coefficient values and possibility to modify the molecular structure to influence nonlinear response. Here we show THG properties of PMMA and DMABI host-guest system, because this system could easily be applicable to create waveguides in comparison to different nanoparticles where it is hard to fabricate thicker films. In this work PMMA and DMABI solutions with different concentrations were prepared, from which thin films were made on glass substrate. THG was measured by irradiating the samples with a tunable femtosecond laser and detecting transmitted signal with a spectrometer. The samples were excited in the 1100-1500nm range. To determine THG efficiency of DMABI, thin films of pure PMMA on glass were used as a reference. We studied phase-matching in this host-guest system through Maker-fringe type measurements. Our results show that DMABI has efficient enough THG so it can be used in optical transistors or frequency combs.

Modelling of SERS substrates using the finite element method, optimisation and experimental planning

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Surface-enhanced Raman scattering (SERS) is an effect occurring on nanostructured substrates where the Raman signal of an analyte is amplified considerably (up to $> 10^8$ times [1]). As such, it is a method well-suited for the detection of substances at very low concentrations. Multiple factors account for this effect, the most important of which is the electromagnetic field enhancement due to surface plasmon resonance. Often these nanostructured substrates use gold or silver.

The EM enhancement effects of SERS can be suitably modeled with the finite element method (FEM) by solving the classical Maxwell equations. For this end, the program COMSOL Multiphysics is used in this work. The goal of the research is to optimize the shapes and parameters of the structures in order to increase the maximal EM field enhancement, as well as the density of enhancement hot-spots. The parameters of the model are also chosen with consideration of the possibilities to create such substrates experimentally. The calculations done so far have yielded EM enhancements for various structures with gold and silver nanoparticles.

In this presentation, the results of our calculations and first experiments with commercially available substrates will be communicated and they will be compared to the literature [2]. In addition, potential methods for making substrates and taking SERS measurements will be inquired into.

Acknowledgments

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Organic light-emitting diodes and electrochemical cells with CsPbBr3 and CsPbI3 nanoparticles

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Nowadays, highly efficient devices are important to reduce energy consumption without losing performance. Light-emitting devices can be used in lighting, displays and labels. All the applications consume around 20 percent of all energy consumption in the world. Organic light-emitting diodes (OLED) are highly efficient but their production is complex. On the other hand, light-emitting electrochemical cells (LEEC) are not so efficient but simple in production. In both devices, perovskite nanoparticles could be introduced as emitters to increase the light emission intensity. An additional advantage of using nanoparticles is the creation of devices by wet casting methods, which in the future could enable the fabrication of emitting devices with the inkjet printer. In the work the following OLED structure was prepared: ITO/PEDOT:PSS/Poly-TPD/nanoparticles /BPhen/LiF/Al and LEEC structure: ITO/nanoparticles:PEO:LiPF6/Al. For all the devices CsPbBr3 or CsPbI3 nanoparticles were used. The performance of the prepared devices will be discussed in the presentation.

Carbene-metal-amide complex with dual light emission band for white light

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Usage of organic light emitting diodes (OLED) has grown in lighting as they have high energy efficiency. Making white light diodes is technically difficult because more than one compound is required. Carbene-metal-amide on the basis of copper complex TCP - dimers with dual emission maxima in blue and orange regions of visible light spectrum - were investigated during this work. Emission spectra and photoluminescence decay at various emitter concentrations in thin films at different temperatures were measured to determine emission mechanism and energy gap between singlet and triplet. Our results show that this could be a promising compound to allow preparation of simple white OLED as the intensity of emitted light varies by changing concentration of the compound.

Filtering of terahertz radiation by a metasurface structure

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We have studied the operation of metasurface structures based on silicon cylindrical rings coated with a layer of gold as a terahertz (THz) bandpass filter. The decrease in the reflection coefficient is due to the constructive interference of electromagnetic waves reflected from various structural layers of the metasurface, which leads to an increase in the transmission coefficient. It is shown that performance of the suggested metasurface filter is rather insensitive on the structural parameter's variations. At the same time the operation spectrum can be adjusted by changing the height of the cylindrical ring. Dependance of the transmittance spectrum on the polarization and incidence of the imping waves is also studied.

Acknowledgments

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Simultaneous message-passing protocol using optical vortices based on the ternary phase encoding

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As the progression of artificial intelligence advances, it might pose a threat to our current way of transferring data. It is essential to develop new secure means of communication furthermore preserve the same efficiency as modern technologies.

Here we propose a development to previous work on a quantum-inspired simultaneous message-passing protocol using structured light.[1] Compared to the previous implementation [2] we implemented the ternary encoding system, where the complex amplitudes of Laguerre-Gaussian modes (acting as a message carrier) have three phase levels. In our work, we demonstrate the performance of the protocol through an image comparison experiment, where the original image is compared with its distorted counterpart. To do so, we applied the perceptual hash algorithm to create a hash representation of each image that has to be compared using the proposed ternary-based message-passing protocol.

The results show that the new encoding system not only reduces the number of required holograms (increased protocol capacity) but furthermore improves the protocol security.

To conclude, optical communication based on structured light paves the way towards new reversible optical gates solutions that have the potential to reduce the consumption of energy required for logical operations, while simultaneously being capable to be transformed into the quantum system.

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Part IV
Poster Session 2

SPIE. STUDENT CHAPTER UNIVERSITY OF LATVIA

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The influence of pump-probe laser frequency on magneto-optical signals in Cs atoms for zero magnetic field detection

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Magneto-optical signals in a caesium vapour cells can be used for extremely precise magnetic field measurement in 3D [1]. A linearly polarized pump beam creates an aligned state in caesium ground state. By applying an external magnetic field in the direction that is perpendicular to the pump beam polarization, created angular momentum distribution starts to precess with a frequency that is proportional to the applied magnetic field strength. The change in angular momentum distribution is probed by linearly polarized light with its polarization axis at a 45 degree angle with respect to the pump beam and perpendicular to the applied magnetic field. This results in dispersion-like absorption signals. This pump-probe geometry is based on [2]. By switching the probe beam polarization plane, it is possible to obtain dispersive absorption signals for two orthogonal magnetic field components.

The obtained results show that the absorption signals have strong dependence on experimental parameters such as probe and pump beam intensity, beam diameters, laser frequency. The frequency impacts the amplitude and the direction of the signals.

Acknowledgments

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Experimental and theoretical investigation of a paramagnetic oxygen impurity centre in $LiYF_4$

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Scintillators are materials used for radiation detection and can therefore be exposed to intensive radiation [1]. As a result of exposure to ionizing radiation, the mechanical and optical properties of the material may be significantly altered.

The structure of persistent defects in $LiYF_4$ is being investigated; therefore, methods for studying radiation-induced defects by combing experimental and theoretical approaches [2] are relevant.

Pre-synthesized $LiYF_4$ single crystals were irradiated by X-rays. For the irradiated samples, EPR and ENDOR spectra angular dependencies were measured, rotating the crystal around two mutually perpendicular axes. Spectra simulations have been performed for the acquired EPR spectra and spin-Hamilton parameters were determined. Conclusions about the defect structure have been drawn from the values of spin-Hamilton parameters [3]. DFT calculations have been carried out and compared with experimental EPR data for the verification of defect structure. Single oxygen impurity ions and oxygen molecules were considered as plausible defect models in $LiYF_4$.

During synthesis of the $LiYF_4$, an electronically neutral oxygen impurity centre is formed. After material irradiation with X-rays, electron configuration on the oxygen defect is changed and a defect, which is stable at temperatures that significantly exceed room temperature, is formed. DFT calculations have some correlation with the experimental EPR/ENDOR data. Several oxygen defect models could be excluded and single oxygen and fluorine vacancy defect pair provided the best results; however, a significant difference in the absolute values of hyperfine structure constants was observed.

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Symmetry properties and accuracy in determining the values of tunneling splitting of torsional states of the HSSSH molecule

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The trisulfane molecule (HSSSH) is the third representative in the series of higher sulfanes of the HSnH type (n=1,2,3...) [1]. Its properties are in many respects similar to those of the hydrogen trioxide molecule (HOOOH), which is also the third representative in the series of polyoxides of the HOnH type (n=1,2,3...). In 2015 M. Quack's group [2,3], performed 2D potential energy surface (PES) calculations for the trisulfane molecule. According to the authors' estimations, the splitting of the ground level due to the violation of parity law in the analyzed molecule should be of the order of 10-12 cm–1, while the ground level splitting due to tunneling should be of the order of 10–23 cm–1. However, the last splitting value was obtained using extrapolation approaches [4,5]. Such a small value of the tunneling splitting of the vibrational ground state of the HSSSH molecule seems inaccessible when calculating the energies of stationary torsional states by variational methods. The full 2D potential energy surface formed by rotation the thiol (S-H) groups (specified by and torsional coordinates) has C2V symmetry. Therefore, it is more convenient to classify torsional states of the molecule using the C2V(M) molecular symmetry group. Thus the 2D PES has to satisfied following condition:

$$U(\gamma_1,\gamma_2) = U(\gamma_2,\gamma_1) = U(-\gamma_1,-\gamma_2) == U(-\gamma_2,-\gamma_1) \tag{1}$$

However some kinetic coefficients have to satisfied little bit different condition:

$$F_{\gamma_1,\gamma_1}(\gamma_1,\gamma_2) = F_{\gamma_2,\gamma_2}(\gamma_2,\gamma_1) = F_{\gamma_1,\gamma_1}(-\gamma_1,-\gamma_2) = F_{\gamma_2,\gamma_2}(-\gamma_2,-\gamma_1) \tag{2}$$

$$F_{\gamma_1,\gamma_2}(\gamma_1,\gamma_2) = F_{\gamma_1,\gamma_2}(\gamma_2,\gamma_1) = F_{\gamma_1,\gamma_2}(-\gamma_1,-\gamma_2) = F_{\gamma_1,\gamma_2}(-\gamma_2,-\gamma_1) \tag{3}$$

The conditions (1-3) were taken into account when processing the calculated data. While the solution of the vibrational Schrödinger equation of restricted dimensionality was performed using complex Fourier series the fittings of the calculated data were made by trigonometric Fourier series which were previously adapted to symmetry properties. All calculations were done using Mathematica package [6]. Previously used program code for compiling and diagonalizing the Hamiltonian matrix, implemented in the framework of package [6], was reset to the precision of 32 significant digits for every value of the terms used in calculations. After every numerical operation the preciosity of the output terms was under control. As result of this the preciosity of the calculated eigenvalues and eigenvectors was not worse than 32 significant digits after diagonalization of the Hamiltonian matrix. Herewith, the time required to diagonalize the Hamiltonian matrix increases by several orders of magnitude. It has been established that the splitting of the ground vibrational state due to tunneling between equivalent configurations of transconformers in the HSSSH molecule is extremely small (3.1*10-22 cm-1). Such small

value of the ground state energy splitting for the trisulfane molecule (which is still much smaller then the estimated in [2,3] splitting of the ground level due to the violation of parity law (10-12 cm-1 ¿¿10-22 cm-1)) give us hope for successful implementation of experiments which would observe the parity law violation in chiral molecules (see more arguments in [2]).

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A study of transition probabilities and magnetic properties of atomic thulium

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Spectroscopic information on the lanthanide rare earth elements is important for solving astrophysical problems, in particular, the ones related to the study of parameters and processes in the atmosphere and circumstellar shell of evolved stars. In present work we report on experimental and theoretical studies of relative transition probabilities and magnetic properties of atomic thulium (Tm). Line intensity distributions were obtained from ^{169}Tm emission spectra produced in a hollow cathode discharge lamp with Ar or Ne. The visible range spectra were recorded applying a high-resolution Bruker IFS 125 HR Fourier-transform spectrometer at the Laser Centre of the University of Latvia, see [1].

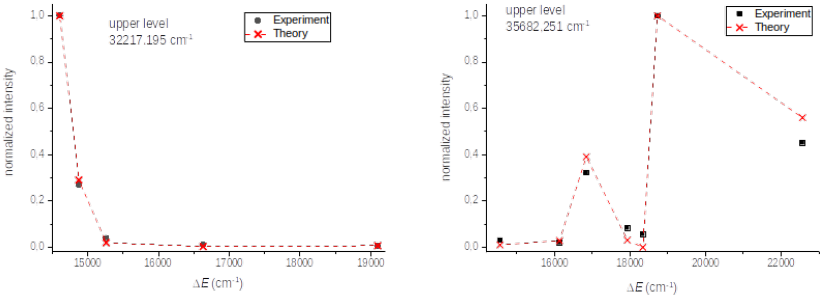

Figure 1: Experimental and theoretical relative intensity distributions

Experimental relative intensity distributions have been determined for branches originated from a common upper level, see examples in the figure for the upper levels 32217.195 cm−1 and 35682.251 cm−1. Spectral sensitivity of overall detection system was calibrated based on K2 intensity distributions within 13 500 – 16 500 cm−1 and Ar branching ratios within 16 000 – 24 000 cm−1. The Zeeman patterns were recorded applying magnetic field about 2000 G for two orthogonal polarizations. The spectrum and probabilities of electric dipole transitions were calculated using a hybrid approach that combines the

configuration interaction (CI) method and many-body perturbation theory (MBPT) [2]. We used a recently proposed modification of this approach, which allows one to reduce the size of a configuration space of a CI calculation and at the same time still include important correlations via MBPT [3]. It was designed for complex systems with an opened electronic shells and a large number of active electrons like Tm.

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Measurements of backscattered photon path length in different areas of human skin

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In several clinical applications and optical diagnostics, it is crucial to know the path length of skin-remitted photons. However, skin composition can differ in certain parts of the human body and lead to significantly varying results. The aim of this study was to investigate how underlying structures, such as bones, muscle, fatty tissue, or blood vessels, affect the mean photon path length, using the photon time-of-flight (PTOF) measurement method.

The measurement set-up consisted of a Fianium white picosecond laser, hybrid detector, data processing card SPC-150 (Becker&Hickl), two optical fibers, and an optical fiber holding system. Laser pulses at seven specific wavelength bands obtained using a set of interference filters in the spectral range 560 – 800 nm were launched into the skin at different parts of the body. Backscattered photons were detected using a second optical fiber, placed at differing distances (1, 8, 12, 16, and 20 mm) from the input fiber. The measured photon time of travel was then converted into path length.

The obtained results verify the dependencies of backscattered photon mean path length on different bodily structures, with the travel time in fatty tissue being the longest in all wavelength bands. Moreover, the differences between path lengths at fixed inter-fiber distances were also analyzed.

Smooth pursuit eye movements in children with reading difficulties

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Smooth pursuit eye movements are essential for keeping a slowly moving target image on the fovea. As a child develops, age-appropriate eye movements are necessary to promote the development of other functions, such as reading. Eye fixation movements and saccades are used during reading, but smooth pursuit eye movements are not directly related to the reading process. Therefore, studies on the relationship between smooth eye movements and reading provide conflicting information and different reasons for whether and why there is a relationship between reading ability and smooth pursuit of eye movements [1].

The study included 378 participants from different schools. The participants were aged between 7 and 13 years. They were divided into two groups: those with normal reading ability and those with reading difficulties. Certified speech therapists used the Acadience Reading test to determine the group each participant belonged to. We measured circular, horizontal, and vertical smooth pursuit eye movements of all participants using the *Tobii Pro Fusion* video-oculography.

Various parameters can be used to evaluate smooth pursuit eye movements in children with reading difficulties, including velocity gain [2], position gain [2], latency [3], and the number and amplitude of saccades [4]. However, an algorithm needs to be developed to assess smooth pursuit movement parameters in children with normal reading and those with reading difficulties using the *Tobii Pro Fusion* eye movement recorder.

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Parameters of saccadic eye movements in children with reading difficulties

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Reading is an essential source of information acquired starting from the preschool age. During reading, rapid eye movements (saccades) and fixations are used to shift gaze from word to word. People with oculomotor disorders may experience reading difficulties, Eye movements can also be applied to assess and monitor reading development in children of early school age. Children with reading difficulties have demonstrated longer fixations and shorter saccade amplitudes compared to typical readers [1]. Significant differences in average fixation duration measurements and frequency of saccades have also been demonstrated in children with and without reading difficulties [2]. The aim of the current study is to assess the performance of saccadic eye movements in children with and without reading difficulties, focusing on latency, accuracy, and maximum speed measurements.

A total of 378 participants aged 7-13 took part in this study. Eye movements were recorded using *Tobii Pro Fusion* eye-tracker (120 Hz). The task consisted of horizontally and vertically oriented saccadic eye movement stimuli presented in a mixed order on a computer screen. Participants were instructed to perform a gaze transfer (saccade) in three different tasks: (1) from a fixation object to a peripheral stimulus (reflexive saccade task), (2) in the opposite direction to the peripherally presented stimulus (anti-saccade task), and (3) to alternate gaze between two peripherally demonstrated stimuli several times (voluntary saccades). According to the study results, the mean latency of the anti-saccade to the right, left, up, and down for children without reading difficulties was accordingly 269 ms, 211 ms, 153 ms, and 157 ms. The mean latency to the right, left, up, and down for children with reading difficulties was 186 ms, 198 ms, 163 ms, and 135 ms, respectively. The peak velocity of anti-saccade to the right, left, up, and down for children without reading difficulties was 309 °/s, 242 °/s, 308 °/s, and 262 °/s, respectively. Finally, the peak velocity to the right, left, up, and down for children with reading difficulties was 375 °/s, 369 °/s, 254 °/s, and 319 °/s, respectively. Based on the results, we conclude that there is no significant difference in the peak velocity of voluntary, reflexive, and anti-saccades in children with and without reading difficulties.

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Effect of eye dominance on fixation stability

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Fixation stability can be influenced by fixation eye movements and age, with stability being lower in very young and old individual as well as those with more pronounced fixational eye movements. It has been suggested that each person has a leading eye that provides better processing, contrast sensitivity, and stability of visual information, leading to an interest in examining whether ocular dominance affects fixation stability. However, there is limited research on the direct influence of ocular dominance on fixation stability, particularly in children. Existing studies have shown no statistically significant effect of ocular dominance on fixation stability.

Bivariate contour ellipse area (BCEA) is a commonly used parameter to assess fixation stability, which is calculated by enclosing the fixation points in an ellipse that approximates the shape of the distributions of eye positions during fixations. The aim of this study is to analyse the influence of the dominant and non-dominant eye on fixation stability by calculating the BCEA.

In this study, we used a video-based eye tracker to measure fixation stability in both eyes of children aged 7 to 8 years old. We analysed the BCEA values separately for the dominant and non-dominant eye and compare them to determine whether there was a significant difference in fixation stability between the two eyes. Participants fixated their gaze on a fixation stimulus presented on a computer screen at a distance of 65 cm. The fixation stimulus compromised 0.6 degrees with a black circle 0.2 degrees in the centre [1] on a grey background (RGB 180, 180, 180). Fixation eye movements were recorded with the *Tobii Pro Fusion* eye tracker device, and data were recorded and analysed using *with Titta Master* program [2] and the *I2MC* algorithm [3].

The initial results obtained from 44 children indicated slightly more stable fixation in the dominant eye (BCEA=0.45 degrees^2) than in the non-dominant eye (BCEA=0.51 degrees^2). However, there was no statistically significant difference observed between the fixation stability of the dominant and non-dominant eye ($p > 0.05$).

We conclude that the mechanism of eye dominance has no significant effect on fixation stability, as there is no significant difference in fixation stability between the dominant and non-dominant eyes.

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The assessment of smooth pursuit eye movement in school-aged children with video-oculography and the NSUCO

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Introduction The main objective of smooth pursuit eye movement tracking is to maintain high image resolution by keeping the eye movement speed close to the speed of the object, particularly in the central part of the retina where visual acuity is highest. Previous studies have reported impaired performance of slow-tracking eye movements in children with reading and learning difficulties [1]. Therefore, analyzing smooth pursuit eye movement tracking can aid in the diagnosis of various neurological disorders and complement the general assessment of visual function in children with reading difficulties. Characterizing smooth pursuit eye movements can also be important for diagnosis, tracking progression, and assessing response to therapy. However, it is crucial to the development of the oculomotor system in children, as test performance may vary between age groups [2]. The objective of this study is twofold: first, to assess the smooth pursuit eye movement performance of children in grades 1-6 from four Latvian schools using the NSUCO test, and second, to compare the obtained results with the age-specific norms established by Maples [2] for smooth pursuit eye tracking performance.

Method To assess horizontal, vertical, and circular eye movements of 77 fourth-grade children (38 girls, 39 boys, aged 9-11) and 48 sixth-grade pupils (28 girls, 20 boys, aged 11-13), we used the NSUCO method and video-oculography.

Results In fourth grade, 67 out of 77 children (87%) completed the smooth eye movement tasks without a single error. Eight children (10%) had one error, and two (3%) had two errors. In sixth grade, 44 out of 48 children (92%) had no errors, one (2%) had only one error, and three (6%) had two or more errors.

Conclusion The results of the NSUCO method in Latvian schools indicate that about 90% of children in grades 4-6 can perform the smooth eye movement test without any error. These findings differ from the study [3] where less than 30% of children showed accurate eye movements. However, it is worth noting that the difference in results obtained is likely due to the different number of children tested.

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The correlation between the parameters of DEM and the Acadience Reading tests

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Introduction Reading is a complex cognitive process that involves acquiring and transforming visual information from a printed page into language by interacting of linguistic aspects with eye movement mechanisms. Eye movements involved in reading include saccades, fixations, and regressions. Studies focusing on the relationship between oculomotor abilities and reading difficulties in students have shown a significant relationship between DEM (*Developmental Eye Movement test*) results and reading abilities. The study aims to investigate the correlation between the DEM test and the Acadience Reading test in children with and without reading difficulties.

Method The study involved 367 children aged 7 to 12 from four Latvian schools. Each participant completed both the Acadience Reading test and the DEM test. A certified speech therapist assessed the children's reading performance using the Acadience Reading test, while optometrists assessed their eye movements using the DEM test. Based on the results of the Acadience Reading test, the participants were divided into two groups: children with and without reading difficulties. The DEM test consists of naming numbers and ascertaining the accuracy of eye saccades and fixation, similar to the reading process while excluding the influence of text comprehension but including the children's articulatory performance.

Results Of the 367 participants, 97 children (26%) had reading difficulties according to the Acadience Reading test, with 46% of 5th graders (11-year-olds) having reading problems. In the DEM test, 30 children (8%) showed higher than age-norm times in naming and eye saccades, of which 11 children had reading difficulties according to the Acadience Reading test. For horizontal saccades, 88 children (24%) showed higher than age-norm times, with 30% having reading difficulties according to the Acadience Reading test. For the vertical saccade part of the DEM test, 51 children (14%) showed higher than the age-norm times, with only 15% having reading difficulties according to the Acadience Reading test. A chi-square test of independence revealed a significant relationship between reading difficulties and the horizontal part of the DEM test in the age group of 7 to 9 years, χ^2=4.39 (1, N=367), $p = 0.036$.

Conclusion The results suggest that the horizontal saccade part of the DEM test is more effective at identifying children with reading difficulties than the vertical part, particularly in the age group of 7 to 9.

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Fixation stability in children with and without reading difficulites

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During reading, fixations are made at specific places in the text, and the location of fixation is affected by the length and complexity of the word [1]. Previous research has suggested that children with poor reading skills make more and longer fixations when performing reading tasks [2]. Therefore, in another study, factors that could influence fixation stability were excluded by using a non-reading task. This study found no statistically significant differences in the stability of fixation between better and worse readers. Fixation stability was evaluated in this study by measuring the amount of saccades during fixation [3]. The aim of our study is to evaluate fixation stability in children with and without reading difficulties by calculating bivariate contour ellipse area (BCEA). Our study involved 378 participants aged 6 to 13. Participants were instructed to fix their gaze on a stimulus presented at a distance of 65 cm on a computer screen. The presented stimulus was 0.6 degrees with a 0.2 degree black circle at the centre of the stimulus [4] against a grey background (RGB values: 180, 180, 180). Eye movements were recorded using *Tobii Pro Fusion* eye tracker device. Data was recorded with *Titta Master* program [5], and fixations were analysed with the *I2MC* algorithm [6]. Currently, we have analysed the results of 63 children (9 to 10 years old). Using the AcadienceTM (DIBELS Next) test, we identified 18 children with reading difficulties. Our initial results show no significant differences in fixation stability between children with and without reading difficulties ($p > 0.05$).

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The visual game stimulus for the treatment of amblyopia

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Amblyopia is a neurological vision disorder characterised by an impaired vision in one or both eyes. "Lazy" eye can be treated with refractive correction (Ibironke et al., 2011; Shrestha & Adhikari, 2013), patching, or occlusion therapy (Pediatric Eye Disease Investigator Group, 2005; Irfan et al., 2013; Khan, 2015), and penalisation treatment of the non-amblyopic eye (Tejedor & Ogallar, 2008; Shrestha & Adhikari, 2013). In recent years, research has increasingly focused on binocular amblyopia treatments aimed at preventing suppression and improving binocular visual function (Kelly et al., 2016; Bossi et al., 2017; Žiak et al., 2017; Ojiabo & Munsamy, 2022). The new binocular therapy with dichoptic presentation adapts the visual stimuli between the amblyopic and the fellow eye. The most commonly used dichoptic game is Tetris, with high-contrast falling blocks and low-contrast stationary blocks that must be placed together to form continuous rows of blocks.

In the previously mentioned studies, the amblyopic eye perceives a dynamic stimulus. Movement perception is rarely evaluated clinically; however, motion perception and oculomotor impairment have been reported in amblyopia, which should be taken into account to better understand this visual disorder and its treatment (Hernández-Rodríguez et al., 2020). Amblyopic eyes are not properly attuned to the timing of the signal, making it more difficult for them to process dynamic visual information (Hu et al., 2021). In addition, motion perception is not affected by a reduction of perceived brightness in the amblyopic eye under dichoptic conditions (Maehara et al., 2019). Nevertheless, in amblyopia, some motion form perception disturbances affect both the amblyopic and the fellow eye, which may be due to changed binocular mechanisms (Birch et al., 2019). According to these facts, steady or long and slow-moving stimuli can be a good solution to start visual training for amblyopia.

Keywords: amblyopia, amblyopia therapy, Tetris game, dichoptic, stimulus

Subjective assessment of comfort in the reality-virtuality continuum

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Various questionnaires are adopted to assess user comfort in the reality-virtuality continuum that includes all possible compositions of physical and digital objects. There is mixed evidence on whether or not using extended reality headsets leads to a higher discomfort in comparison to using conventional flat-panel monitors. We have explored this topic by summarizing the results of several user studies.

User studies were conducted using different devices: Meta Quest 2 (playing mini golf, 86 subjects), Microsoft HoloLens 2 and Samsung S24E650 (typing text, 59 subjects), Zeiss VR One (watching video, 20 subjects), and Eyesi indirect ophthalmoscope simulator (searching for targets, 15 subjects). The severity of symptoms was assessed before and after completing the visual task. All subjects used their habitual optical correction if necessary to achieve good visual acuity at near and far.

Regardless of the device used, certain symptoms were more common than others. In particular, the majority of individuals experienced eye fatigue and strain after engaging in near work for 30 minutes. Although the HoloLens 2 headset seemed to compromise comfort the most, the severity of symptoms was generally mild for most individuals, and did not differ substantially across the image presentation methods. Nausea and double vision were rare, with only a few subjects experiencing these symptoms for a brief period of time.

In summary, our research indicates that certain symptoms may not be associated with using particular devices, but rather with the specifics of the visual task, which should be considered when developing standard comfort assessment questionnaires.

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