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Manufacturing and testing of all-silica fibers resistant to UV and gamma radiation

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Keywords: All-silica preforms manufacturing, chlorine free silica, OH content, optical fibers, solarization, UV-induced loss, hermetic carbon coating, hydrogen treatment.

The all-silica optical fibers were shown to be suitable light guides for power applications in near IR, visible and UV spectral regions. Improvement of fiber resistance to UV and gamma irradiation is an important task for the development of modern energetics and laser technique. This study examined the influence of the composition of the core material [1, 2, 3], preform production technology [4] and posttreatment with hydrogen on the optical stability of the all-silica optical fibers to UV radiation. Elaborated fiber coating, consisting of carbon and polyimide layers, allows hydrogen saturation at 250°C but shows excellent hermeticity at room temperature.

Comparative study of the light guides not saturated with hydrogen showed that silicas with both high and low content of hydroxyl groups might have sufficient initial UV transparency and resistant to UV irradiation. Of much greater importance is the occurrence of defects in the structure of silica causing absorption in the region of 200 - 400 nm as well as presence of Si-H and Si-Cl groups, which act as precursors for defects with absorption peaks at 214nm and 330 nm. The method of deposition of a reflective layer had a significant effect on the incidence of defects and Si-H groups in the fiber core. The most significant effect on induced loss was caused by hydrogen treatment of the fibers.

The findings of this study provided strategies of UV stable and low loss all-silica fibers production for wavelength region 200 nm - 1060 nm. Hydrogen, absorbed in silica structure, significantly increase loss in longer wavelength spectral region (see Fig. 1).

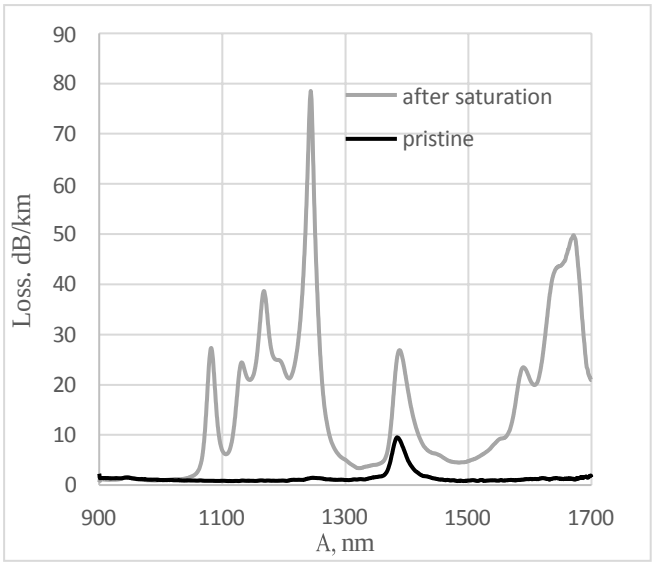

Fig. 1: Spectral attenuation curves of hydrogen in fiber 200/220/245P. Core material: Low OH silica.

Further development of UV and radiation resistant fibers for longer wavelength could be done in Ceram Optec SIA based on low OH, halide-free silica and possible replacement of hydrogen with deuterium.

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From Building Block to Application:A conceptual framework for Deep Tech commercialization

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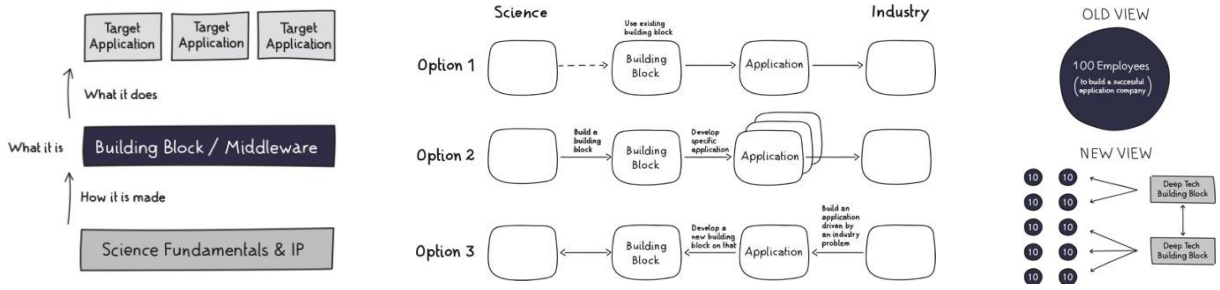
Keywords: Deep Tech, Commercialization, framework, concept, building block, application

Deep Tech represents rather a fundamental enabling-technology platform for multiple different applications, than an application-technology serving a specific purpose. Additionally, Deep Tech is based on new scientific advances and resource-intensive in its nature. (Romasanta et al., 2022) As a result, complexity and duration of the transfer process from science to industry are increasing, which causes the need for more innovative and pragmatic transfer solutions. General difficulties in the transfer process of technologies are broadly discussed in scholarly literature. (Kaushik et al., 2014) By contrast, few researchers have addressed the difficulties in the technology transfer process of Deep Tech, especially by providing new conceptual approaches.

Deep Tech does not only impede the transfer process, but also creates new perspectives on possible solutions due to its specific characteristics. Initial investigations show that successful Deep Tech companies such as BioNTech and Open AI consciously or even unconsciously make use of similar transfer approaches. It appears that those companies are dividing the transfer process. This might have a considerable influence on their successful technology transfer and therefore enables them to create more innovations.

We intend to address the highly relevant problem of the ongoing challenges in the technology transfer process with new perspectives derived from the characteristics and challenges in the context of Deep Tech.



To reduce complexity, we are suggesting a specific approach of decomposing the commercialization process within our conceptual framework. The entire commercialization process of Deep Tech appears to be based on two main stages. The primary focus of the first stage is the creation of a core technology as a platform, which provides the foundation for subsequent application-specific developments. In our concept the core-technology serves as a building block for the second stage, which concentrates on further development of the technology-base in a variety of market-driven application fields.

The main outcome of our work in progress article will be a conceptual two-stage technology transfer framework, derived from Deep Tech specific properties and practical success stories in the context of existing literature. The paper seeks to advance the academic discourse on technology commercialization and point out new directions for further research. The publications outcome will contribute to a greater understanding of existing difficulties and possible solutions in the general technology transfer and in particular for the case of Deep Tech. This is especially relevant at the moment, given the growing interest in Deep Tech despite the scarcity of scholarly publications.

We invite input from practitioner's experiences, whether they concur with or contradict our approach. Additionally, we are especially looking forward to discuss the topic with experts and researchers from different countries and backgrounds in the context of optics and photonics.

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Efficient Single-Emitter White OLEDs Based on Monomer and Dimer Emission of Thiazoline Carbene-Metal-Amide Organocopper Complexes

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Keywords: OLED, electroluminescence, carbene-metal-amides, white emission

Materials with thermally activated delayed fluorescence (TADF) properties have been intensively studied as possible alternative to phosphorescent emitters in OLEDs. Carbene-metal-amide (CMA) complexes are considered as a new subclass of TADF materials. The CMAs exhibit excellent photophysical properties such as near 100% photoluminescence quantum yield (PLQY) and short photoluminescence lifetime ($r < 1$ μs) [1].

In this work we investigate copper (I) CMA type organometallic complexes with 1,3-thiazoline as carbene and carbazole derivatives as amide fragments [2]. By altering the substitution of the carbene and the amide fragments a series of eight compounds was obtained. The materials exhibit bright bluish-green to green photoluminescence in doped (5%) PMMA films with PLQY up to 0.86 and radiative rates (k_r) reaching 7.2×10^5 s^{-1} for compound **2** (Fig. 1a). Compounds **1** and **2** with highest photophysical parameters in the solid state were chosen for OLED preparation via vacuum deposition method. At an optimized emitter concentration, the device based on compound **1** showed a dual electroluminescence pattern with external quantum efficiency reaching 16.5% and peak luminance as high as 44215 cd/m^2. The dual electroluminescence in this case originates from bluish-green emitting monomers and orange-red emitting dimers. As a result, highly efficient single-emitter white OLEDs could be obtained. The devices based on compound **2** showed slightly inferior efficiency parameters and lower intensity of dimeric emission indicating a limited molecular stacking.

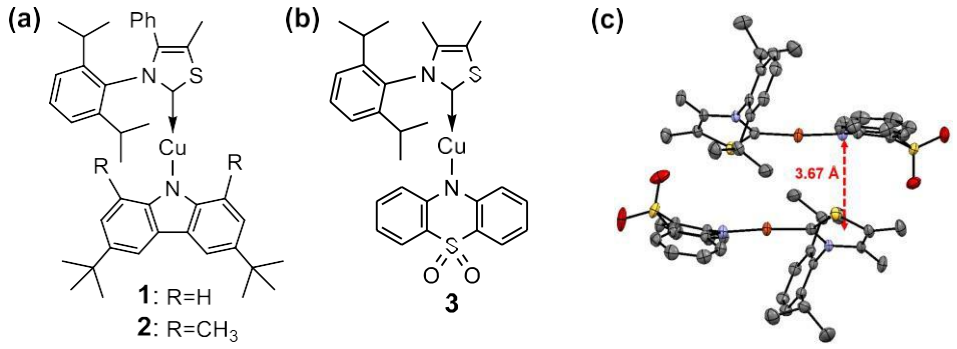

Fig. 1: (a) Structure of compounds (**1** and **2**) used in OLEDs. (b) Structure of compound **3**. (c) X-ray structure of dimer of compound **3**. Ellipsoids are shown at 50% probability level.

Compound **3** (Fig. 1b), a close structural analogue of **1** and **2**, provided an insight into dual emission mechanism of the explored CMA emitters [3]. X-ray structure of the orange-red emitting crystals of **3** revealed the existence of face-to face stacked dimers with an intermolecular distance of 3.67 Å. The emission of the dimers is related to the formation of a persistent ground-state dimer and originates from intermolecular charge transfer between the carbene and amide ligands of the neighbouring molecules.

In conclusion, the demonstrated dimer electroluminescence of the organocopper complexes provides opportunities for white OLED manufacturing cost reduction by simplifying the device architecture and using cheaper emitting materials.

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Optical whispering gallery micro-resonators (WGMR)

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Keywords: Optical whispering gallery mode resonator, biosensor, optical frequency comb.

Optical whispering gallery mode (WGM) microresonators made from transparent optical materials operate by the total internal reflection effect of light in a broad wavelength range without necessity to have any mir- ror coatings. We demonstrate silica microsphere WGM resonator applications for temperature sensing and glucose biosensor. Second our research direction is optical frequency comb generation in silica micro- spheres by Kerr-nonlinearity to create multi-wavelength source that can be used as a laser source in fiber op- tical fiber telecommunications.

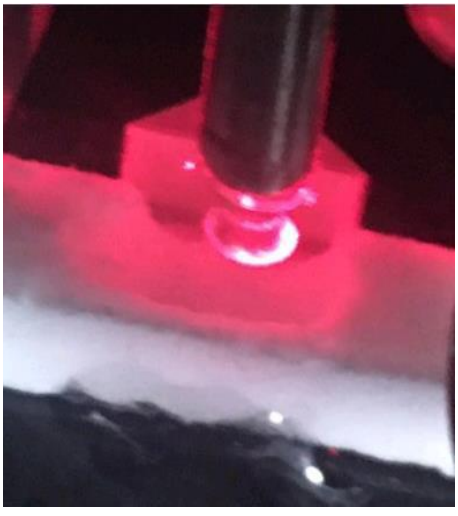
Research experience on whispering gallery mode resonators was brought to the University of Latvia from the Max Planck Institute of Quantum optics in Munich where thermal-noise-limited laser stabilization on a crys- talline CaF_2 and MgF_2 WGMR was demonstrated [1-2].

At the University of Latvia we fabricate WGMR microspheres from high optical purity single-mode silica fiber used in telecommunications by three methods: melting on oxy-hydrogen flame, using fiber splicer and CO_2 laser. Microspheres with a diameter in the range 150-500 μm are produced by this method having opti- cal quality Q factors in the 10^7 -10^8 range. When the microsphere is placed in water, the Q factor decreases to 10^6 and resonance line widths are about 1 GHz. The resonator surface can be functionalized with thin lay- ers for specific applications. In our group, we demonstrated a sensitive glucose sensor by coating the silica microsphere surface with glucose oxidase enzyme and gold nanoparticles that increase sensitivity due to the surface plasmon resonance effect [3].

Besides silica, we have made WGMR humidity sensor from glycerol droplets [4] and a laser wavelength sen- sor from numerous plexiglas (PMMA) microspheres attached to a tapered fiber [5]. *COMSOL* modeling al- lows us to visualize the whispering gallery modes of resonators with surface irregularities [6]. Presently we study integrated polymer optical microring resonators on glass substrate from SU-8 photoresist made by op- tical lithography.

The second range of applications is to exploit the very high optical Q factor in the 10^7 range, allowing to reach GW/cm^2 circulating intensities where Kerr effect takes place, by pumping with a CW laser (1550 nm, 200 mW EDFA power), because the optical mode cross-section is only about 10 μm^2. We have made optical Kerr effect frequency combs with spectral line separation of 400 GHz using microspheres with 170 μm di- ameter and demonstrated as carriers for telecom data at 10 Gbit/s data rates [7]. From silica microrod resona- tors made on a CO_2 laser lathe with 700 μm diameter, we got frequency combs with line separation of 100 GHz (telecom standard) and applied 40 Gbit/s data rate for a single comb line [8], see Fig. 1b.

a)



b)

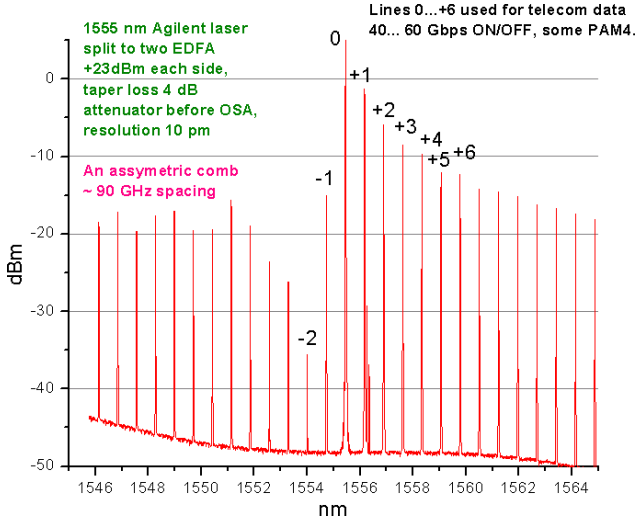


Fig. 1: a) Microrod WGM resonator excited with a red laser through a touching point with a coupling prism. b) Optical frequency comb produced from a 700 μm diameter silica micro-rod resonator with channel spacing of 100 GHz that can be used as a multi-wavelength laser source for telecommunications [8].

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Project No VPP-EM-FOTONIKA-2022/1-0001 Project title: "Smart Materials, Photonics, Technologies and Engineering Ecosystems". Latvian Quantum Initiative.

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Low energy photon application for analysis of heterogeneous fiber composite materials

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Keywords: infrared spectrometry, optical methods, fiber materials

Annually tons of sheep wool fibres, that are not used for textile fabrication, are a secondary by-product with wide field of application possibilities, including production of activated carbon [1,2]. Taking into account, that wool fibres can be stored for long time before their application, it is necessary to estimate the impact of wool's storage conditions on the production of activated carbon. In the present work, various parameters, for example, temperature, presence of air and daylight as well as humidity, were selected for comparison. After storage of fibres under selected conditions, thermogravimetry/differential thermal analysis followed by with Fourier transform infrared spectrometry were used in order to estimate the impact of each parameter on the thermal decomposition processes. A particular attention is noted to the low energy, infrared photon interaction with the released gaseous compounds and analysis of the registered signals. The interpretation of the infrared spectra allows to distinguish qualitative content of each decomposition step.

It was estimated that the decomposition of the wool fibers takes place in the three major steps. The most detected compounds were H_2O, CO_2, CO. Which all indicate a distinct step of thermal degradation. These steps are evaporation of H_2O with a maximum at approximately 100 °C. Collapse of the wool's amino acids, most notable at temperature range of 200-400 °C, indicated by release of nitrogen containing compounds Carbonization indicated by release of CO_2 and CO, notable in a temperature range of 400-900 °C.

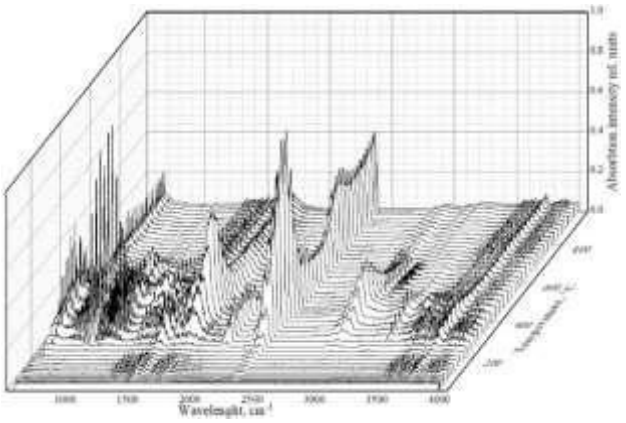

Fig. 1: FTIR spectra of released gaseous compounds from sheep wool.

Infrared spectrometry as an optical research method allows precisely determine the thermal degradation steps of variously stored sheep wool fibers. The obtained results will be used for developing recommendations for activated carbon fabrication conditions from sheep wool.

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Autofluorescence as an indicator for skin cancer post-operative scar evaluation

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Keywords: skin cancer, post-operative scar, diagnostics, autofluorescence

Skin cancer is the most commonly diagnosed type of cancer in the United States [1]. Among skin cancers malignant melanoma (MM) is the most aggressive and lethal type of tumor that is caused by the uncontrolled growth of melanocyte cells in the skin. The incidence of MM has been increasing in recent decades, creating great challenges for healthcare system. Post-operative MM observation protocol requires regular patient check-ups [2]. This autofluorescence (AF) imaging could be an extra indicator for dermatologist to evaluate the patient's scar during the healing.

The post-operative scar screening process is quick, painless and non-invasive. The light emitting diodes illuminate the skin at 405nm and captures the images with the in-built camera, the images are stored and processed in a cloud-based system, giving feedback parameters that could indicate whether the post-operative scar is healing well, this gives the dermatologist a better chance to evaluate the pigmentation and borders of the healing scar and any possible pigmentation or irregular borders that are not so clearly visible with a na- ked eye. Also, this method serves as an image archive for dynamic observation of the patient in longer time period.

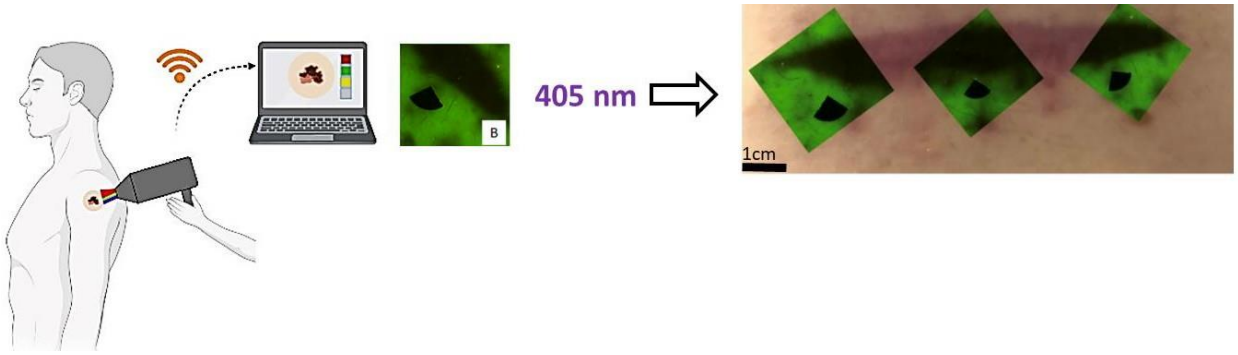

Fig. 1: Patient measurement setup (on the left) and an example (on the right) how the AF images of the post-operative scars look when placed on top of the clinical colored image. Black single use stickers placed for image stabilization purposes.

The study took place at Semmelweis University, Hungary from December'21 till October'22, includes 10 MM patients who underwent surgical lesion removal (8 male, 2 female; ages: 56.3±3.4 years; average Bres- low thickness 0.82±0.53 mm), and 7 of them were imaged in post-operative visits (2 had a healthy healing scar; 5 had to undergo reoperation and were imaged again).

At the end of the study, after 2 post-operative patient imaging visits and data analysis, we conclude that:
1) using the AF imaging is a useful visual screening tool for the dermatologist when evaluating the MM patient after the surgery during the follow-up visits;
2) the changes in AF intensity ratio did not have a specific trend during the first 4 months;
3) the AF intensity ratio increased of the scars after the re-operation between 4th and 8th to 10th month, showing that the scar is healing;
4) tumor specific microenvironment can also possibly alter the process of wound healing and therefore the AF intensity;
5) AF intensity ratio can be an indicator for wound healing.

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Bio-based optical fibers: Environmental sensing and short-range communication

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Keywords: optical fiber, sensing, biopolymer, sustainability

Optical fibers enable modern high-capacity communication networks [1] with the best glass optical fibers (GOFs) capable of carrying signals with an attenuation coefficient as low as 0.2 dB/km [2]. However, GOFs are brittle, inflexible, difficult to modify or postprocess, and their energy-intensive fabrication require massive facilities. Commercial plastic optical fibers (POFs) are lightweight, flexible, and easier to modify, making them attractive candidates in short-distance applications despite their higher optical losses (>100 dB/km) and limited operation temperature range [3]. However, the commercially available POFs are made exclusively from fossil resources.

We engage in developing mechanically robust, lightweight, and sustainable optical waveguides for environmental sensing and short-distance optical communication from renewable biomaterials. We use biopolymers such as cellulose derivatives and other polysaccharide-based hydrogels for wet spinning optical fibers under ambient conditions. Environmental changes in humidity or strain, for example, affect the guided light, allowing optical environmental monitoring. We have demonstrated several proof-of-concept applications on environmental sensing such as humidity, touch, breath, textile integration and short-range high speed data communication [4-6].

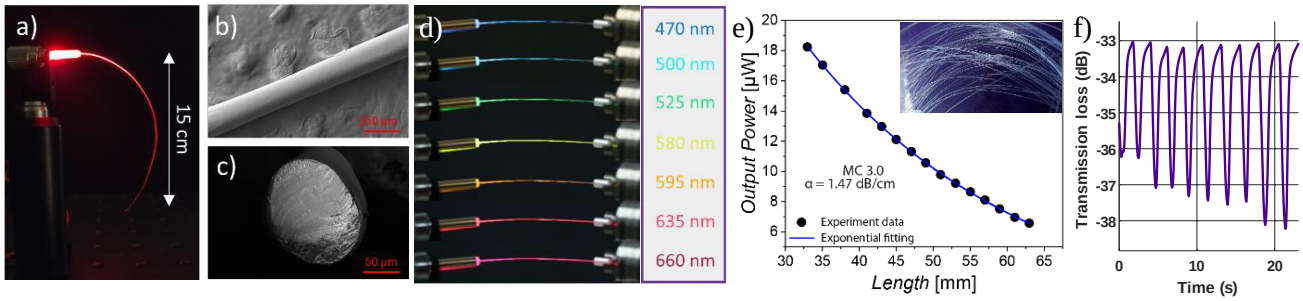

Fig. 1: a) Biopolymeric fiber and SEM images from its b) side and c) tip, d) waveguiding across the visible spectrum, e) attenuation data from cutback method measurements with an inset of a fiber bundle, and f) respiratory rate monitoring, where 33 breaths per minute was observed.

Biopolymers offer a wide range of refractive indices between 1.3-1.6 in Vis-NIR, making them suitable for simple core-cladding as well as more complex waveguide designs. We have demonstrated bare multimode optical fibers with attenuation coefficient between 1.47-4.5 dB/cm. Due to their intrinsic sensing abilities, biopolymer waveguides can be used to measure multiple environmental conditions simultaneously across the transmission range around 400-1700 nm. The fibers are mechanically robust, biocompatible, and biodegradable and can be readily integrated to various substrates including textiles. Current challenges include controlling structural integrity, uniformity, and preventing high optical loss.

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Fiber Bragg grating based solutions to industrial problems

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Keywords: Fiber Bragg gratings, fiber optics sensors, temperature, industrial

To improve quality, reduce downtime, and reduce cost, there is an increasing need for more measurements in the industry. More measurement can also enable a better fundamental understanding of processes. Measurement systems using fiber Bragg grating (FBG) sensors [1], can enable measurement that is not possible or, too expensive using electronic sensors. However, the industrial environment is demanding with requirements of high reliability in a dirty environment with rough handling. Industrial customers are, for good reasons, conservative and want a complete and proven measurement system.

Proximion has developed FBG-based measurement solutions for several different industrial applications. A common advantage compared to an electrical solution, is that a single fiber can contain many sensor points. Proximion has developed products with up to 100 sensors on a single fiber and has also shown continuous strain and temperature measurements [2]. Other advantages are immunity to electrical and magnetic fields and the possibility to have a long distance from the sensor to the read-out equipment.

Continuous steel casting is a critical process step in steel manufacturing. By inserting up to 50 fibers in the copper plates in the mold, where each fiber is equipped with 45-70 sensors, a thermal map can be generated of the casting [3]. This allows for process optimization as well as the detection of cracks and break-out prevention. Proximion systems are used by steel plants all around the world.

A ball bearing can be instrumented with a fiber Bragg grating in the outer ring with multiple strain- and temperature-sensor in a single fiber. The strain induced by a ball rolling over the sensor position will create a strain, and hence a wavelength modulation of the sensor. From the wavelength modulation, one can calculate the axial and radial force applied to the grating. This product is developed together with a bearing manufacturer. The bearings have found uses for pumps, compressors, maritime thrusters, and large mining mills.

For large chemical reactors, it can be important to monitor vertical temperature distribution. This can be used to detect hot spots as well as determine layers in the tank. Here Proximion provides long sensor fibers enclosed in stainless steel capillaries together with cabling. An example of a measurement can be seen in fig. 1.

Modern aircrafts use composites for low weight, high strength, and good fatigue resistance. However, composites are sensitive to high temperatures and an overheat detection system is needed. For this Proximion has developed fibers with up to 800 sensor points in each fiber. By accurate manufacturing control, the sensors achieve sufficient temperature accuracy without the need for any individual calibration.

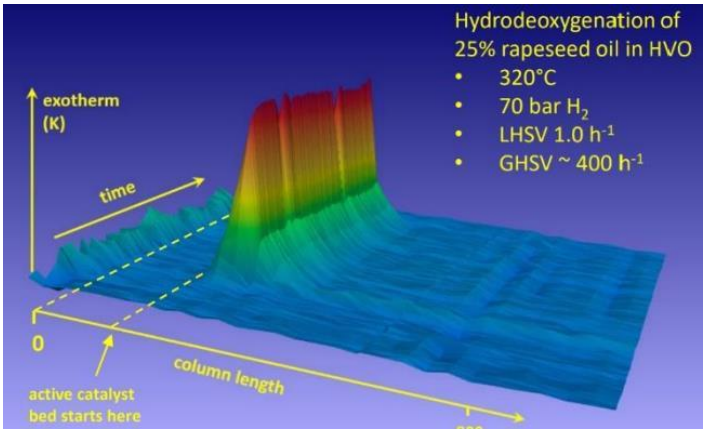

Fig. 1 Measurement of the distribution of the exotermic heat during catalytic reduction of rapeseed oil to biofuel

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Polymer Photonic Platform: application centered photonic platform

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Keywords: photonics, polymer photonics, photonics integrated circuits.

Integrated circuits are essential parts of almost all modern technologies from personal computers, medical devices to cars and spacecrafts. Much of the functionality of these electrical components can be replaced with photonic components to create photonic integrated circuits which use light instead of electrons. Higher speed, lower energy consumption and greater bandwidth are just a few advantages compared to conventional circuits.

In the last couple of decades, huge effort has been put into the development of different photonics platforms based on various materials such as Si, Si_3N_4, GaAs, InP, $LiNbO_3$, and others. Only a few of them (Si, Si_3N_4, InP) have grown to an industrial level of multi project wafer (MPW) services of photonics integrated circuits (PICs). Silicon photonics is the dominant mostly due to compatibility with CMOS process and MPW services are offered by multiple parties: IMEC, Leibniz Institute for High Performance Microelectronics (IHP), AIM Photonics and others. Silicon nitride photonics is gaining ground owing to the broad wavelength range starting from visible wavelengths. MPW services of silicon nitride photonics are provided by IMEC and others[1]. InP allows the possibility to implement both active and passive devices on a single chip. MPW services of InP PICs are provided by Smart Photonics and Fraunhofer HHI[2]. While various photonic platforms have matured to an industrial level, they still have numerous challenges including limits set by material properties, expensive fabrication and complicated hybrid integration. Currently there is no one integrated photonic platform that offers all desired functionalities and manufacturability on the same platform. Silicon photonics has emerged as a preferred platform due to its high-density and high-yield manufacturability leveraging the CMOS ecosystem, although it lacks optical gain, the Pockels effect, and other characteristics [3].

Polymer photonics offer various advantages compared to inorganic counterparts: 1) Tunable optical properties through guest-host systems; 2) Simple fabrication techniques; 3) Integration of other elements for hybrid platform; 4) Wide wavelength range [4]. Here the main advantage is the tunability of optical properties through mixing active materials into polymers. This counters the monolithic nature of inorganic platforms allowing for an essential shift in photonic device designing - from a platformed-centered to an application-centered approach. One of key aspects in active photonic element fabrication (optical-switches, frequency combs and others) are material that exhibits Kerr effect. Among inorganic photonic materials Si_3N_4 and SiC have some of the highest values of Kerr coefficient around 10^{-18}-10^{-19} m^2/W [1]. At the same time many organic dyes have Kerr coefficient $>10^{-16}$ m^2/W [5]. This indicates that by introducing 10% of specific organic dye in polymer we can fabricate 10 times more efficient devices that is essential for low-power applications or efficient high-bandwidth processing.

The goal of this polymer photonic initiative is to develop a workflow for the fabrication of basic photonic components/elements that can be further used to test new photonic devices and optical materials. This system will be based on three main parts - computational simulations of optical devices, materials and element fabrication workflow, and producible photonic elements.

This work is done in the frame of National research program VPP-EM-FOTONIKA-2022/1-0001 "Smart Materials, Photonics, Technologies and Engineering Ecosystem"

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Photodoping of Titanium dioxide for light modulation

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Keywords: Photochromism, photodoping

A plethora of different kinds of organic, inorganic as well as hybrid materials have been proposed for the development of new kinds of photonic materials for optical storage, signal processing, chemical sensors as well as smart windows [1]. Out of these, transition metal oxides are one of the most popular as their combine excellent stability with low-cost. However, the most popular transition metal oxides of tungsten and vanadium are scarce and thus possess supply as well as environmental safety risks [2].

Recently, we have previously reported on titanium dioxide nanoparticles that undergo photodoping during UV irradiation in anaerobic conditions [3]. This has been accompanied by changes in light transmittance in a wide wavelength range. Furthermore, this phenomenon was seen to be reversible, allowing photodoping to be un-done.

Experimental results showed that the particles consisted of single phase crystalline anatase, even at high dopant concentrations. This acts as an affirmation of the high capabilities of the employed synthesis method to deliver heavily doped titanium dioxide nanoparticles. The influence of doping on the induced photodoping, studied via different spectroscopic methods exhibited an increase in the absorbance of the nanoparticles within the visible and infra-red wavelength ranges. Not only was the absorptivity influenced by the chemical doping with cations, but also the absorptivity change rate, when undergoing photodoping. This allows for the usage of the particles in

In conclusion, doping of titanium dioxide with different cationic dopants can not only change the optical properties of the material itself, but also the behavior of the material when going through additional doping procedures, such as photodoping. This allows to vary the optical properties of the nanoparticles to a great degree, allowing them to be used for dynamic light modulation.

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Advantages of polarization optical-time-domain reflectometer in fiber optical communication lines monitoring

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Keywords: polarization optical time-domain reflectometer (POTDR), optical signal polarization monitoring

The optical signal state of polarization gives a number of new possibilities in optical fiber cable monitoring solutions. However, there is a rather limited choice of measurement techniques. The authors propose a polarization monitoring technique based on time-amplitude analysis, which has high timing resolution (2 - 3 ps RMS) and high stability for testing and monitoring of optical fiber lines.

To increase the accuracy and stability of the existing POTDR measurement technique, method setup (see Fig. 2) is developed. In the setup direct modulation laser and probe pulse generator are used for optical pulse generation in the transmission part of POTDR. Probe pulse generator's amplitude, frequency and pulse width are adjusted depending on the monitoring optical fiber line's length. The output of direct modulation laser is connected to the Polarizer_1 to have polarized probe pulses. The output of Polarizer_1 is then connected to the optical 3-port circulator and is used for the separation of transmitted and reflected signal's directions.

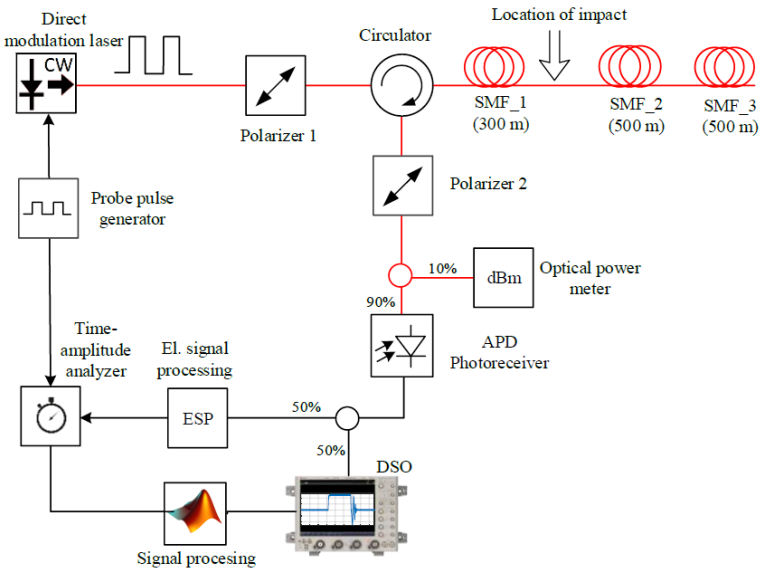

Fig.2. POTDR measurement setup for monitoring fiber optical lines

The common port of the optical circulator is connected to the optical fiber (the same fiber section configuration as in method 1) under test. The output of the optical circulator is connected to Polarizer 2. Polarizer 2 converts the variation of signal SOP into the variation of optical power. The output of the Polarizer 2 is then connected to 10/90 optical power splitter, where the 10 % output port is connected to the optical power meter and 90 % output port - to an APD photodiode. The optical power meter is used to control the optical power level of the APD photodiode's input. The APD photodiode can detect very low levels of optical signals (typically -40 dBm) and it converts them into electrical signals, which are parallelly captured by a digital storage oscilloscope (DSO) and time-amplitude analyzer. The electrical signal processing (ESP) was used to provide a Transistor-Transistor Logic (TTL) signal level to the time-amplitude analyzer's input. For the DSO's and time-amplitude analyzer's received signal processing and visualization purposes, MATLAB software is used.

Conclusion: This method is based on the time-amplitude analysis of event flows, which has higher timing resolution (2 - 3 ps RMS) and high resolution of nanosecond pulse amplitude measurement (8 - 10 bit). The proposed method will be further evolved and improved in the laboratory environment.

Acknowledgment: This research was funded by the European Regional Development Fund (ERDF) project No. 1.1.1.1/20/A/076

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Fabrication, modification, and characterization of Al/PAAO/Au LSPR substrates for optical sensing of vascular endothelial growth factor-A

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Keywords: vascular endothelial growth factor-A, porous anodic aluminum oxide, LSPR, biosensor, aptasensor

Localized surface plasmonic resonance (LSPR) substrates have unique optical properties that can be used as biosensors with improved sensitivity for detection of specific proteins. Vascular endothelial growth factor-A (VEGFA) is a multifunctional cytokine with important roles in normal and pathological angiogenesis [1]. VEGFA together with other angiopoietins initiates tumor angiogenesis and growth. Therefore, VEGFA is an important biomarker for different diseases. In our study we tested the usability of thin gold films on self-organized porous anodic aluminum (PAAO)/Aluminum substrates for refractometric detection of most abundant human VEGFA isoform - VEGF165.

We used two types of PAAO layers for fabrication of metal-oxide-metal plasmonic substrates: 1. PAAO films with constant thickness; 2. continuous thickness gradient PAAO films [2]. Constant thickness PAAO layer on Al surface with pore diameter ~30 nm and interpore distance ~110 nm was prepared using two-step anodization in 0.3 M oxalic acid electrolyte at 40 V potential [3]. Variable thickness gradient PAAO layer (100 nm to 1 um thick) with same pore diameter was made by gradually pulling out the Al sheets out of electrolyte during second anodization. The fabricated PAAO layers were covered with 25 - 30 nm thick Au film (Fig.1). Bulk RI sensitivity calibration was done using salt solutions with different refractive indexes. The obtained Au film was functionalized with anti-VEGF 3' thiolated DNA aptamer SL2B. Scattering mode and reflection micro-spectroscopy was done using fiber coupled spectrometer. After functionalization with DNA aptamer and subsequent treatment with bovine serum albumin, Au films were used for the detection of VEGF165 isoform. Change of intensity of light scattering and shift of scattering maxima wavelength was detected at presence of 0.5 - 1 ng/ml VEGF protein. Reflection mode and scattering mode with p-polarized illumination produced showed good signal to background ratio and sensitivity in the 700 nm - 750 nm spectral region. Therefore, Au films on PAAO/Al templates are suitable substrates for optical detection of elevated concentrations of VEGFA. Their refractometric sensitivity is comparable to nanoparticle array-based sensors [4].

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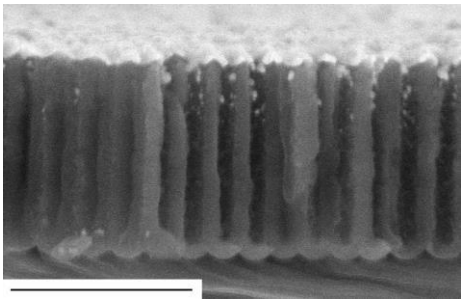

Fig. 1: Scanning electron microscope image of PAAO layer with Au film. Scale bar 500 nm.

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Development of Hybrid Fiber Optical Transmission System with Integrated FBG Sensor Network

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Keywords: Fiber Bragg grating (FBG), fiber optical sensors, hybrid fiber optical transmission systems.

With the growing amount and increase in complexity of various hybrid fiber optical systems, it is necessary to optimize realized resources and their allocation as well as to improve the overall security. In this research we have developed a hybrid wavelength division multiplexed passive optical network (WDM-PON) data transmission system that is unified with fiber Bragg grating (FBG) optical sensor network. In addition to that, we have created a spectrally hidden data transmission system and implemented its hidden data transmission channels between the channels of the standard WDM-PON system. Such architecture can be applied for hybrid data transmission and optical sensor systems as well as for steganography application solutions.

Fiber optical transmission systems (FOTS) are becoming more complex as technologies (such as fiber optical sensors) and other applications are starting to rapidly utilize the optical fiber architecture. Thus performance improvements and effective resource solutions as well as improvement of the transmitted data security is necessary [1-4]. One of the ways to ensure resource optimization is by combining compatible technological systems as it is done in this research where the available frequency spectrum is effectively used to provide the operation of WDM data channels, FBG optical sensors and spectrally hidden channels between each and every WDM data channel. Moreover, such configuration with spectrally hidden data channels provide an additional layer of security, as it is not so conspicuous for the third parties, such as eavesdroppers in situations where they are looking for particular optical frequencies of interest.

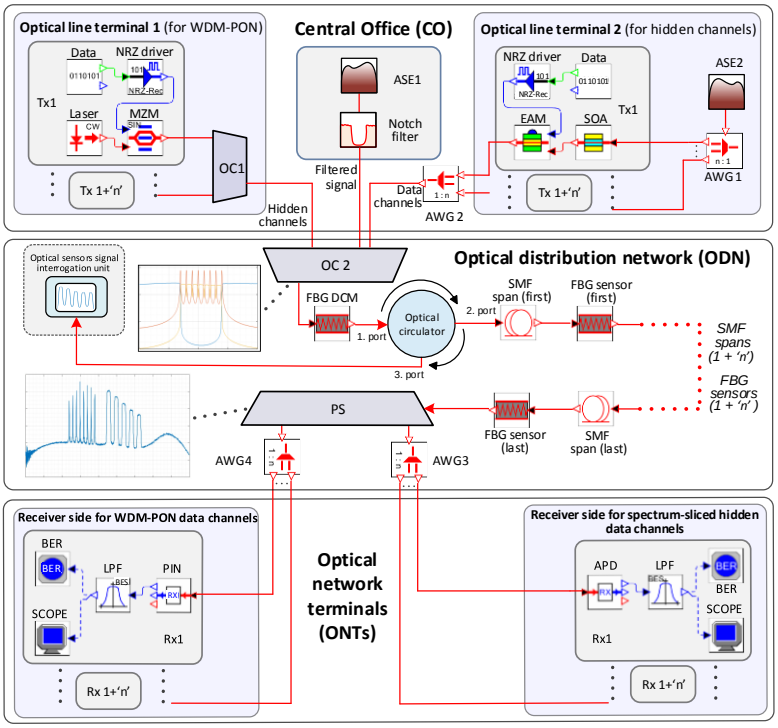

Fig. 1: Developed hybrid FOTS with integrated FBG sensor network

In conclusion, authors have developed a hybrid unified optical data transmission and optical sensors system that can be used for Structural Health monitoring (SHM) applications, Internet of Things (IoT) solutions etc. Such hybrid systems require extensive configuration tests and adjustments in order to provide the necessary performance of each individual system and to avoid overlapping of WDM-PON and spectrally hidden channels as well as WDM-PON and reflected optical sensors' signals as during the operation of FBG optical sensors, their reflected signal frequencies are changing as a response to the impact of measured physical parameters.

Acknowledgment: This research was funded by the European Social Fund within project No. 8.2.2.0/20/1/008.

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Development of Integrated Lossy Mode Resonance Sensor Based on Polymer Photonics

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Keywords: lossy mode resonance, photonic integrated circuits, SU-8

A promising phenomenon such as lossy mode resonance (LMR) is of great interest for sensor applications. Until now, this phenomenon has been shown only in fibers or planar waveguides [1,2]. At the same time, it is known that such a technological area as photonic integrated circuits (PICs) began to develop rapidly, so the transfer of LMR technology to PICs has prospects and commercial potential, especially considering the use of such a flexible and inexpensive polymer as SU-8. This study proposes the development of an integrated polymer-based LMR sensor that will also contribute to the development of hybrid organic-inorganic PICs. This research shows the influence of polymer waveguide and cladding geometries on the LMR behavior of the given sensor design shown in the Fig. *1*. Waveguides of various widths (from 10 µm to 25 µm) and thicknesses (from 10 µm to 25 µm), as well as various lossy oxide coatings and thicknesses from several to hundreds of nm, were tested to determine the optimal design. In addition, the LMR effect in waveguides of this geometry was compared with LMR effect in planar polymer waveguides. Based on the results of this study, optimal waveguide and lossy coating dimensions will be selected that can provide the highest sensitivity for detecting biological entities such as extracellular vesicles in cancer applications.

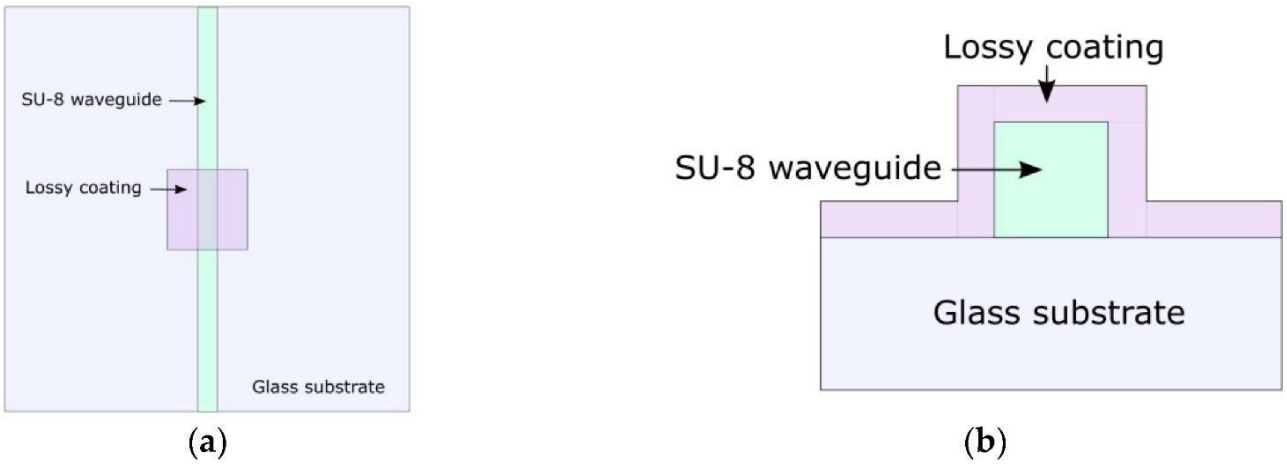

Fig. 1: Integrated LMR sensor design: (**a**) top view, (**b**) cross-sectional view [3].

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Fiber Bragg Grating Optical Sensors for Infrastructure and Object Monitoring Solutions

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Keywords: Fiber Bragg grating (FBG); fiber optical sensors (FOS); structural health monitoring (SHM);

Structural health monitoring (SHM) of different objects and architectures has recently been a topical part of realized research in civil engineering, marine, aviation field, etc. One of the most suitable ways of SHM realization is by utilizing the Fiber Bragg grating (FBG) optical sensors. In this research we have analyzed and categorized most recently studied fields and solutions regarding the SHM applications where FBG sensor technology has been realized. Additional attention is given to the security solutions that are accomplished by using SHM applications and based on the gathered data, forecasts for upcoming research fields are made.

SHM applications realized with FBG optical sensors [1,2] are actively studied (see Table 1), however there are different approaches applied, methods used and solutions developed based on the specific needs. Nevertheless, we have investigated and structured the main aspects that are common for all those researches (see in Fig 1.). FBGs are used either standard or apodized (e.g. gaussian, raised cosine, tilted etc.). SHM applications utilize single, quasi-distributed or distributed architecture while providing multiplexion of the FBGs (typically wavelength division multiplexing (WDM)). Most often during SHM temperature, strain or pressure is measured in either composite, concrete or polymer structures.

Table 1. Number of scientific publications regarding FBG SHM solutions in most well-known scientific databases

No. of scientific publications	Scopus					Web of Science					ScienceDirect				
SHM with FBG sensors	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022	2018	2019	2020	2021	2022
	38	47	30	33	32	26	34	29	27	27	7	5	8	6	8
In total	180					143					34				

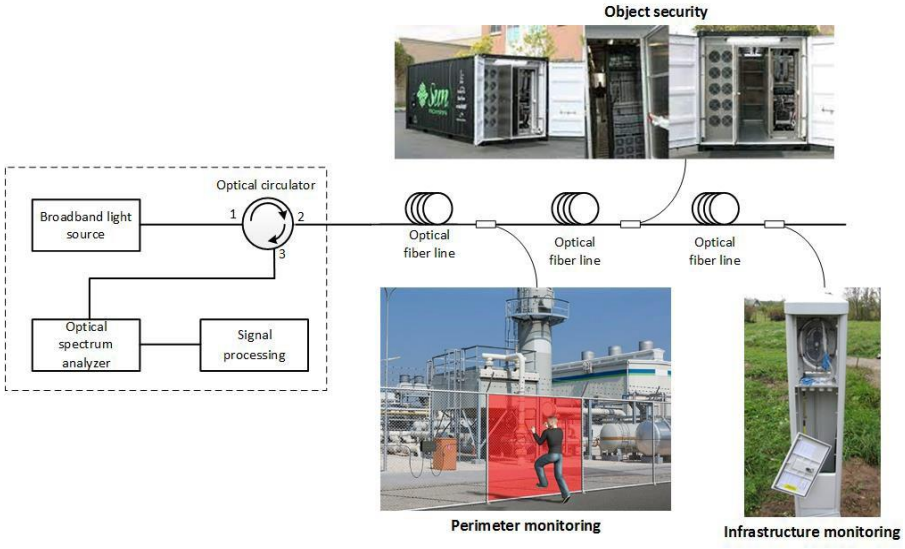

Fig. 1: FBG sensor for infrastructure real-time monitoring solutions.

In conclusion, SHM applications that use FBG optical sensors are a topical part of the modern research field and there are numerous configuration variables used (described previously) while performing SHM applications with FBGs in industries such as civil engineering, aviation, marine, energy and security solutions.

Acknowledgment: This research was funded by the National Research Program within project No. VPP-EM-FOTONIKA-2022/1-0001 and European Social Fund within project No. 8.2.2.0/20/1/008.

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Modelling the performance of the optical phase retrieval teoretical wavefront sensor

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Phase retrieval dealing with the inverse problem of recovering the unknown phase of signal solely from magnitude measurements, and method developed substantially in the last decades. There have been demonstrations of PR applications in real-time AO systems [1]. Most popular WFS on phase retrieval is a phase diversity WFS, which does phase retrieval from two slightly defocused images, but method appeared to be limited sensitivity for high aberrations. Fast development of phase retrieval algorithms open new possibilities for sensitive and relatively fast phase estimation.

In our research we model the performance of PR based on optimization aproaches to be implemented in optical wavefront sensing. To conform the physical requirement we propose different resolution systems with input image of 2^5, 2^6, 2^7, 2^8 pixel matrices. PR algorithm utilises Wirtinger Flow approach with steep gradiend descent optimisation. We estimate linearity of the theoretical system modifications for linearity, retrieved phase resolution and quality, and speed parameter.

Results show that all modifications are linear for most of the aberration ranges, but tend to become erroneous with input magnitudes comparable to system noise. Optimal for physical implementation is a 64 and 128 pixel systems, as those provide sufficient speeds of retrieval and relevant resolution of up to 110 and 250 Zernike modes, respectively. Large format system allows high resolution but is significantly slower and larger errors in retrieved phases are present.

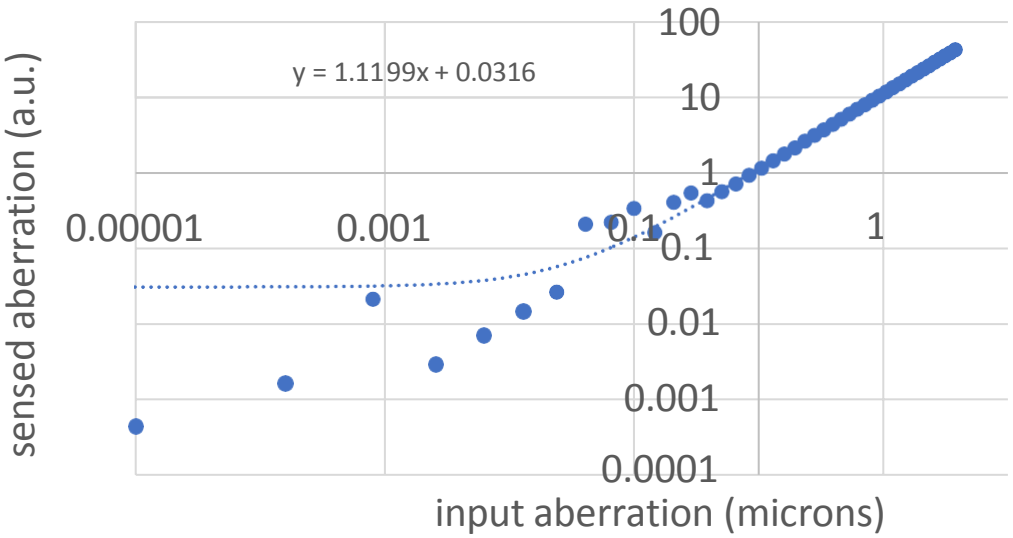

Figure 1. Linearity of the 128 px phase retrieval system.

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Hyperspectral lidar development and applications

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Keywords: Lidar, Hyperspectral, Remote Sensing, Target classification, Supercontinuum, Fluorescence.

Hyperspectral lidar combines the ranging-, sensitivity- and photon efficiency of lidar with the target classification and characterization known from hyperspectral imaging. Our group has developed robust hyperspectral lidars and explored various applications in the field. Our method is based on violet laser diodes and supercontinuum light sources in combination with a double Scheimpflug lidar principle[1]. These geometric conditions are later refined by raytracing. The optimal optical configuration is implemented through CAD software with a sandwich structure in which the optical elements are clamped. The piece is then 3D printed with plastic filament and reinforced with metal bolts.

We explain our hyperspectral lidar principle, revise our recent design advances and demonstrate spectacular field applications. Examples include; insect classification by wing thickness, detection of fluorescently tagged insects, daytime profiling of vegetation canopies, and tree species classification.

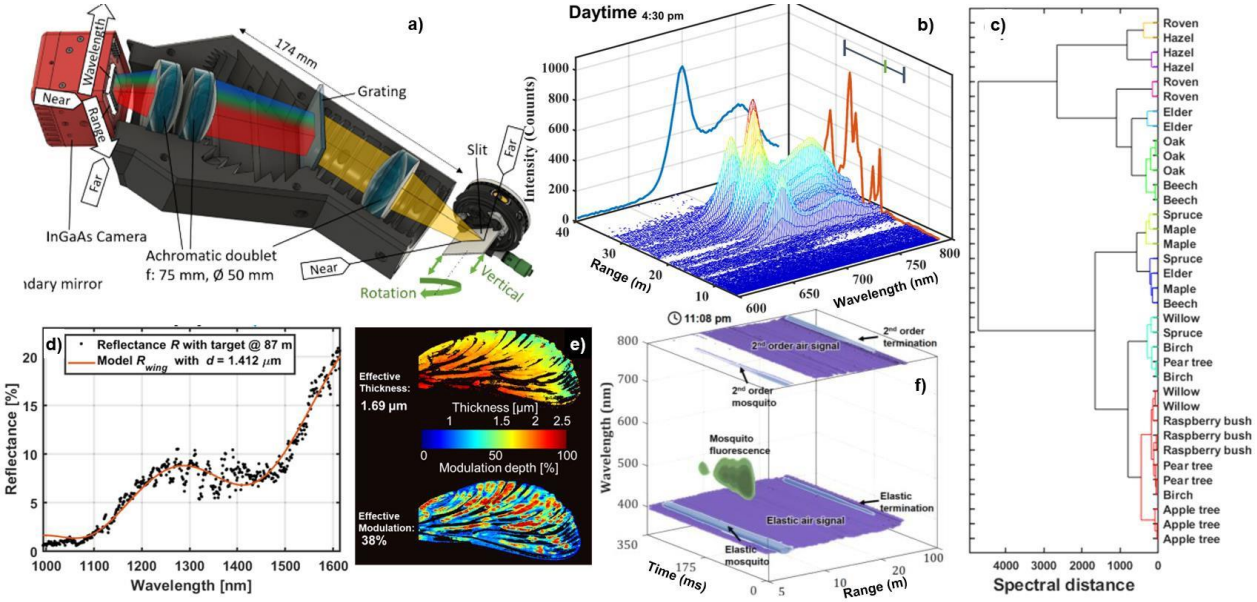

Fig. 1. Various advances in hyperspectral lidar. a) 3D printed sandwich structure[2]. b) Daytime fluorescence profiling of vegetation[3]. c) Unsupervised clustering of tree species from Skåne[4]. d) Spectral lidar echo from an insect wing[2]. e) Hyperspectral imaging of the same wing[5]. f) Hyperspectral lidar signal from a mosquito fed with fluorescent solution[1].

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IR polishing for high performance Earth observation applications

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Keywords: infrared optics, aspherical optics, crystalline materials, low micro-roughness

More than 50% of the incident rays of the light on the earth are within the infrared range, defined from 0.75 - 1000 µm, and can only be explored using special optics. Within the framework of a project with the European Space Agency to study IR radiation on the Earth, asphericon manufactured high-precision IR aspherical lenses for high-performance applications. From the wide range of possible materials silicon monocrystals, Zinc sulfide (ZnS), and IG2 glass were used. All of them work in the range from 1.4 µm (short-wavelength infrared) to 15 µm (long-wavelength infrared). Thanks to asphericon‘s special polishing processes, all aspherical optics achieve microroughness RMS values up to 0.93 nm.

Instead of the SPDT process which is mainly used for machining the IR materials were for the manufacturing the lenses used subapertural polishing. It allows us to reach significantly better microroughness and get rid of the typical mid-spatial structure produced by single-point diamond turning. Also, the productivity of the whole process is very high. The greatest improvement was reached on polycrystalline ZnS where the polishing time of the aspherical surface of diameter 85 mm was only 45 minutes with final microroughness 2,5 nm RMS.

	Microroughnes Sq [nm]	Form deviation RMSi [nm]
IG2 asphere	0.93	35
ZnS asphere	1.7	56
Si asphere	0.94	22

Tab. 1: Summary of the reached microroughness on the aspherical surfaces using asphericon’s developed polishing process.

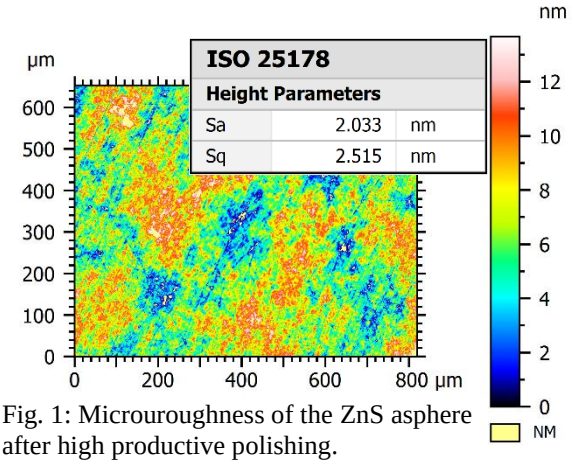

Fig. 1: Microuroughness of the ZnS asphere after high productive polishing.

Developed polishing processes are continuously improved and adapted to new materials currently to CaF_2 and MgF_2. The knowledge is also transferred to the polishing of free-form surfaces to low microroughness and form deviation. In parallel with pushing the limits of those parameters as low as possible, asphericon also focuses on the high-productive polishing of materials for the infrared part of the spectrum and coating.

Various PAAO-based hybrid multilayered structures for refractive index sensing: FDTD simulation study

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Keywords: nanomaterials, thin films, optical sensing and sensors, multilayer design

The porous anodized aluminium oxide (PAAO), also known as nanoporous anodic alumina, is a versatile material: its combinations with other materials allow application in the fields of catalysis, drug release, sensors, energy, and other devices. PAAO is relatively easy to manufacture, thus PAAO-based structures are an attractive research field [1]. It is already demonstrated that PAAO with colloidally deposited gold nanoparticles is a feasible refractive index sensor [2].

In this work, the results of finite-difference time-domain (FDTD) simulations will be presented showing various possible structures based on PAAO and their potential to work as a refractive index sensor. The concept of optical sensor (Fig. 1 (a)) is based on light interaction with the structure: if the reflection spectrum changes upon a change in surrounding (immersion) medium, the proposed structure can work as a refractive index sensor.

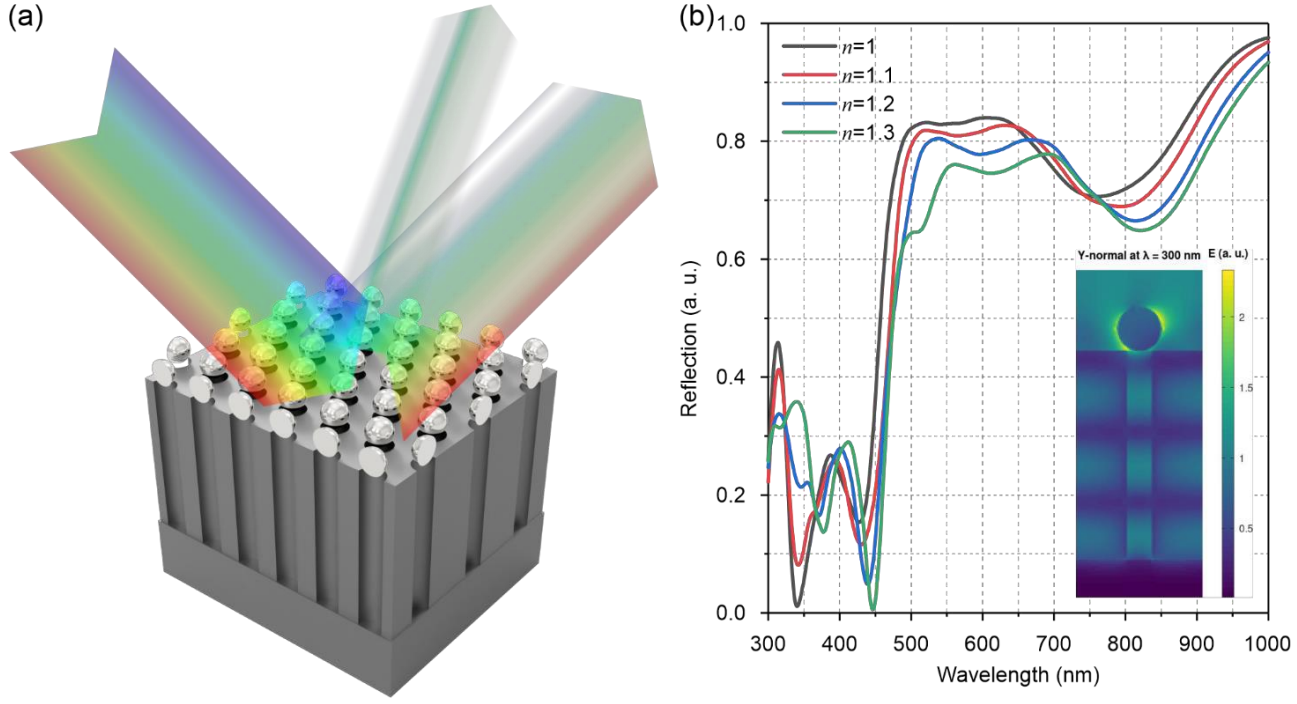

Fig. 1: (a) Artistic impression of light interaction with PAAO and silver nanoparticles (not to scale). (b) Simulated reflection spectra at different refractive indices for a 290 nm thickness PAAO covered with silver nanoparticles after illumination at 45° with p-polarized light. The inset shows the electric field distribution in the cross section of the structure at 300 nm wavelength.

In the case of 290 nm thickness PAAO covered with 60 nm diameter silver nanoparticles (Fig. 1 (b)), the peaks at around 500-700 nm wavelengths shift towards longer wavelengths. Similar shifts in the FDTD simulated spectra are observed for PAAO structures covered with a diamond-like carbon and silver nanocomposite film or a gold film. Thus, PAAO-based hybrid multilayer structures have a potential to be used in optical refractive index sensors. Experimental testing of such sensors is underway.

This research is part of the postdoctoral project "Patterned hybrid multilayer films for optical sensors" (no. 1.1.1.2/VIAA/4/20/615) sponsored by the European Regional Development Fund.

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The more the better? Display brightness considerations for optimal user experience in mixed reality

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Keywords: mixed reality, display brightness, ocular accommodation, user experience

For Industry 4.0, mixed reality is one of the leading enabling technologies. What is required for mixed reality headsets to be efficiently and comfortably used for professional purposes? Display brightness is one of the most discussed factors. However, the majority of discussions around display brightness are devoted to the necessity of its increase [1]. As said in the headset manual: "Increase brightness of the display. Holograms look best when the display is at its brightest level" [2]. This recommendation does not consider the specifics of the work environment and the variability of user needs [3]. Thus, it remains unclear whether maximizing display brightness is optimal for sustained near work in mixed reality.

To address this issue, we assessed the changes in ocular accommodation, pupil diameter, and user comfort after near work using a headset. Subjects performed a 30-minute near-vision task under the maximum and minimum display brightness of the Microsoft HoloLens 2 headset. The ocular accommodation and pupil diameter were registered using an eccentric infrared photorefractor PowerRef 3 (Plusoptix GmbH, Germany). The user comfort was assessed using a questionnaire.

As a result, no considerable differences were revealed in the ocular accommodation and pupil size following the near work under both maximum and minimum display brightness. However, subjects reported ocular discomfort following the near-vision task in mixed reality under maximum display brightness. For many of them, a decrease in display brightness led to the relief of symptoms. Still, the visual experience was not op- timal because of the imprecise color presentation inherent to the low display brightness condition.

Our findings indicate that putting the user's needs at the center of technology development and providing the manual adjustment of display brightness (in addition to automatic) is crucial for the mass adoption of extended reality technology and its implementation in work environments. Moreover, further technology improvements are needed to replicate colors in a full range at all display brightness levels not only to enhance the user comfort but also to provide the opportunity to use headsets for professional tasks in which precise color presentation is required for task completion.

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A portable sub-ns pulsed MIR laser source for sensing

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Keywords: Nonlinear optics, down-conversion, gas sensing

Many greenhouse gases have absorption lines in the spectral region between 2 µm and 3 µm [1], which can be exploited for range-resolved gas concentration measurements. To perform such a measurement, one needs to have a laser source capable of producing pulses with a spectral line width narrow enough to be able to target a specific absorption line. Furthermore, the shorter the pulse duration, the better the range resolution one can achieve. Optical parametric processes are often used to reach the desired wavelengths where direct laser output is unavailable. For longer pulses, from a few nanoseconds and up, optical parametric oscillators (OPOs) can be used, and for ultrafast pulses, with pulse durations below a few tens of picosecond, optical parametric generators/amplifiers (OPG/OPAs) can be used. However, a pulse duration gap exists between these two techniques, resulting in cumbersome techniques such as synchronous pumped OPO to achieve high efficiency [2]. We have developed a compact sub-ns pulsed source based on backward wave OPO (BWOPO) [3], realized in bulk periodically poled KTP. In our BWOPO scheme, the idler is counter-propagating to the pump, allowing feedback to be established without needing a cavity. This allows us to efficiently generate 450 ps pulses with a narrow spectral linewidth from a microchip laser in a single pass configuration. It is only possible to achieve this with quasi-phase-matching (QPM). To efficiently generate the counter-propagating waves a large phase mismatch has to be compensated for, requiring in a very short poling period. The poling period used in this case was 580 nm, representing state-of-the-art in QPM material, which resulted in an idler at 2155 nm counter propagating to the 1030 nm pump and 1973 nm signal. Due to the interaction's counter propagating nature, the backward wave inherently has a narrow spectrum.

The pump laser was a microchip laser with 450 ps long pulses with a pulse energy of around 40 µJ and repetition rate of 9 kHz. The system's overall efficiency was above 50 %, resulting in more than 10 µJ in the 2155 nm beam. The pump and generated idler spectrum can be seen in Fig. 1 (a) and 1 (b), respectively. It is clear that the idler has not inherited the broad spectrum of the pump, which has instead been transferred to the signal. This allows narrow bandwidths to be achieved even if the pump laser has a broader spectrum.

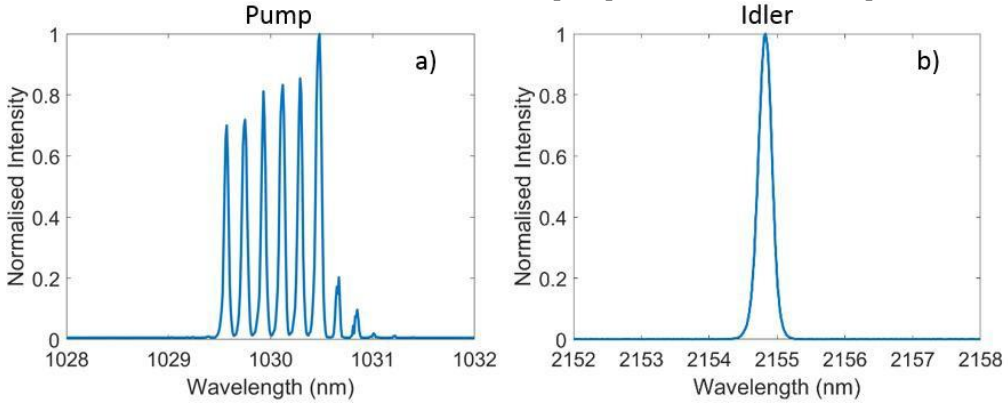

Fig. 1: Spectrum of a) the pump, and b) idler.

While this paper has focused on a sub-ns laser source at 2155 nm, the technique can easily be applied to any wavelength between 1.6 µm and 3 µm, limited by the transmission of the KTP crystal. This type of laser source would also be beneficial for medical [4], and military applications among others.

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Quantum applications with diamond needles

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Keywords: Diamond needles, Color centers, Luminescence, Chemical Vapor Deposition

The discovery of stable at room temperature luminescent point defects, combined with outstanding mechanical, optical, and thermal conductivity properties, has piqued the interest of researchers in diamond today [1]. Color centers in diamond are distinct physical systems or point defects that can absorb photons in the spectral region where diamond is transparent, causing crystal colorization when sufficient concentration is pre- sent [1]. Over 500 different color centers in diamond have been documented, both synthetic and natural, but only a few have been thoroughly studied [2]. The well-known nitrogen-vacancy centers and, more recently, silicon- and germanium-vacancy centers are among them. Understanding and utilizing their properties has resulted in the development of a plethora of quantum technology platforms. Color centers, for example, have been used for magnetic and current sensing with nanometer spatial resolution [1], storing quantum infor- mation at room temperature for more than one second [1], establishing quantum entanglement between dis- tant electron spins [3, 4], biomedical imaging [3, 4], single photon generation, diodes [4], resonators [1], bio- markers or drug delivery carriers [2], and so on.

In this work, we concentrate on the possible use of diamond needle crystals in quantum applications. Diamond needles are pyramid-shaped single crystals with a base thickness of up to a few micrometers and an apex thickness of a few nanometers. The production of diamond needles involves the use of both selective oxidation and chemical vapor deposition processes. In this article, we describe the optical characteristics and features of diamond needles that have been enriched with various color centers and show how they can be used to make high-sensitivity thermometers, nanoscale magnetometers, and single photon emitters.

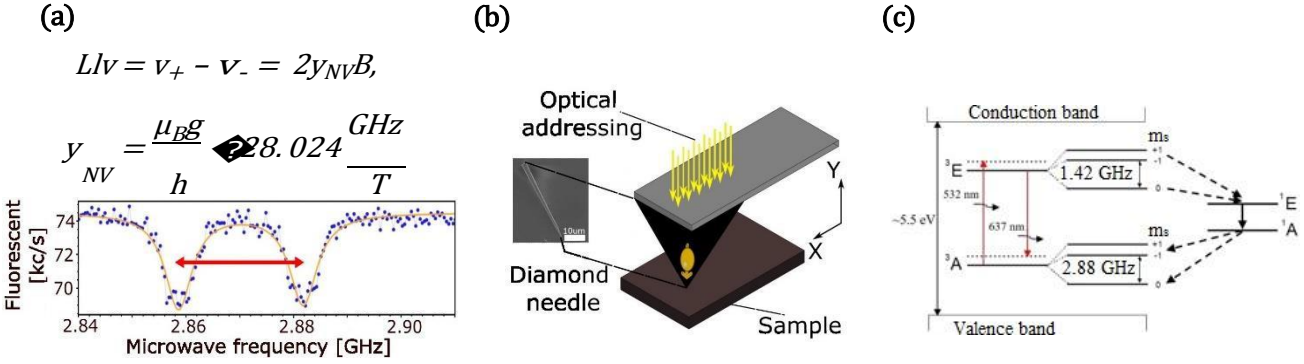

Fig. 1: An example of a diamond needle with a nitrogen vacancy center (NV) (c) used to demonstrate scanning probe microscopy (b). In this case, the diamond needle is serving as a scanning probe for magnetic fields (a).

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Quantum Photonics using Structured Photons

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Keywords: structured light, quantum photonics, quantum metrology

Shaping the transverse structure of quantum light has attracted a lot of attention in quantum photonics ranging from fundamental studies to quantum information applications. A powerful way to describe any spatial structure in the paraxial limit are orthogonal transverse spatial modes e.g. Laguerre-Gauss modes. Amongst many other things, such modes show interesting features like a theoretically unbound quanta of orbital angular momentum (OAM) per single photon related to a twisted phase structure. Moreover, such spatial structures serve as a versatile testbed for novel complex quantum states [1].

In this talk, I will give a brief introduction to the concept of spatial structures and show some of the key areas of their application in quantum optics and quantum information. I will present advanced schemes of spatial-mode modulation and how they can be used to improve optical fiber networks [2] as well as to generate spatial-mode N00N states. The latter describes states where N photons are in an extremal superposition between two orthogonal spatial modes. Our results show that such states when realized with OAM modes, i.e. twisted N00N states, can be used to achieve super resolving angle measurements as shown in Fig. 1 a) [3].

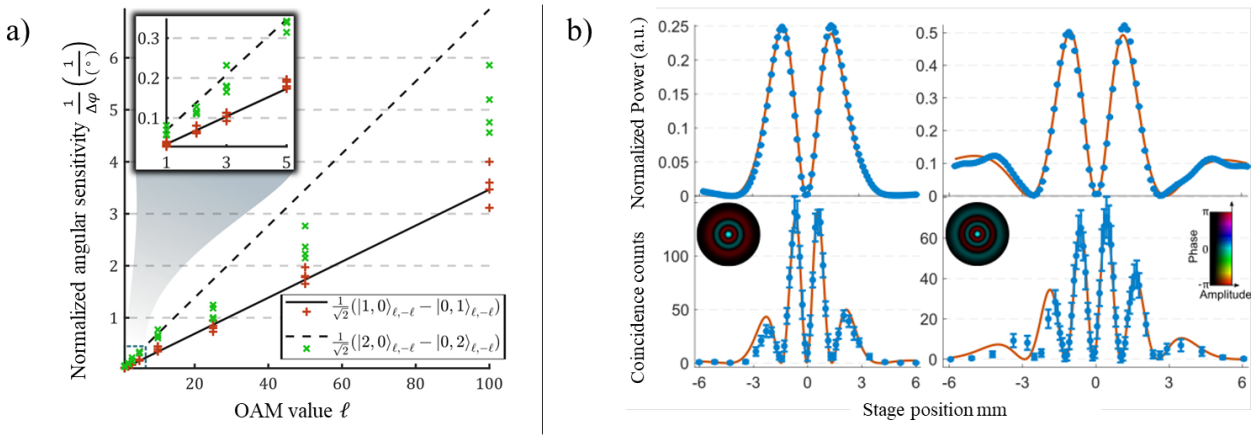

Fig. 1: a) Twisted N00N states show increased angular sensitivities for larger OAM values and for two-photons (green) compared to single photons (red). The plotted lines show the theoretically expected behavior. b) Experimentally recorded data of the Gouy phase's effect on radial mode superpositions between a Gaussian and radial mode of order 3 (left) and order 4 (right). The top row shows the classical behaviour, the bottom row shows the effects of the quantum Gouy phase for N00N states using the same pair of modes for both cases.

In addition, we studied spatial mode N00N states in connection to a fundamental wave phenomenon, the so-called Gouy phase anomaly. It describes the anomalous phase delay of transversely confined waves when propagating through a focus. When probing it in quantum domain, i.e. when probing the quantum Gouy phase we find that it behaves different from classical light waves in terms of phase evolution as well as spa- tial mode order (see Fig.1 b). We further show that it might be beneficial in longitudinal sensing and high- light that the so-called photonic de Broglie wavelength is not sufficient for describing the behavior of photon number states [4].

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Heart rate variability measurement by means of ECG, PPG, and CorSense mobile monitor by Elite HRV application

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Keywords: ECG, PPG, mobile monitor, Poincaré plot, heart rate variability, variance impact factor

The human heart rate (HR), heart rate variability (HRV), and possible chaotic behavior of human pulsating blood are very important health-indicators. New development of very accurate automatic HRV systems using a minimum number of bio-signals, e.g., photoplethysmographic devices (PPG), have become a challenging issue for personalized medicine. According to the report on the global PPG Sensors market size, the PPG sensor market was valued at USD 874.93 million during last year and is expected to expand at a CAGR of 42.1% during the forecast period, reaching USD 7204.82 million by the year 2028. This report could accurately predict about many upcoming custom trends and believed changes in consumer behavior in PPG markets. In our study we present a few illustrative Figures.

This study was not business oriented, but aimed to propose a accurate system by examining nonlinear dynamics of PPG and ECG for HRV determination based on inter beats intervals (IBI). ECG is a electrophysiological phenome measured over body whereas PPG is bio-optical change caused by blood volume pulses in small blood vessels and capillaries of the skin based on tissue absorption, its scattering, and also light transmission properties as a function of light wavelength. PPG can be recorded by using a components that comprises a light-emitting diode (LED) and a phototransistor (PTr). The PPG sensors were placed on the tip of the forefingers. The received biosignal pair has the proficiency of a hybrid feature, which were combined as ECG and PPG features on the merged Poincaré plots. Merged Poincare's plots were used to characterize the irregularity and chaotic behavior heart rarte. It was seen that the PPG signal changes more than other biosignals, e.g., ECG as a function of the human age. Notwithstanding the PPG is increasingly used for measuring the physiological state of individuals of different ages in daily life. In the Figure 1 it is shown the Poincaré plots for ECG, PPG, and CorSense Elite HRV for three cases.`

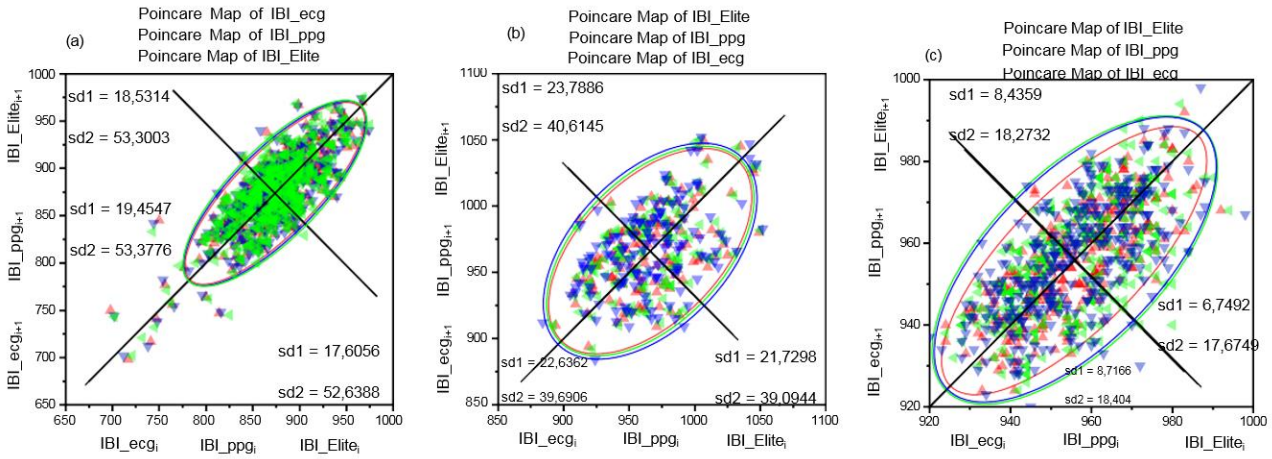

Fig. 1: Examples of elliptic of merged Poincaré plots where the x-axis is an IBI as a function of the next IBI based on ECG, PPG, and Elite HRV. (a) for 43 year male, (b) 45 year male, and 71 year male. Red color for ECG, blue for PPG, and green for Elite HRV

The future work would be evaluation of ways to define the parameter accuracy in the PPG, ECG, or CorSense Elite HRV records as a function of human age, gender, and clinical vascular patients.

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Vector magnetometer based on NV centers in diamond

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Keywords: NV centers in diamond, quantum sensors, magnetometry, GNSS denied navigation

NV (nitrogen - vacancy) centers in diamond are point-like defects consisting of one carbon atom substituting nitrogen atom and an adjacent vacancy (Fig. 1, Left). NV centers, like other defects in a diamond, give the diamond a specific color, depending on the concentration of nitrogen in the diamond, a yellowish - brownish hue (Fig. 1, Center). Due to this NV centers are also called color centers.

Fig. 1: **Left**, a schematic representation of the atomic structure of an NV center in a diamond crystal lattice, N - nitrogen atom, V - lattice vacancy, C - carbon atoms. **Center**, diamond samples used in laboratory research and prototype device development. **Right**, NV symmetry axes and laboratory-frame directions ***x***, ***y***, and ***z***. A magnetic field ***B*** projects on to the four NV orientations, causing Zeeman shifts of the energy levels of the NV centers that can be measured using spectroscopic methods in combination with a laser and a microwave source [2].

Diamond is a compact, physically and chemically robust as well as non-toxic platform, capable of operating in harsh environments with high pressures up to 60 GPa and temperatures ranging from cryogenic temperatures to 600 K, NV centers can provide high measurement rates (up to 100 kHz) due to their physical properties [1].

NV centers in diamond is an emerging quantum sensor technology that can be used for high sensitivity (50 pT/Hz$^{1/2}$) 3D magnetic field measurements in low-SWaP requirement applications e.g., magnetic geo-referencing (Fig. 1, Right) [2] in GNSS denied situations, magnetic field imaging [3] of soil samples on the Moon and radiofrequency spectral analysis [4] for radar detection.

Based on our previous academic NV research experience [5, 6, 7, 8] and a successful feasibility study on developing a vector magnetometer prototype device based on NV centers done for ESA (Fig. 2) we are working on advancing this technology.

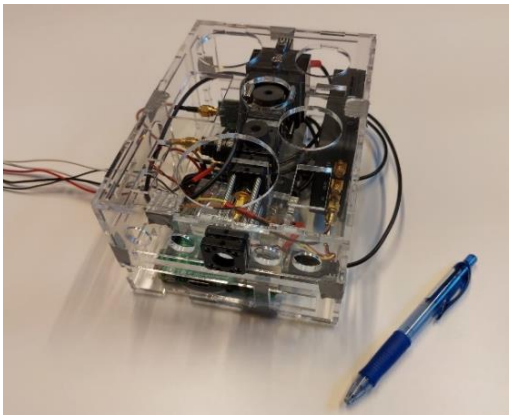

Fig. 2: An NV based vector magnetometer prototype device developed for an ESA feasibility study.

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Analysis of the parameters of the process of laser marking of new industrial materials for high-tech applications

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Keywords: fiber laser, laser marking, laser surface texturing, contrast, roughness, nanostructures

Achieved high-tech results in the laser center of "Rezekne Academy of Technologies". From the time of creation until now, it has been in the development of effective surface treatments leading to the improvement of the technological properties of new modern materials with wide applicability. A major achievement in recent years is the laser surface marking of austenitic steels (AISI 304) [1], which leads to an increase in surface hardness over 2.7 times, wear resistance over 1.7 times, scratch resistance 1.4 times, etc., which directly depend on the laser processing modes. Through the modes of laser surface treatment, textures with reduced or increased roughness can be achieved, which can be reduced more than 1.5 times or increased by more than 3 times. Surface structures with hydrobonds and hydrophilic properties are polished, which enables wide application in various fields. These changes lead to an extension of the service life of products in machine building, equipment construction, and in the household.

Improvement of the surface by laser processing has also been achieved on Titanium Gr1 and GR5, which are used in medicine and for the manufacture of prostheses and implants, aircraft construction, cosmonautics, etc. An increase in hardness over 2.6 times was achieved, and the roughness could be reduced by 1.4 times or increased by over 2.3 times. These changes lead to a change in the tribological properties, as the wear resistance is improved, and the contact friction can be reduced up to 2 times or increased up to 3.4 times.

The laboratory has accumulated scientific research experience for surface modification of aluminum sheet materials Al 99.95, Al 1050 and 2219 to obtain hydrophilic and hydrophobic properties. High contrast surface markings of up to 40 % have been achieved [2, 3].

Methods have been developed for marking and surface treatment of copper sheet materials. Contrast markings and surface structures for high hydrophobicity and hydrophilicity were achieved by varying the surface roughness[4, 5].

As the need to reduce harmful emissions (CO2, CO, NO2, CH, and SO2, etc.) released into the environment and their capture increases, solutions are sought for the surface structures of the materials that create a process of retaining them. In addition, barrier-marked surfaces can be produced where easily released substances cannot be retained on the surface. For the purposes of this research, materials from the group of Incoloy and Inconel applicable in the production of pipes and installations for the transmission of gases or liquids under pressure for long distances are used.

These achieved scientific studies show how laser technologies will increasingly find wide application in industrial production [6].

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Realization of Fiber-Bragg-Grating-Based Optical Sensors for Real-Time Transport Traffic Induced Strain Monitoring

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Keywords: Fiber Bragg grating (FBG); fiber optical sensors (FOS), road infrastructure monitoring;

Research focuses on the Fiber Bragg grating (FBG) optical strain and temperature sensors' embedment and integration within the road pavement infrastructure, thus providing the capability for such physical parameter measurements (SHM solution). Results gathered in this particular research show that FBG sensors can in real-time detect the induced strain values of each passing vehicle's axle.

Road infrastructure monitoring [1-3] and particularly asphalt pavement has been a topical field of research in recent times. Due to the various types of fiber optical sensors available in the market and research fields, it is possible to use, for instance, FBG optical strain and temperature sensors to provide real-time transport traffic monitoring and analysis. During the recent construction process of some parts of Latvian A8 highway, we developed the method and integrated FBG strain and temperature optical sensors within the road infrastructure (see in Fig.1.). As vehicles move across the road and pass the embedment point of the strain optical sensors, their axle induced strain can be recorded (see example in Fig.1.). This data can later be processed and used for various monitoring applications, such as the traffic analysis, enumeration of passing vehicles, recording of the axle count of each vehicle, its type - truck, bus or car, as well as vehicle's moving speed and weight.

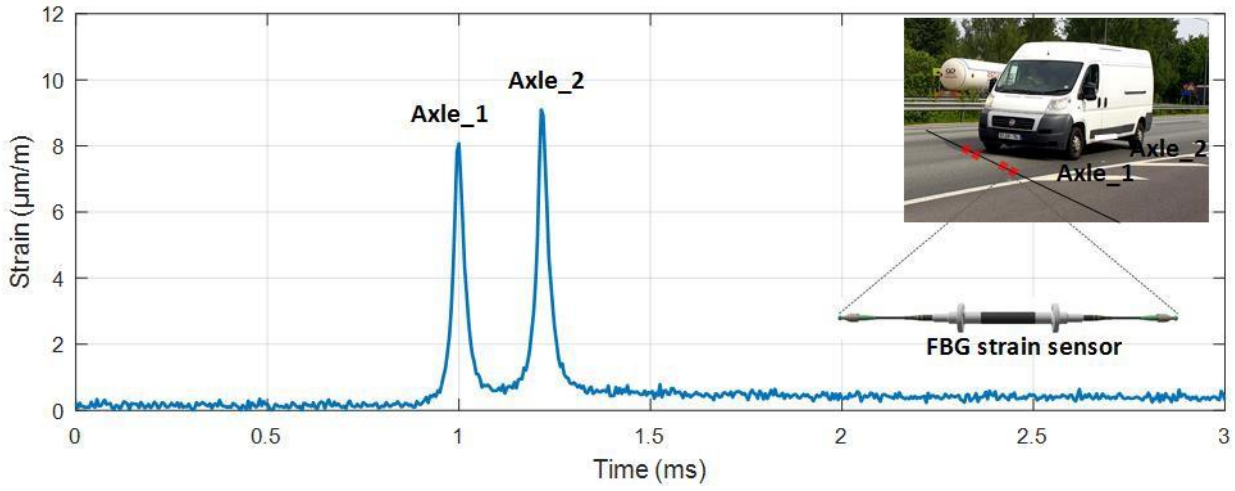

Fig. 1: Real-time transport traffic strain monitoring with FBG optical sensor.

In conclusion, FBG optical sensors are topical technology that can be integrated within the road infrastructure to provide physical parameter measurements of the transport traffic. Additionally, such functionality also allows structural health monitoring (SHM) realization of the specific part of the road pavement infrastructure, as the FBG optical sensors provide long-term monitoring capabilities.

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