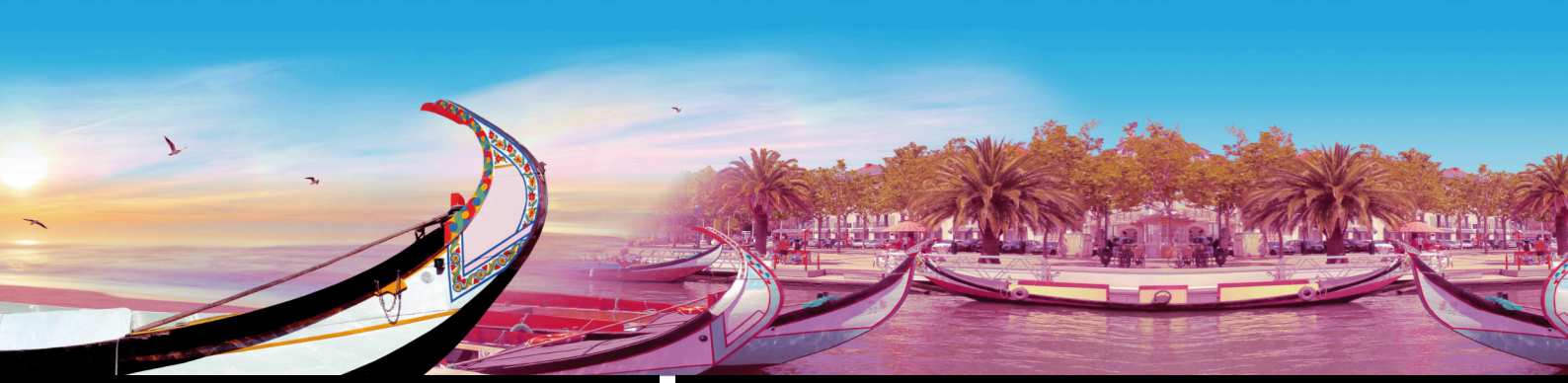
AOP 2024



Aveiro, Portugal,
July 16-19, 2024

VI International Conference on
Applications of Optics and Photonics

BOOK OF ABSTRACTS

Edited by: Manuel Filipe P. C. M. Costa

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Portuguese Society for
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SFO Société Française d'Optique French Branch of the EOS

SIOF Società Italiana di Ottica e Fotonica

SOFE

HSCI Hands on Science

Ciências ULisboa

ia instituto de astrofísica e ciências do espaço

NOVA SCHOOL OF SCIENCE & TECHNOLOGY

LIBPhys

SPM SOCIEDADE PORTUGUESA DE MATERIAIS

CENIMAT i3N

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LASER World of PHOTONICS

EDP sciences

ORDEM DOS ENGENHEIROS

Photonics Finland

FISUA DESDE 1993 ASSOCIAÇÃO DE FÍSICA DA UNIVERSIDADE DE AVEIRO

FÁBRICA CENTRO CIÊNCIA VIVA aveiro

CICECO Aveiro Institute of Materials

sensors

photonics

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Preface

For the sixth time, since 2011, the Portuguese Optics and Photonics community celebrates, meeting with colleagues from all over the world, at the AOP2024 conference to be held in Aveiro, Portugal, July 16 to 19, 2024, the remarkable contribution of Optics and Photonics to the development of our societies and humankind, reviewing the state-of-the-art and foreseeing the future evolution and developments in the field.

The AOP conferences organized by SPOF, the Portuguese Society for Optics and Photonics, are designed to set the best friendly relaxed and nurturing environment to foster the establishment of the widest range of cooperation projects and relationships with colleagues and institutions from all around the world while increasing the external visibility of Portugal' Optics and Photonics research.

Over two hundred participants will present and attend one hundred and eighty-five presentations covering all field of optics and photonics both fundamental and applied. Five plenaries, thirteen keynote and thirty-two invited lectures by world renowned researchers and scholars as well as top level young researchers in all fields of Optics and Photonics, set the high-quality standard of a varied and exciting scientific program. In a novel special session "Optics and Photonics Research Labs and Centers in Portugal and International Cooperation" eleven major Portuguese and one foreign research institute center or lab will be presented and the prospects of future cooperation and development are going to be explored and discussed with the conference participants in an open round table.

With high anticipation and enthusiasm, we are looking forward to have the pleasure to welcome our friends and colleagues from all over the world in the lovey city of Aveiro for a most exciting productive and enjoyable AOP2024 conference!

Braga, June 27, 2024.

Manuel Filipe Pereira da Cunha Martins Costa

(President of SPOF and chairperson of the AOP2024 conference)

AOP 2024 – General Program

	16 July 2024 Tuesday	17 July 2024 Wednesday	18 July 2024 Thursday	19 July 2024 Friday
8:15 - 8:45		Registration	Registration	Registration
8:45 - 9:45		Plenary session 3	Plenary session 4	Plenary session 5
9:45 - 11:00		Parallel Sessions 2	Parallel Sessions 5	Parallel Sessions 8
11:00 - 11:30	Registration	Coffee-break	Coffee-break	Coffee-break
11:30 - 12:30		Parallel Sessions 3	Parallel Sessions 6	Parallel Sessions 9
12:30 - 14:00		Lunch	Lunch	Awards & Closing ceremony *Farewell*
14:00 - 15:00	Opening ceremony	Special Session & Roundtable - Optics and Photonics	Parallel Sessions 7	
15:00 - 16:00	Plenary sessions 1 & 2			
16:00 - 16:30				
16:30 - 17:00	Coffee-break	Coffee-break + Poster Session	Social Program - bus tour to the beaches of Barra and Costa Nova and guided tour to the Vista Alegre Museum	
17:00 - 17:30	Paralell Sessions 1			
17:30 - 18:00		Parallel Sessions 4		
18:00 - 18:30				
18:30 - 19:00	Social Program - Welcome Reception			
19:00 - 19:30		*SPOF' General Assembly*		
19:30 - 20:00			Conference Dinner	
20:00 - 20:30				
20:30 - 21:00		Social Program - Walking tour around Aveiro center		
21:00 - 21:30				
21:30 - 22:00				
22:00 - 22:30				

AOP 2024 – Detailed Program

TUESDAY, JULY 16

14:00 - 15:00 - Opening Ceremony - Room A

Prof. Dr. Artur Silva (Vice-Rector for Research, Innovation and 3rd Cycle of the University of Aveiro)
Prof. Dr. Vitor Amaral (Vice Director of the Physics Department of the University of Aveiro)
Prof. Dr. Humberto Michinel, Secretary General of the Interntional Commission for Optics
Dr. Gilles Pauliat, Past-President of the European Optical Society
Dr. Eric Rosas, Secretary of the Iberoamerican Optics Network
Prof. Dr. José António de Carvalho Paixão, President of the Portuguese Physics Society
Prof. Dr. José Fernando Mendes, Director of the i3N Aveiro
Prof. Dr. Manuel Filipe Costa, Chairperson, President of the Portuguese Society for Optics and Photonics, SPOF

15:00 - 15:45 - Plenary PL1

Room A - Chair(s): Rogério Nogueira

Plenary	**Optical Communication in Very Long Space Links**	Peter Andrekson

15:45 - 16:30 - Plenary PL2

Room A - Chair(s): Humberto Michinel

Plenary	**Varifocal System: Basics and Nonconventional Applications**	Jorge Ojeda Castañeda

16:30 - 17:00 - *Coffee-Break*

17:00 - 18:30 - Paralell Session 1.1 | Energy, Sustainability and Smart Cities I

Room A - Chair(s): Micael Nascimento and Marta Ferreira

15664 (Invited)	**Implementation of Alternative Organic Anodes Based on Processable Graphene Derivatives and Applied to Solar Cells**	Alvaro Guerra-Him
15418 (Invited)	**Revolutionizing Water Management: The Impact of Optical Fiber Sensors on Reducing Water Loss in Distribution and Agriculture**	Tiago Neves
15234 (Invited)	**The Role of Optical Structures in Cu(In,Ga)Se2 Ultrathin Solar Cells**	Pedro M. P. Salomé
14910	**Enhancing Airport Navigation Using Visible Light Communication**	Manuela Vieira
14911	**Enhancing Urban Traffic Management with Visible Light Communication and Reinforcement Learning**	Gonçalo Galvão

17:00 - 18:30 - Parallel Session 1.2 | Lasers and Nonlinear Optics I

Room B - Chair(s): Rogério Nogueira and Margarida Facão

15490 (Keynote)	**2D Quantum Droplets with Large Angular Momenta**	Humberto Michinel
15286 (Invited)	**Role of Modulation Instability in Numerical Analysis**	Shalva Amiranashvili
15215 (Invited)	**Solitonic Light Bursts and Momentum Supercontinuum Generation in Nonlinear Time-varying Dielectric Media**	Fabio Biancalana
14882 (Invited)	**Binary Classification of Low-resolution Images Using the Collective Modes of a Two Dimensional Array of Photonic Crystal Nanolasers**	Cristina Masoller

17:00 - 18:30 - Parallel Session 1.3 | Optical Metrology and Image Processing

Room C - Chair(s): Carlos Marques and Diana Guimarães

15493 (Keynote)	**Questioned Document Examination Using Optical Coherence Tomography**	Manuel J. Marques
15228	**Enhancing Spectral Imaging Data Quality with Multiple Exposure Fusion Techniques**	Joana Teixeira
15258	**Use of Optical Techniques for Surface Analysis of Rock Art Engravings from the UNESCO Heritage Site of Valcamonica**	Micaela G. Coronel
15665 (Invited)	**Evaluation of Deformation in Aluminum Plate Under Laser Thermal Stress Using Shearography Technique**	Kenia-María R. Camaño

18:30 - 19:30 - Welcome Reception

WEDNESDAY, JULY 17

8:15 - 8:45 - *Registration*

8:45 - 9:45 - Plenary PL3

Room A - Chair(s): Orlando Frazão and Joana Vieira

Plenary	**Understanding the Ocean Using Submarine Optical Fibre Cables**	Miguel Gonzaléz Herraés

9:45 - 11:00 - Paralell Session 2.1 | Industrial Applications I

Room A - Chair(s): Luis Rino and Eric Rosas

15367 (Invited)	**Optical Sensorization for the Monitorization of Composite Parts on Manufacturing, Assembly, Integration and Testing Phases**	Paulo Antunes
15032 (Invited)	**Optics and Photonics in Wind Industry: Challenges and Opportunities**	Tiago Paixão
15789 (Invited)	**Multimodal Spectral Imaging for Industrial Applications**	Pedro Jorge
14971	**A LiDAR Based Obstacle Detection Framework for Railway**	Francisco Afonso

9:45 - 11:00 - Parallel Session 2.2 | Biomedical and Medical Applications of Optics & Photonics I

Room B - Chair(s): Susana Novais and Sónia Pereira

13367 (Keynote)	**Low-cost Plasmonic Probes for Single-molecule Detection**	Nunzio Cennamo
15343	**Non-intrusive Monitoring of Vital Signs in the Lower Limbs Using Optical Sensors**	Joana R. Simões
12231	**Synchrotron Radiation Fourier Transform Infrared Spectroscopical Analysis of Biomolecules in MRC-5 Fibroblast Cells Treated With Biomass-derived Carbon Dots**	Marijana Petković

9:45 - 11:00 - Parallel Session 2.3 | Nano-Photonics and Optoelectronics I

Room C - Chair(s): Paulo Ribeiro and Nélia Alberto

15264 (Keynote)	**All-optical Techniques for In-fiber Excitation and Interrogation of Acoustic Resonances**	Martina Delgado-Pinar
15397	**Electrically Pumped Flipped-cavity NanoLEDs on InP Membrane Platform**	Ekaterina D. Malysheva
15483	**D-Shaped Photonic Crystal Fiber SPR Sensor for Oil Humidity Monitoring**	Amanda F. Romeiro
15654	**Does Size Matter? Assessing Size-Dependent Performance of Gold Nanoparticles in Plasmonic Optical Fiber Sensors**	Gil C. Tavares

11:00 - 11:30 - *Coffee-Break*

11:30- 12:30 - Parallel Session 3.1 | Energy, Sustainability and Smart Cities II

Room A - Chair(s): Manuela Vieira and António Baptista

13187 (Keynote)	**Strategic Investigations for Soil Analysis and Monitoring Using Laser-Induced Breakdown Spectroscopy**	Haider M. Al-Juboori
15400	**Detection of Contaminants in Wood Waste Using Hyperspectral Imaging, X-Ray Fluorescence and Laser-Induced Breakdown Spectroscopy**	Diana Capela
15401	**Unlocking the Value of Li Deposits Using Spectroscopic Techniques: Overview and Future Directions**	Diana Guimarães

11:30- 12:30 - Parallel Session 3.2 | Optical Communications I

Room B - Chair(s): Sandra Franco and Carlos Marques

12180 (Invited)	**WDM C-Band Four Channel Using Cascaded Multimode Interference on SiN Strip Waveguide Structure**	Dror Malka
15201	**Efficient Generation of Two Coherent Spectral Lines Using Two Mutually Injection Locked DFB Lasers**	Leonardo Rama
15326	**Electrically Tunable Free Space Lithium Niobate Optical Filters**	Mojdeh Vakili

11:30- 12:30 - Parallel Session 3.3 | Quantum Optics I

Room C - Chair(s): Margarida Facão and Gil Fernandes

15320	**Impact of Fast Power Fluctuations Caused by Atmospheric Turbulence on Polarization Measurements**	Sara Mantey
15368	**Link Analysis for Satellite-Based Quantum Key Distribution**	Mariline Costa
14974	**Penrose Scattering in Quantum Vacuum**	José T. Mendonça
15288	**Searching for Bias in Commercial Quantum Random Number Generators**	Maurício J. Ferreira

12:30 - 14:00 - *Lunch*

14:00 - 16:00 - Special Session & Roundtable - Optics and Photonics - Portugal

Room A - Chair(s): Manuel Filipe Costa

	Visual Optics and Ophthalmic Instrumentation Research Lab	Sandra Franco | CFUM&UP UM
	Optical Sensors and Photonic Integrated Circuits at Instituto de Telecomunicações	Rogério Nogueira | IT
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	Optics & Photonics @ Laboratory for Instrumentation, Biomedical Engineering and Radiation Physics (LIBPhys) Nova Pole	Paulo Ribeiro | UNOVA
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	Advanced Monitoring and Structural Integrity at INEGI	Paulo Tavares | INEGI-UP
	Optics and Lasers @ IBEB	Tânia Ferreira-Gonçalves | IBEB-UL
	CICECO, Universidade de Aveiro	Maria Rute André | CICECO-UA
	High peak and average power near and mid-IR lasers via ultrafast OPCPA. The Laboratory of Intense Lasers	Hugo Pires | IST-UL
	Ultrafast Bio- and Nanophotonics Group at INL	Jana Nieder | INL
	The Institute of Physics and Aerospace Sciences of the University of Vigo at Ourense (Spain)	Humberto Michinel | IPAS-UVIGO

16:00 - 17:30 - Poster Session and *Coffee-Break*

15202 (Poster 1)	**An Affordable Optical Detection Scheme for LSPR Sensors**	Alessandro Fantoni
15181 (Poster 2)	**Color Picker System for Point-of-care Colorimetric Devices**	Alessandro Fantoni
15377 (Poster 3)	**Low Cost Vector Mode Direct Write Lithography for Optical Waveguide Fabrication**	Alessandro Fantoni
15659 (Poster 4)	**Chitosan-coated Optical Fiber Sensor for the Detection of Bisphenol A**	Ana I. Freitas
15592 (Poster 5)	**Optical Study of Gallium Oxide Thin Films Deposited by RF-sputtering**	Ana S. Sousa
15371 (Poster 6)	**Accommodative and Binocular Predictors for Ocular Symptoms**	António M. G. Baptista
15353 (Poster7)	**Influence of Anterior Keratometry and Axial Length Repeatability in Intraocular Lens Power Calculation – A Bibliographic and Simulation Study**	António M. G. Baptista
15603 (Poster 8)	**pH Sensors Based on PAni-coated Specialty Optical Fibers**	Armando Rodriguez
12442 (Poster 9)	**Photoinduced Birefringence in Azopolymers Measured at 1550 nm**	Beatriz G. Soares
15315 (Poster 10)	**Distributed Acoustic Sensing on SAGRES Submarine Cable**	Catarina Monteiro
15615 (Poster 11)	**Use of Laser Technology for the Postural Classification of Bedridden People**	David S. Canzobre

15650 (Poster 12)	**Reflection Fiber Loop Mirrors for the Measurement of Strain and Temperature**	Diogo A. Azevedo
15618 (Poster 13)	**Ion-implanted β-Ga2O3 Microtubes & Nanomembranes for Photonic Applications**	Duarte M. Esteves
14542 (Poster 14)	**Electric Power Generation from Solar Irradiation by Using Multiplexed Holographic Lenses and a Hybrid Photovoltaic Thermal System**	Eder M. Alfaro
15663 (Poster 15)	**Low-cost Prototype for Real-time Analysis of Liquid Crystal-based Optical Sensors**	Francisco Gameiro
15300 (Poster 16)	**High Photoinduced Birefringence in Thermally Treated Layers of the Azopolymer PAZO with Significantly Changed Absorbance Spectrum**	Georgi Mateev
15336 (Poster 17)	**Mobile System to Detect Plastic Particles in Critical Scenarios: Potential Approach for Attachment in UAVs**	Guilherme Pereira
15239 (Poster 18)	**Independent Dynamic Bandwidth Allocation Algorithms' Co-existing in Virtual Passive Optical Networks and Their Progression to Coherent PON**	Gulmina Malik
15621 (Poster 19)	**FBG-based Torque and RPM Sensor Embedded in a 3D-printed Structure for Aerospace Applications**	Gustavo Saturno
15352 (Poster 20)	**Advanced Algorithms for Optimization of QKD Encoding Subsystems**	Hugo F. Costa
15342 (Poster 21)	**Development of an Experimental System for Nonlinear Material Study and Characterization**	Hugo Pires
15327 (Poster 22)	**OPCPA Optimization for Ultrafast Near-infrared Lasers**	Hugo Pires
15332 (Poster 23)	**Ultrafast Lasers Towards TRIR Spectroscopy**	Hugo Pires
13927 (Poster 24)	**Optical Properties of N-doped Graphene and Carbon Nitride Quantum Dots**	I-Ming Hung
12234 (Poster 25)	**Ultrafast Laser-assisted Production of Nano-and Micro-plastics and Their Interaction With Cells**	Iva Popović
11850 (Poster 26)	**Non-destructive Gratings Recorded in Bi2TeO5 Photorrefractive Crystals**	Ivan de Oliveira
15230 (Poster 27)	**The Link Between Ocular High-order Aberrations and Accommodative Disorders**	Jessica Gomes
15294 (Poster 28)	**Optimization of an Acousto-Optic Modulation System for Laser Power Stabilization**	Jhonathan Barrios
15302 (Poster 29)	**Raman-based DTS for Forest Fire Detection Using Existing Telecommunications Fiber Networks**	Joana Vieira
15625 (Poster 30)	**Volatile Organic Compounds Sensor Based on Chitosan-coated Multimode Interferometer**	João M. Leça
15323 (Poster 31)	**Development and Characterization of Fiber Optic Sensors for Radiation Detection**	João P. Silva
12901 (Poster 32)	**Design and Characterization of a Compact Extended Cavity Laser Diode with Applications in High-resolution Spectroscopy and Absorption-based Laser Sensors**	Juan C. A. Navarro
13236 (Poster 33)	**Low-cost Laser Frequency Stabilization Using Analog Multiplier Integrated Circuit and Piezo-Modulation Mirror**	Juan C. A. Navarro
14368 (Poster 34)	**Colour Image Encryption System Based on a Nonlinear Joint Transform Correlator in the Fractional Fourier Domain**	Juan M. Vilardy
14622 (Poster 35)	**Simultaneous Authentication of Three Users or Images Using an Image Encryption System Based on a Nonlinear Joint Transform Correlator in the Fourier Domain**	Juan M. Vilardy

15359 (Poster 36)	**Comparative Analysis of Physiological Vergence Angle Calculations From Objective Measurements of Vergence**	Karola Panke
15644 (Poster 37)	**Non-intrusive and Low Visual Impact Relative-displacement Sensors Based on Fiber Bragg Gratings for Structural Health Monitoring Applications**	Luís Pereira
12232 (Poster 38)	**Synergistic Effect of Near Infrared Light and Ag-based Metal-organic Frameworks, Loaded with Sulphur or Nitrogen Carbon Dots, on Wound Healing**	Maja D. Nešić
15549 (Poster 39)	**Lighting Preferences of Iberian Sausages for Spanish Observers**	Manuel Melgosa
15321 (Poster 40)	**Liquid Crystal-based Immunosensor for the Optical Detection of Cortisol**	Maria S. Soares
15498 (Poster 41)	**Enhancing Cross-Correlation Techniques for Distributed Fibre Optic Sensors: A Study on Fitting Methods and Spectrum Window Analysis**	Mariana Santos
15624 (Poster 42)	**Enzymatic Plasmonic Optical Fiber Biosensor for Uric Acid Detection**	Mariana Sebastião
15237 (Poster 43)	**Colorimetric assay for magnesium detection envisioning heart failure management at point-of-care**	Miguel Vidal
12233 (Poster 44)	**Biomolecular Changes in A2780 Ovarian Cancer Cells Induced by a Photoactive System Based on Carbon Dots Loaded With Ru Complex**	Milutin Stepić
15200 (Poster 45)	**Optical Fiber Sensor for Voice Assessment**	Nélia Alberto
15657 (Poster 46)	**Fiber Optic Sensor for Arterial Pulse Wave Analysis on the Carotid Artery**	Nicole Teixeira
15182 (Poster 47)	**Development of a High-precision, Portable and Automated Mobile Laser Scanner for the Recording and Digitation of Texture and Micro-marks in Archaeological and Heritage Stone**	Pablo Pardiñas
15653 (Poster 48)	**Azobenzene-based Customized Surfaces: A New Approach Towards the Development of Orbital Angular Momentum Devices**	Paulo A Ribeiro
15209 (Poster 49)	**Microdisplacement SMF-sensor Based on Ultrafast Laser-assisted Etching Method**	Rosa A. Perez-Herrera
15231 (Poster 50)	**Polarization-controllable Multiwavelength L-band Fiber Optic Ring Cavity Laser**	Rosa A. Perez-Herrera
15213 (Poster 51)	**Frequency Stabilization of an Extended-cavity Diode Laser Using Polarization Spectroscopy**	Rafael Sarmiento
15053 (Poster 52)	**Development of Test Methodologies for Characterising Light Guides for Use in Automotive Interiors**	Rita Moreira
12656 (Poster 53)	**Design of Optical System Components for Small-UAV LiDAR Applications**	Rodrigo Rendeiro
12657 (Poster 54)	**Vegetation Health Evaluation Using Cost-effective Aerial Reflectance Measurements**	Rodrigo Rendeiro
15241 (Poster 55)	**Optical Deflectometry-Based Surface Inspection System For Combustion Device Covers**	Rodrigo Rito
15380 (Poster 56)	**Accommodative Response and Ocular Aberrations Among University Students**	Sandra Franco
15661 (Poster 57)	**Impact of Virtual Reality on the Visual System**	Sandra Franco
15187 (Poster 58)	**Ocular Aberrations Modulate the Accommodative Response Estimated Across Different Refractive Errors**	Sandra Franco
15372 (Poster 59)	**Fabrication and Characterization of a Refractometric Sensor Based on Optical Fibers Coated with Oxidized Graphenes**	Sindi D. H. Piñeres

15242 (Poster 60)	**Excitation of Localized Surface Optical Plasmon Resonances LSPR in PMMA Capillary Fibers Coated with Ag Nanoparticles for Sensing Applications**	Sindi D. H. Piñeres
15586 (Poster 61)	**Optical Characterization of Transition-metal Activated Microwave-assisted Hydrothermal Synthesized Zn_2GeO_4 Nanorods**	Sónia O. Pereira
15083 (Poster 62)	**Liner Cavity Fiber Laser Configurations for Refractive Index Measurements**	Susana Silva
15295 (Poster 63)	**Plasmonic Immunosensors Based on Spoon-shaped Waveguides for Fast and On-site Ultra-low Detection of Ochratoxin A in Coffee Samples**	Thais A. Silva
15652 (Poster 64)	**Optical Fiber Sensing Design to Simultaneously Monitor Relative Humidity and Temperature**	Tiago Amaral
15340 (Poster 65)	**Design and Fabrication of Asymmetric Mach-Zehnder Interferometers Based on EpoClad and EpoCore Strip Waveguides**	Tiago E. C. Magalhães
14284 (Poster 66)	**Accelerometers Based on Fiber Bragg Gratings for Wind Turbine Blades Structural Health Monitoring**	Yannis Magalhães

17:30 - 19:00 - Parallel Session 4.1 | Optics and Photonics Education and Outreach

Room A - Chair(s): João Lemos Pinto and Manuel Filipe Costa

15158 (Keynote)	**An Easily Usable Device for Enhancing Geometrical Optics Instruction**	Chien-Heng Chou
15595 (Keynote)	**Hands-on Optics: In and Out**	José B. V. Dorrío
15613 (Invited)	**Art and Science at Formal and Non-formal Spaces**	Mikiya Muramatsu

17:30 - 19:00 - Parallel Session 4.2 | Optical Instrumentation for Space and Astronomy

Room B - Chair(s): Carlos Marques and Paulo Tavares

15669 (Keynote)	**Optical Sensors For Resident Space Object Surveys**	Miguel Bergano
15341 (Invited)	**Drone-suspended Quantum Gradiometer for Detection of Unexploded Ordnance and Geo-prospecting**	Ruggero Giampaoli
15208 (Invited)	**Some Approaches for light and Color on the Surface of Mars**	Manuel Melgosa
12437	**Emulation and Testbed Prototyping of Laser Beam Propagation Characteristics Through Atmospheric Turbulence for Optical Satellite Feeder Links**	Haider M. Al-Juboori

17:30 - 19:00 - Parallel Session 4.3 | Optical Fibers, Sensors and Applications I

Room C - Chair(s): Orlando Frazão and Susana Silva

15656 (Keynote)	**Optical Frequency Combs in Distributed Optical Fiber Sensing**	Vicente Durán
15519	**From Fibre Design to Fibre sensor: Preparation Methods as Key Factor for High-quality Coupled-core-fibre Sensors**	Florian Lindner
15325	**A Comparative Study of Surface Plasmon and Tamm Plasmon Polaritons for Hydrogen Sensing**	Miguel A. S. Almeida
15599	**Coil-shaped Optical Fiber Sensor for Compression Measurements**	Amanda F. Romeiro
15619	**Monitoring Reinforced Concrete Structures Using Iron Thin-Film Coated Optical Fibre Sensors**	Pedro M. Silva

19:00-20:30 - SPOF' General Assembly - Room A

19:30-21:30 - *Social Program*

THURSDAY, JULY 18

8:15 - 8:45 - *Registration*

8:45 - 9:45 - Plenary PL4

Room A - Chair(s): Paulo Antunes and Margarida Facão

Plenary	**Quantum Key Distribution**	Armando Nolasco Pinto

9:45 - 11:00 - Parallel Session 5.1 | Materials Processing and Characterization I

Room A - Chair(s): Sérgio Veloso and Sónia Pereira

15627 (Invited)	**Exploring New Approaches to Fabricate 2D Layered Materials Supported Gold Nanoparticles for Optical Biosensing**	Sara Fateixa
15313 (Invited)	**Optical Spectroscopic Insights into III-nitrides: Rare-earth Implanted Nanowires for Light-emitters and Scandium-alloyed Films for Ferroelectrics**	José P. S. Cardoso
15674 (Invited)	**NIR Triggered Elastic Liposome Containing Magneto-plasmonic Nanoparticles for Treatment of Skin Cancer**	Ana R. O. Rodrigues
15270	**Optical Characterisation of Phase Change Materials Leakage in Coaxial Fibres after Cutting**	Nathalia Hammes

9:45 - 11:00 - Parallel Session 5.2 | Optical Fibers, Sensors and Applications II

Room B - Chair(s): Susana Novais and Joel Borges

14021 (Invited)	**High Aspect-ratio Au@Ag Plasmonic Nanorods on Optical Fibers for Remote Glyphosate Detection**	Paulo S. Santos
15318 (Invited)	**Advancements in Graphene Oxide: Deposition Techniques, Sensing Applications, and Optical Fiber Integration**	Catarina Monteiro
15620	**Exploring the Refractive Index Sensitivity of Gold-Coated Optical Fiber Tips: The Influence of Key Parameters**	Ana S. Assunção
15370	**Wrapping Optical Fibers in a Helical Shape and Exploring its Sensing Opportunities Through Fiber Bragg Grating and Multimode Interferometer**	João Preizal

9:45 - 11:00 - Parallel Session 5.3 | Industrial Applications II

Room C - Chair(s): Paulo Antunes and Marta Ferreira

15662 (Invited)	**An Industry View of Automotive Lamps Engineering**	Daniel C Trigo
15081 (Invited)	**Automation Technologies to Scale PIC Testing from Lab to Fab**	Matt Foreman
15221 (Invited)	**Fiber Optic Monitoring Solution for Predictive Maintenance of Pantographs and Overhead Powerlines**	Francisco Araújo
12360	**Artificial Intelligence-enhanced Colorimetric Assessment of Self-cleaning Road Marking Paints**	Orlando Lima Jr.

11:00-11:30 - *Coffee-Break*

11:30 - 12:30 - Parallel Session 6.1 | Biomedical and Medical Applications of Optics & Photonics II

Room A - Chair(s): Claver Pinheiro and João Leça

15596 (Invited)	**Plasmonic Tilted Fiber Bragg Gratings: from Refractometers to Biosensors**	Médéric Loyez
15459 (Invited)	**New Strategies for Multimodal Cancer Therapy Based on Plasmonic Lipogels**	Sérgio R.S. Veloso
15245	**Development and Validation of a Pulse Wave Velocity Monitoring Device**	Camilo A. R. Díaz

11:30 - 12:30 - Parallel Session 6.2 | Optical Communications II

Room B - Chair(s): João Lemos Pinto and Ana Maria Rocha

15115	**Experimental Study of the Spatial and Temporal Coherence of a Semiconductor Laser with Optical Feedback**	María D. Gijón
13934	**Modelling Investigation of Atmospheric Turbulence-induced Beam Deviation for LEO/GEO FSO Communication Link**	Haider M. Al-Juboori
15764	**Passive imbalance fabrication effect on a linearly driven MZM in an oDAC-based PAM-4 Transmitter**	Adebayo Emmanuel Abejide
15394	**Beaconless Self-alignment Method for Indoor Optical Wireless Communications**	André C. Campos

11:30 - 12:30 - Parallel Session 6.3 | Optical Design Illumination and Visual Sciences

Room C - Chair(s): Sandra Franco and António Baptista

15591 (Invited)	**Spectral Corrections in Solid-state Lighting Measurements**	Eric Rosas
14913	**Unlocking Traffic Control: Exploring Intersection Dynamics with Visible Light Communication**	Manuel A. Vieira
15354 (Invited)	**The Critical Role of Exam Room Lighting in Presbyopia Correction**	Karola Panke

12:30 - 14:00 - *Lunch*

14:00 - 15:30 - Parallel Session 7.1 | Materials Processing and Characterization II

Room A - Chair(s): Sara Fateixa and Marco Peres

15355 (Keynote)	**UV-Vis-NIR Persistent Luminescence in Germanate-based Materials**	Joana Rodrigues
15392	**Development of Multifunctional Liposomes Containing Magnetic/Gold Nanoparticles**	Fabio A. C. Lopes
15334	**High Reflectivity Band Distributed Bragg Reflector Based on Silicon-rich SiNx-SiOy at 80°C Plasma-enhanced Chemical Vapour Deposition**	Irene R. Lamoso
15651	**Refractive Index Analysis of Planar Interfaces by Prism Coupling Technique**	Alessandro Fantoni
15456	**Highly Efficient Deep Red-emitting Mn^{4+} Phosphors for Enhanced Plant Growth and Advanced Optical Thermometry**	Sudipta Som

14:00 - 15:30 - Parallel Session 7.2 | Nano-Photonics and Optoelectronics II

Room B - Chair(s): Cátia Leitão and Médéric Loyez

15521 (Keynote)	**Structuring Light with Optical Metasurfaces**	Marco Piccardo
15092	**Fully Connected Feedforward Neural Network for the Prediction of Amorphous Silicon Grating Couplers Efficiency**	Daniel Almeida
15322	**Manipulation of Microparticles in Optofluidic Devices Fabricated by Femtosecond Laser Micromachining**	Carolina Cameira
12303	**Smartphone Interrogation of Narrow Bragg Gratings in G.652 Fibre**	Hypolito J. Kalinowski
12940	**Study of Photoelectric Effect in Gallium Oxide-based Sensors**	Marina Sparvoli

14:00 - 15:30 - Parallel Session 7.3 | Lasers and Nonlinear Optics II

Room C - Chair(s): Maria Inês Carvalho and Orlando Lima

15363 (Keynote)	**Multidisciplinary Applications for High Power Laser Pulses: an Update of the L2I Facility**	Hugo Pires
15112	**Abrupt Transition to Coherent Emission in a Semiconductor Laser with Optical Feedback**	María D. Gijón
15139	**Yb:YAG Fibre Laser Applied to the Conservation of Built Heritage: Preliminary Results on the Removal of Black Crusts from Granite**	Mateo E. Bonifacino
15324	**Quartic Soliton Solutions of a Mode-locked Laser Distributed Model with Normal Fourth-Order Dispersion**	Diogo Malheiro
15240	**Unlocking New Dynamics in Paraxial Fluids of Light with an Optical Feedback Loop**	Tiago D. Ferreira

15:30 - 19:30 - *Social Program*

19:30 - 22:30 - *Conference Dinner*

FRIDAY, JULY 19

8:15 - 08:45 - *Registration*

8:45 - 09:45 - Plenary PL5

Room A - Chair(s): Humberto Michinel

Plenary	**Turbulence Impacted Wavefront Corrections Without Conventional Adaptive Optics**	C S Narayanmurthy

9:45 - 11:00 - Parallel Session 8.1 | Theoretical and Computational Optics

Room A - Chair(s): Nuno Silva and Cátia Leitão

15602 (Keynote)	**Numerical Evaluation of Strain Transfer Model for Steel-reinforced Optical Fiber Cable Embedded in a Cylindrical Concrete Beam with Two Void Inclusions**	Mira Kabbara
15382	**Towards All-optical Extreme Learning Machines**	Vicente Rocha

15338	**Accelerating Spectral Imaging with Optical Computing: A Fourier-Based Feature Extraction Approach**	Tomás Lopes
15396	**Mixed Reality Meets Spectroscopy: Interactive 3D Visualization of Spectral Signatures**	Rafael Cavaco
15349	**Numerical Analysis of the Impact of Printing Angle on the Performance of 3D-printed Optical Components**	Ana M. Almeida

9:45 - 11:00 - Parallel Session 8.2 | Materials Processing and Characterization III

Room B - Chair(s): Luis Rino and Iran Rocha Segundo

15584 (Keynote)	**Modifying Optical Properties of β-Ga_2O_3 by Ion Implantation and Irradiation**	Marco Peres
15347	**Studies on Characterization of pH-Dependent Synthesis of Zn2GeO4:Mn Persistent Luminescence Nanomaterials, Morphology, Optical Properties and SARS-CoV-2 Protein Surface Modification.**	Piotr Kuich
15351	**Optical, Morphological, Chemical, Structural, and Photocatalytic Effects of Iron Modified Nano-TiO2**	Élida M. Margalho
15379	**Nanoparticles Enhanced Laser Induced Breakdown Spectroscopy of Gemstones**	Haider M. Al-Juboori

9:45 - 11:00 - Parallel Session 8.3 | Nano-Photonics and Optoelectronics III

Room C - Chair(s): Alessandro Fantoni and Pedro Jorge

12494 (Invited)	**Towards Cost-effective Interrogation Techniques to Monitoring Metropolitan Optical Fiber Networks: The GT_OnE Approach**	Camilo A. R. Díaz
15477 (Invited)	**Exploring the Localized Surface Plasmon Resonance Phenomenon in Au-Ag Nanoparticles Embedded in an Oxide Thin Film**	Joel Borges
13933	**Low Noise White Light Interferometry with Broad Cavity Interrogation Band and Fast Sampling**	Paulo Robalinho
15386	**Comparative Analysis of Ethanol Gas Sensors Based on Bloch Surface Wave and Surface Plasmon Resonance**	João P. M. Carvalho

11:00-11:30 - *Coffee-Break*

11:30 - 12:30 - Parallel Session 9.1 | Biomedical and Medical Applications of Optics & Photonics III

Room A - Chair(s): Nélia Alberto and Hypolito Kalinowski

12510	**POF Sensor for Dynamic Physiological Evaluation in a Dog-Assisted ASD Therapy: A Case Study**	Maria Gaitán-Padilla
15660	**Muscle Activity Detection Using Photoplethysmography and Machine Learning Algorithms**	Camilo A. R. Díaz
15287	**Thermal Blood Flowmeter Based on Cascaded Fabry-Pérot Interferometers Improved by Enhanced Harmonic Vernier Effect**	Ruirong Gong

11:30 - 12:30 - Parallel Session 9.2 | Quantum Optics II

Room B - Chair(s): Armando Nolasco Pinto and Paulo Antunes

15628 (Invited)	**Continuous Variables Quantum Cryptographic Systems – Development, Deployment and Accreditation**	Daniel Pereira
15233	**An FPGA-based Physical Layer for a CV-QKD System**	Margarida Almeida
15365	**High-performing Synchronization Techniques for Quantum Key Distribution Systems**	Alexandra Felisberto
15376	**Quantum Technology Pathways for Paraxial Fluids of Light**	Nuno A. Silva

11:30 - 12:30 - Parallel Session 9.3 | BioNano & Medicine

Room C - Chair(s): Cátia Leitão and Pedro Jorge

15790 (Keynote)	**Intracellular Nanothermometers. From Florescent Proteins to Quantum Sensing Probes**	Jana Nieder
15655	**Optical Fibre Sensors for the Evaluation of Vital Signs in a Smart Seat**	Ana Mourão
15791	**Development of all-polymer interferometric biosensors for label-free detection**	Tiago Magalhães

12:30-13:30 - Awards and Closing Ceremony
Farewell

Abstracts

Optical communication in very long space links

Peter Andrekson[1*]

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ABSTRACT

I will discuss the transition from using radio waves to laser beams in deep space transmission systems. Laser beams spread out much less than radio waves and therefore permit much higher data rates. This is needed because of the currently very low information rates possible since a very tiny fraction of the power in the beam is captured, for example, when sending data from Mars to Earth and is referred to as a "science return bottleneck". There are three basic limitations in such optical links; The available optical power at the transmitter, the size of the optical apertures, and the sensitivity of the receiver used. While the former are limited by engineering constraints, the latter is fundamentally limited by vacuum noise that exists everywhere. I will describe our recent results when using a near "noiseless" optical amplifier in the receiver to demonstrate record receiver sensitivity at high bit rates. These amplifiers do not rely on stimulated emission as is normally the case but on so-called nonlinear refraction and referred to as phase-sensitive parametric amplifiers. We have used optical fibers [1] as well as compact chips with silicon nitride waveguides [2] to demonstrate amplification with exceptional performance. Such amplifiers may play an important role in future deep-space optical communication systems. A comparison of performance with different approaches for sending optical signals across very long distances will also be made.

Acknowledgements: The wishes to acknowledge contributions from Jochen Schröder, Ravikiran Kakarla, Kovendhan Vijayan, Rasmus Larsson, Magnus Karlsson, and Mikael Mazur. Funding has been provided by the Swedish Research Council (grant VR-2015-00535) and by the KA Wallenberg Foundation.

References:

[1] Kakarla, R., Schröder, J. & Andrekson, P.A. "One photon-per-bit receiver using near-noiseless phase-sensitive amplification. Light Sci Appl 9, 153 (2020). https://doi.org/10.1038/s41377-020-00389-2

[2] Zhichao Ye et al. "Overcoming the quantum limit of optical amplification in monolithic waveguides," Sci. Adv.7, eabi8150 (2021) https://doi.org/10.1126/sciadv.abi8150

Varifocal System: Basics and Nonconventional Applications

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ABSTRACT

We discuss the basic concepts for achieving tunable magnifications with zero throw. The magnification can be anamorphic. We show that this type of varifocal systems is useful for setting nonconventional zoom systems.

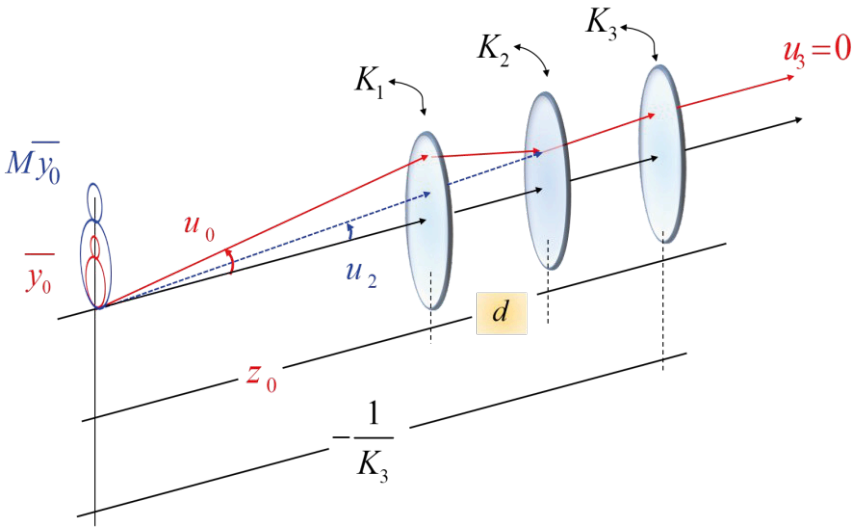

Figure 1. Schematics of a tunable Fourier transformer.

Hopkins described a method for designing optical systems with several elements of fixed optical powers [1]. Here, we extend Hopkins formulation by considering optical systems that use varifocal lenses. We discuss the use of varifocal lenses for setting nonconventional zoom systems. These systems are useful for implementing tunable magnification, with zero throw. The magnification can be anamorphic. They are also useful for coupling the size of the Fourier spectra, for implementing nonconventional array illuminators [2], and for controlling the visibility of the interference fringes in Talbot-Lau interferometers [3].
As a simple example of our proposal, in Figure 1, we display a schematic diagram for implementing a Fourier transformer with tunable scaling. Two lenses are varifocal, with powers K_1 and K_2, respectively. These lenses magnify the size of the input image, without modifying the axial position, z_0, of the input plane. This is the zero-throw condition. Furthermore, as the magnification varies, the interlens separation, d, remains constant. The third lens has a fixed optical power K_3. This lens implements optically a Fourier transformation of the input. We do not display the Fourier plane.

Keywords: Varifocal lenses, Nonconventional Zoom Systems, Tunable Anamorphic Magnifications, Talbot-Lau Interferometers.

References:
[1] H. H. Hopkins, “The gaussian optics of multilens systems,” Conference on optical instruments, Chapman & Hall, London, 1962, pp. 133-159.
[2] C. M. Gómez-Sarabia and J. Ojeda-Castañeda, "Tunable, Nonmechanical, Fractional Talbot Illuminators," Optics (MDPI), 4, 602-612, 2023.
[3] C. M. Gómez-Sarabia and J. Ojeda-Castañeda, "Talbot-Lau devices: a reappraisal,” Frontiers in Sensors, 10.3389/ fsens.2023.1328490 vol. X, January, 2024.

Implementation of alternative organic anodes based on processable graphene derivatives and applied to solar cells

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ABSTRACT

Global energy demand continues to be supplied by fossil fuels such as coal, oil and natural gas; however, these forms of energy generation entail environmental problems such as the emission of greenhouse gases, acid rain, among others. For this reason, the scientific community has focused on the development of various technologies based on renewable sources, such as wind, solar, geothermal energy, etc. [1]. Solar energy has been considered a promising, clean and renewable energy; therefore, photovoltaic devices have been under constant study for many years. Currently, emerging photovoltaic devices such as Perovskite (PeSCs) or Organic (OSCs) solar cells have gained much attention due to various properties [3]. These emerging devices have achieved, at the laboratory level, power conversion efficiencies (PCE) of more than 20% (for OSCs [4]) and 25% (for PeSCs [5]). However, for the commercialization of these alternative technologies, numerous limiting factors such as stability, scalability and toxicity need to be overcome. Similarly, advances in new and efficient electrodes, both anodes and counter electrodes, are being intensively investigated [6,7]. Herein is shown the fabrication, characterization, and application of cost-effective, semi- transparent alternative anodes for optoelectronic devices, particularly in photovoltaic applications. The TLGA (Three-layer Graphene Anode) and HMGA (Hybrid Multilayer Graphene Anode) achieved average electrical resistances of ~ 170 Ω/sq and ~ 134 Ω/sq, respectively, and average transmittances (at 550 nm) of ~ 74 % and ~ 79 %, respectively. To validate the optoelectronic application of these anodes, TLGA and HMGA were implemented, as a concept test, in OSCs based on PM6:Y7. Preliminary results indicated a PCE of ~ 8 %, ~ 4 %, and ~ 1.4 % for the ITO (reference), TLGA, and HMGA, respectively. These results suggest that graphene derivatives have a promising application as an alternative electrode to ITO in photovoltaic devices, offering an opportunity to improve manufacturing processes.

Keywords: Graphene derivatives, graphene electrode, organic and hybrid solar cells.

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References:

[1] P. Lykas, *et al., Int. J. Hydrog. Energy* 43, 437 (2023)
[2] F.-C. Chen, *Adv. Optical Mater.* 7, 1800662 (2019)
[3] Z. Zheng, *et al., Joule* 6, 171 (2022)
[4] P. Basumatary, *et al., Mater. Res. Bull.* 149, 111700 (2022)
[5] Y. Fernández-Arteaga, *et al., Sol. Energy* 225, 656 (2021)
[6] A. Guerra-Him, *et al., J. Mater. Sci: Mater. Electron.* 34, 513 (2023)

Revolutionizing Water Management: The Impact of Optical Fiber Sensors on Reducing Water Loss in Distribution and Agriculture

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ABSTRACT

Water is a scarce and essential resource that must be preserved. Despite advancements in technology, such as pressure measurements, vibration sensing, and AI-driven improvements, significant water losses persist. Currently, water distribution networks suffer from up to 30% water loss due to leaks and inefficiencies, translating into millions of euros in lost water annually. In agriculture, the situation is equally dire, with vast amounts of water intended for irrigation wasted due to undetected leaks and inefficient water use practices [1]. The primary challenge lies in the high cost of current technologies and the lack of a solution capable of continuous monitoring over long distances at an affordable price. Distributed fibre sensors are excellent candidates for this purpose because they can provide kilometres of measurements with a single acquisition system, resulting in a very low cost per measurement point.
FiberSight, a CERN startup, is pioneering this field with a strong focus on green technology and innovation for sustainability. The company is developing the first continuous humidity sensor based on optical fibers [2]. This technology promises to revolutionize water monitoring by offering a cost-effective and highly efficient solution. Over the past few months, FiberSight's technology has undergone extensive validation, demonstrating its potential to address the pressing need for more effective water management solutions [3].
FiberSight's innovative technology offers a solution by enabling continuous, real-time monitoring of water distribution and usage. This allows for immediate detection and resolution of issues, significantly reducing water waste. With applications in water distribution, precision agriculture, and the monitoring of large structures such as tunnels and dams, FiberSight's sensors represent a significant advancement in sustainable water management.

Keywords: FiberSight, water leaks, distributed fibre sensors, agriculture, humidity.

References:
[1] Tiago Neves, Manuel Soeiro, Mariana Santos, Paulo Maia, Maurício Carvalho, João Rodrigues, “Enhancing Water Leak Detection with Distributed Temperature and Humidity Fiber Sensor”, Optical Fiber Sensors, pp. W4.44, Optica Publishing Group, 2023
[2] Tiago FP Neves, Li Zhang, Fan Yang, Kenny H Tow, Paolo Petagna, Luc Thévenaz, “A kilometre-range distributed relative humidity sensor”, Seventh European Workshop on Optical Fibre Sensors, vol 11199, pp, 319-322, 2019
[3] Tiago FP Neves, Lorenzo Scherino, Rémy Bernard, Monika Bouet, Aymeric Pastre, Regina Magalhães, Sonia Martin-Lopez, Hugo F Martins, Paolo Petagna, Luc Thévenaz, “Humidity-insensitive optical fibers for distributed sensing applications”, Applied optics, vol 62, 15, pp 4017-4029, 2023

The role of optical structures in Cu(In,Ga)Se_2 Ultrathin Solar Cells

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ABSTRACT

From a fundamental perspective, the operation of solar cells is primarily governed by two key phenomena: light absorption and carrier collection. This work explores innovative solar cell systems aimed at enhancing these phenomena through an ultrathin approach. Therefore various solar cell designs optimized for total light absorption and minimal rear interface recombination within a reduced absorber layer. In the photovoltaics (PV) sector, (Ag)Cu(In,Ga)Se2 (CIGS) thin-film solar cells are known for their consolidated efficiency, high energy yield, recyclability, and significant footprint in the European market. Reducing the CIGS layer to sub-micrometer thickness aligns with sustainable energy transition goals—using less material and reducing processing time. However, updating cell architecture is crucial to address interface recombination and incomplete absorption. This involves implementing interface passivation and light management schemes.

This work discusses innovative rear interface designs that address the challenges of scaling down the CIGS-based absorber. High-performance substrates embedding passivation and/or light management solutions were developed through optimized, scalable nanofabrication procedures, suitable for integration into ultrathin CIGS-based solar cells. These designs cater to conventional rigid, flexible, and bifacial configurations. Passivation and light management schemes were primarily evaluated using 1D electrical and 3D optical simulations — Poisson and drift-diffusion calculations, and finite-difference time-domain (FDTD) methods, respectively. For effective passivation, various dielectric materials and nano-contact schemes were tested. For optimized absorption, dielectric and metallic nanostructures were explored for their scattering properties. Incorporating dielectric nano-contact schemes on Mo in sub-micrometer CIGS-based solar cells significantly improved the open circuit voltage (Voc) compared to non-passivated references. A rear interface passivation scheme based on SiOx, covering 92% of the passivated area, resulted in Voc gains exceeding 100 mV compared to baseline cells, reducing rear surface recombination velocity from 10^7 to 10^3 cm/sec. Additionally, integrating randomly distributed Au nanoparticles under an AlOx 77% passivated line contact scheme yielded an experimental optoelectronic gain of 3.7 mA.cm^{-2}. This was attributed to enhanced rear reflectance and scattering, improved charge carrier collection, and reduced rear surface recombination velocity, as demonstrated by 3D optical and 1D electrical simulations.

We address sub-wavelength schemes through various high-resolution, scalable process flows based on nanoimprint lithography (NIL), which can be simplified to a stamping-based procedure. These innovative rear interface designs have led to absolute experimental light-to-power conversion efficiency gains of up to 2 % (abs.) and optoelectronic gains above 6 mA.cm^{-2}. over reference cells.

Enhancing Airport Navigation Using Visible Light Communication

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ABSTRACT

This study introduces an innovative approach to facilitate navigation within crowded multi-terminal airports by harnessing Visible Light Communication (VLC) technology. Utilizing existing luminaires as transmission points, encoded messages are conveyed through modulated light signals to offer location-specific guidance to users. Equipped with tetrachromatic LEDs and VLC capabilities, these luminaires efficiently transmit data, as demonstrated through analysis of coverage maps and implementation of the OOK modulation scheme. A novel mesh cellular hybrid structure is proposed, eliminating the need for traditional gateways and enhancing system flexibility.
Integrating VLC into Edge/Fog architecture, the system capitalizes on VLC's advantages such as wireless connectivity and secure line-of-sight communication, while leveraging existing lighting infrastructure. This integration enables distributed data processing, storage, and communication at the network edge, thereby improving system performance and responsiveness.
The paper presents a detailed airport model generation and analyses two user categories: pedestrians and luggage/passenger carriers. Users are equipped with PINPIN optical sensors to receive and interpret modulated light signals, facilitating localization and positioning calculations. A communication protocol tailored to VLC specifications is discussed, alongside coding and decoding techniques to ensure reliable transmission.

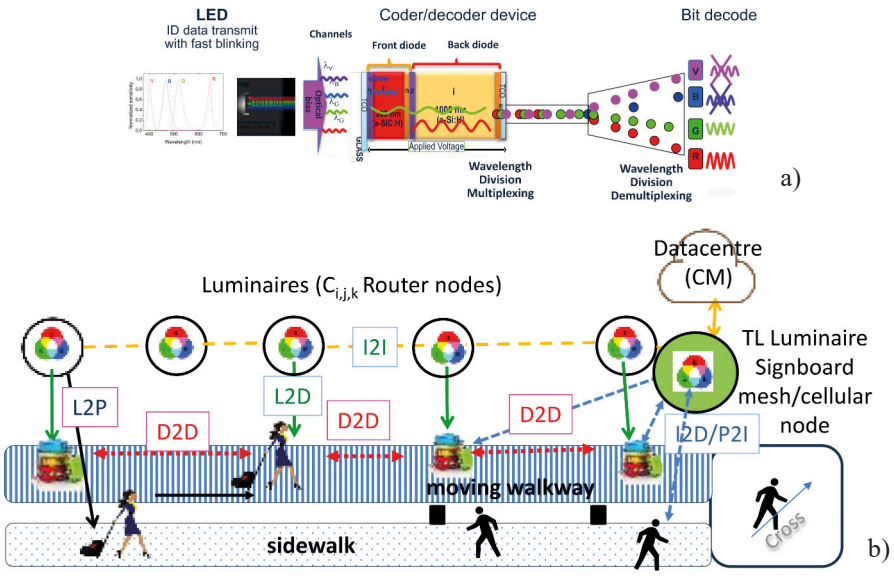

Figure 1. Configuration and operation of the PIN/PIN receiver. b) Edge/Frog hybrid architecture

The study conducts a bidirectional communication process to determine optimal paths through the venue, in an airport, employing developed wayfinding algorithms. These algorithms offer turn-by-turn directions, highlight landmarks, alert users about crowded areas, and suggest alternate routes. Using an agent-based simulator, traffic control for both user categories is assessed in various geometric scenarios, with results on user halting and average speed analyzed and discussed. By leveraging VLC and existing luminaires as transmitters, this approach enables indoor navigation independent of GPS signals, typically unavailable indoors. Results demonstrate the system's effectiveness in self-localization, travel direction inference, and route optimization to static or dynamic destinations, ultimately enhancing accessibility for .

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Enhancing Urban Traffic Management with Visible Light Communication and Reinforcement Learning

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ABSTRACT

This paper introduces Visible Light Communication (VLC) as an integrated approach to enhance the efficiency of traffic signals and vehicle trajectory at urban intersections. A multi-intersection traffic control system is proposed, combining VLC localization services with learning-based traffic signal control. By leveraging light communication between connected vehicles and infrastructure, VLC utilizes headlights, streetlights, and traffic signaling to transmit information. Through interactions between vehicles (V2V) and infrastructure (I2V), joint transmission and data collection are facilitated via mobile optical receivers. The performance of VLC can be influenced by atmospheric conditions, such as dust, smog, or haze, which introduce additional attenuation, scattering, and absorption of light, affecting communication quality. These factors are considered during the analysis of the outdoor coverage map.
The system aims to reduce waiting times for pedestrians and vehicles while improving overall traffic safety. It is designed to be flexible and adaptive, accommodating diverse traffic movements during multiple signal phases. VLCcooperative mechanisms, range of transmission, relative pose concepts and queue/request/response interactions, helps to balance the traffic flow between intersections and to improve the overall performance of the road network.

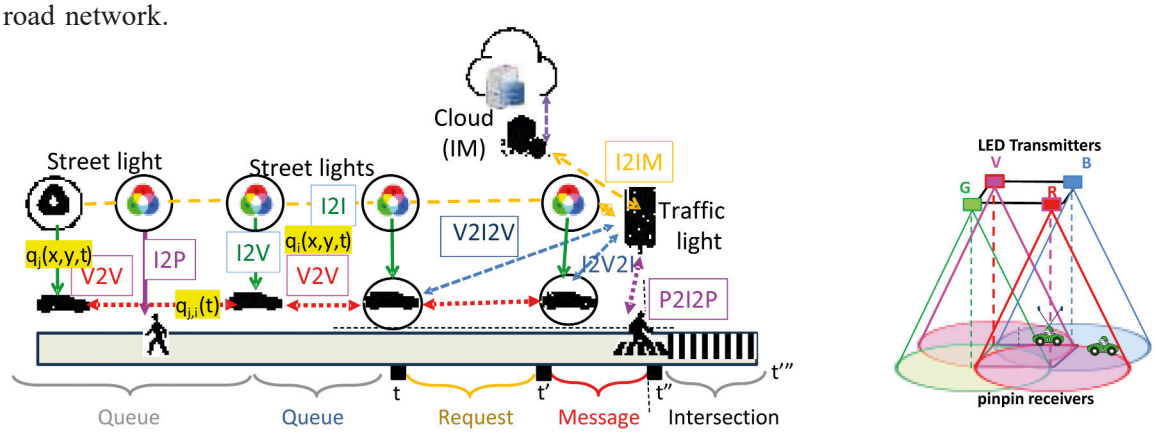

Figure 1. Architecture model and lighting plan.

The multi-intersections scenario is evaluated using the SUMO urban mobility simulator, demonstrating advantages in terms of reduced waiting times and travel times for both vehicle and pedestrian traffic flows. To effectively schedule traffic signals for safe and efficient travel, a reinforcement learning scheme based on various VLC queuing/request/response behaviors is employed. The system places an agent at each intersection, controlling the traffic lights by utilizing VLC-ready vehicles' communication of their positions, destinations, and intended routes.
The agents calculate optimal strategies to enhance traffic flow at their respective intersections and communicate with each other to optimize overall traffic flow. The proposed method utilizes a learning algorithm to build a knowledge base using input from the aforementioned information, enabling dynamic identification of control actions. The feasibility of applying reinforcement learning in real-world traffic scenarios is discussed, and the results indicate the decentralized and scalable nature of the proposed approach, especially for multi-intersection scenarios.

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2D Quantum Droplets with Large Angular Momenta

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ABSTRACT

In this work, we present numerical and analytical evidences of the existence of stable quantum droplets (QD) endowed with large angular momenta and with physical properties resembling liquid superfluids. We apply variational procedures to the mean field equation governing two-dimensional symmetric QD, to find simple yet very precise formulae for the droplet profile and the relationships between its main parameters, such internal and external radii of the bright rings, the chemical potential or the number of atoms of the QD.

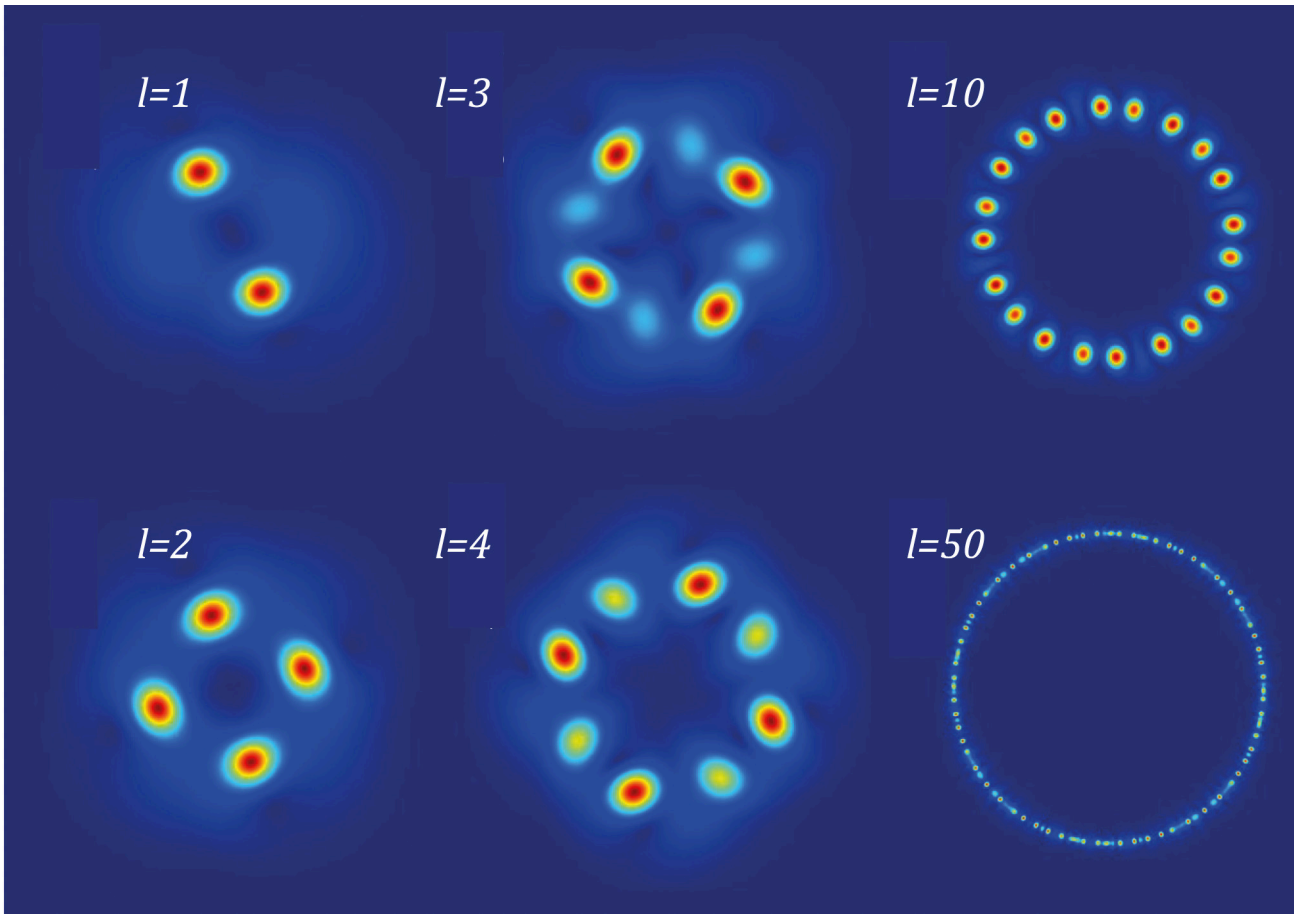

Figure 1. Splitting of unstable vortex rings due to modulational instability yielding $n=2l$ spiralling soliton blobs.

Keywords: Solitons, vortices, quantum droplets

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Role of Modulation Instability in Numerical Analysis

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ABSTRACT

Modulation instability (MI, Fig. 1) is undoubtedly one of the most common and important instabilities in nature. It is responsible for many physical effects: rogue waves in deep water, supercontinuum generation in nonlinear optical fibers, formation of stable solitary pulses, to name a few [1].

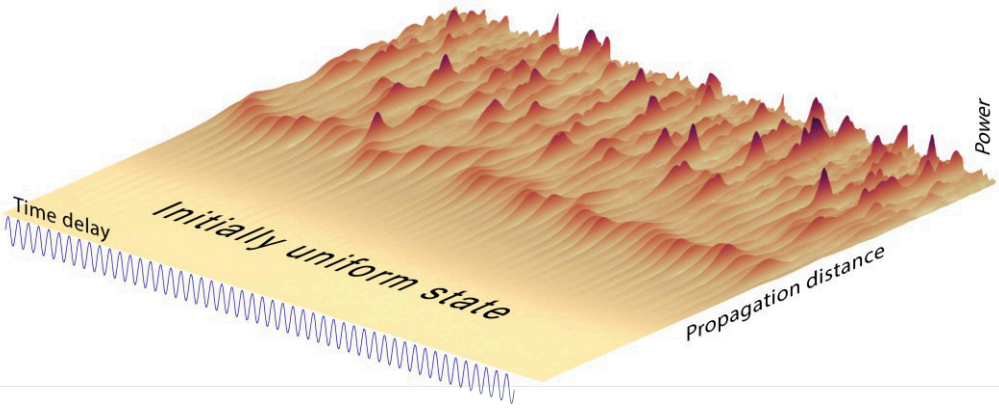

Figure 1. This is a typical scenario of modulation instability, which was calculated numerically and can be gradually distorted by the appearance of what are called spurious tones. We figure out how to avoid them.

In addition to physical phenomena, MI has important applications to the numerical solution of wave propagation equations, e.g., for the multiplicative and additive split-step solvers of the generalized nonlinear Schrödinger equation (GNLSE) [2-4]. As it happens, the description of growing modulations on a carrier-wave background is so fundamentally simple that it can be done directly for a given numerical method. The comparison between continuous and discrete MI theories provides important information about the validity of the split-step method for GNLSE and allows to avoid the spontaneous appearance of the so-called spurious tones.

Keywords: nonlinear optics, generalized nonlinear Schrödinger equation, modulation instability, splitting methods, spurious tones

References:

[1] G. P. Agrawal, Nonlinear Fiber Optics. New York, USA: Academic, 2007
[2] S. Amiranashvili, M. Radziunas, U. Bandelow, K. Busch, and R. Čiegis, "Additive splitting methods for parallel solutions of evolution problems," Journal of Computational Physics, vol. 436, pp. 1-14, 2021.
[3] F. Severing, U. Bandelow, and S. Amiranashvili, "Spurious four-wave mixing processes in generalized nonlinear Schrödinger equations," J. Lightwave Technol., vol. 41, no. Y, pp. 5359-5365, 2023.
[4] S. Amiranashvili and R. Čiegis, "Stability of the higher-order splitting methods for the generalized nonlinear Schrödinger equation," Mathematical Modelling and Analysis, (2024 in print).

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Solitonic light bursts and momentum supercontinuum generation in nonlinear time-varying dielectric media

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ABSTRACT

Since their initial conception [1] and theoretical study [2], time-varying dielectric media have become a topic of recent intense interest due to their unconventional and novel linear and nonlinear properties [3]. Particular attention has been devoted to media whose refractive index varies periodically (so-called *photonic time crystals*, or PTCs), that are able to generate linear momentum bandgaps and nonlinear momentum gap solitons [2]. In this work we present a novel way to investigate momentum gap solitons in PTCs by using the framework of the *nonlinear Mathieu equation*, an equation the linear version of which is used to study parametric instabilities in physics. The nonlinear version of Mathieu equation has the potential to give exact information on temporal solitons in PTCs, and the dynamics of their formation and evolution. Further we use coupled mode theory to study the new phenomenon of *momentum supercontinuum generation*, the formation of a broad momentum spectrum from a narrow one, when pulses are injected into the nonlinear PTC [4]. These phenomena pave the way for a better understanding of how to experimentally construct a real-world PTC [5], and the operability conditions of such a paradigm-shifting device.

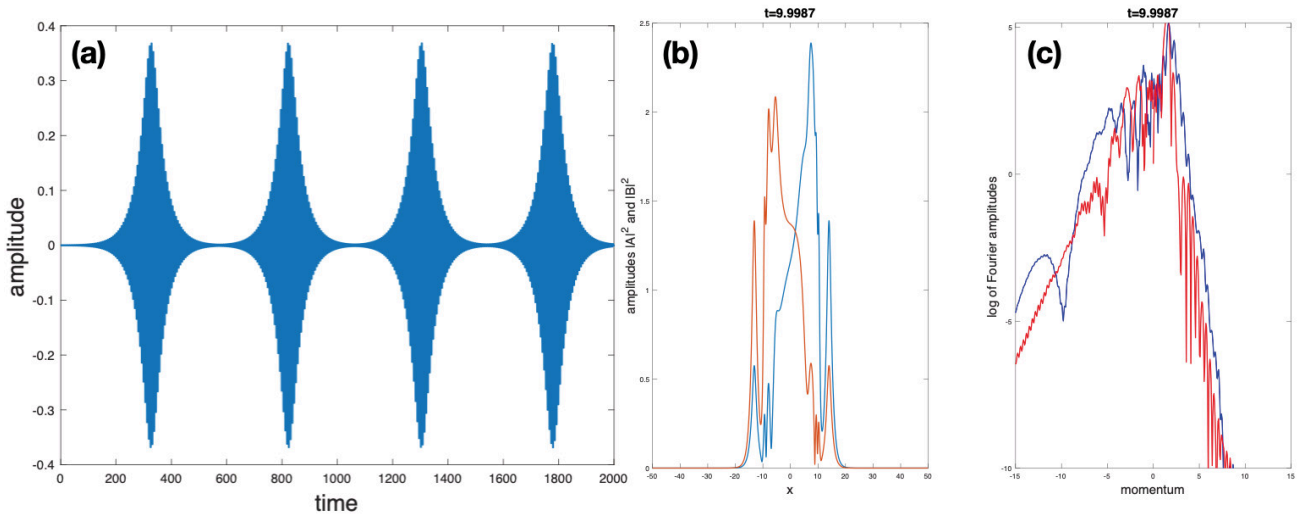

Figure 1. (a) Formation of solitonic light bursts in PTCs from the nonlinear Mathieu equation. (b,c) Momentum supercontinuum generation in PTCs emanating from a gaussian input pulse, using nonlinear coupled mode theory (blue lines: forward wave; red line: backward wave). The generation of several momentum gap solitons propagating in opposite directions is observed. Energy always increases in time during propagation, due to the non-conservative nature of the problem, and more and more solitons are formed.

Keywords: Nonlinear optics; Solitons; Photonic Time Crystals; Time-Varying Dielectric Media; Supercontinuum.

References:

[1] F. Morgenthaler, IRE Trans. On Microw. Theory Tech. 6, 167 (1958).
[2] F. Biancalana et al, Phys. Rev. E 75, 046607 (2007); F. Biancalana et al, Phys. Rev. A 77, 011801 (2008).
[3] M. M. Asgari et al, arXiv:2404.04899v1.
[4] F. Biancalana et al, submitted (2024).
[5] A. Boltasseva et al, Optical Material Express 14, 592 (2024).

Binary classification of low-resolution images using the collective modes of a two dimensional array of photonic crystal nanolasers

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ABSTRACT

Recent advances in nanolaser design and manufacturing make these devices attractive candidates for high-performance optical computing systems with ultra-low power consumption. In this work, I will present our work aimed at exploiting the symmetry properties of the collective modes of a two-dimensional nanolaser array for a simple binary classification task. The output of the classifier is the activation (yes/no) of a collective optical mode of the array under a spatially modulated optical pump that encodes the information of the input (a low resolution image) to be classified. The system's parameters are optimized in such a way that only a given class of input images efficiently excites the selected mode of the array.

Questioned document examination using optical coherence tomography

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ABSTRACT

The ability to distinguish legitimate from counterfeit documents, with high throughput, sensitivity, and selectivity is an ever-evolving challenge, particularly in high-stakes situations such as international border crossings. Over the last decade, an increasing number of security features have been introduced by authorities in identification documents.
The latest generation of travel documents (such as passports and national ID cards, but equally photocard driving licences) forego paper substrates for several layers of polycarbonate, which allow security features to be embedded within the document. These security features may contain information at either the superficial and sub-surface levels, thus increasing the document's resilience to counterfeiting. As the documents become harder to forge, so does the sophistication of forgery detection. There appears to be an unmet and evolving need to identify (and classify) such sophisticated forgeries, in a non-destructive, high throughput manner.

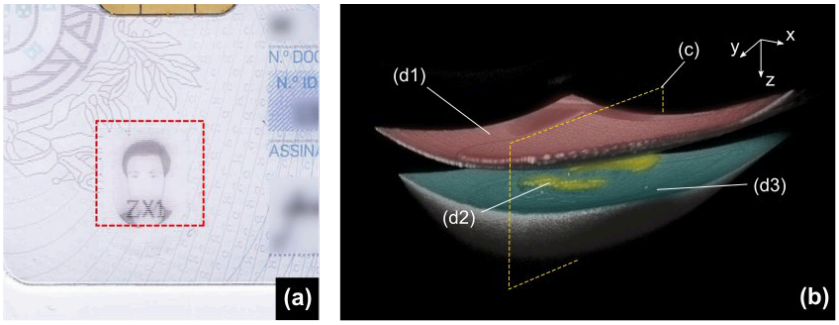

Figure 1: OCT imaging of security feature from Portuguese national ID card; (a) approximate location of scan; (b) 3-D rendered volume of the sub-surface structure of the security feature.

In this communication, building on a prior publication from our group [1], we present the application of optical coherence tomography (OCT) imaging on assessing security features in specimen passports, national ID cards and driving licences, including some confirmed counterfeited documents. OCT allows sub-surface imaging of translucent structures, non-destructively enabling quantitative visualisation of embedded security features, and providing their location in three-dimensional space.

Keywords: low-coherence imaging, non-destructive imaging, forensic sciences, questioned document examination, identification documents

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References:
[1] M. J. Marques, R. Green, R. King, S. Clement, P. Hallett, and A. Podoleanu, 'Sub-surface characterisation of latest-generation identification documents using optical coherence tomography', *Science & Justice*, p. S1355030620303336, Dec. 2020, doi: 10.1016/j.scijus.2020.12.001.

Enhancing Spectral Imaging Data Quality with Multiple Exposure Fusion Techniques

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ABSTRACT

Spectral Imaging techniques, such as Raman Spectroscopy and Laser-induced Breakdown Spectroscopy (LIBS), play pivotal roles in chemical analysis. In contrast to traditional imaging techniques, spectral imaging greatly expands the accessible information by relying on localized spectral data analysis. Nevertheless, the main drawbacks of these techniques include saturation, matrix interferences, and the existence of non-specific radiation like background emission or fluorescence[1,2,3].

This work investigates the possibility of enhancing the dynamic range by applying methods that are often used in RGB imaging. We present an approach to fuse datasets obtained with the same technique but with varying acquisition settings. This approach involves computing a global weight map based on the well-exposedness and local contrast metrics inspired by multi-exposure fusion techniques[4]. The resulting weight maps are combined using the Laplacian Pyramid algorithm[5], creating a final map for each wavelength that integrates information from multiple acquisitions.

Our method demonstrates improved image contrast and signal-to-noise ratios, mitigating constraints like fluorescence and signal saturation. We validate our approach with case studies focused on mineral identification using both Raman and LIBS data. By applying unsupervised clustering for mineral identification in a rock sample, we show that the multi-exposure fused dataset significantly enhances classification performance in LIBS imaging.

Keywords: Raman Spectroscopy, Laser-Induced Breakdown Spectroscopy, Unsupervised Clustering, Signal Processing

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References:

[1] Capela, D. et al. Robust and interpretable mineral identification using laser-induced breakdown spectroscopy mapping. Spectrochimica Acta Part B: At. Spectrosc. 106733 (2023).
[2] Wang, Z. et al. Recent advances in laser-induced breakdown spectroscopy quantification: From fundamental understanding to data processing. TrAC Trends Anal. Chem. 143, 116385 (2021).
[3] Gierlinger, N. & Schwanninger, M. The potential of raman microscopy and raman imaging in plant research. Spectroscopy 21, 69–89 (2007).
[4] Merianos, I. & Mitianoudis, N. Multiple-exposure image fusion for hdr image synthesis using learned analysis transformations. J. Imaging 5, 32 (2019).
[5] Burt, P. J. & Adelson, E. H. The laplacian pyramid as a compact image code. In Readings in computer vision, 671–679 (Elsevier, 1987).

Use of Optical Techniques for Surface Analysis of Rock Art Engravings from the UNESCO Heritage Site of Valcamonica

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ABSTRACT

The documentation of cultural heritage using digital techniques to obtain high quality 3D models is now considered a necessary and vital practice to provide a complete monitoring, protection and maintenance plan. In addition, these techniques can also be used for quantitative analysis of the physical characteristics of the support materials [1]. In the case of petroglyphs, which are engravings made by scraping or pecking away rock in a subtractive process, they are undeniable documents of world history [2]. In this sense, Valcamonica, an Alpine valley in northern Italy, the first Italian UNESCO World Heritage Site, has one of the largest concentrations of outdoor rock art in Europe. This paper presents the process of digitisation and surface analysis of a sample of Verrucano Lombardo sandstone, which forms the basis of these engravings. The 3D reconstruction of the rock surface was carried out using a high-precision Microepsilon laser line sensor and an IFM 3D camera coupled to a three axes precision stage. Furthermore, a LEUZE line profile sensor and a Zygo NewView 600 interferometric microscope were used to analyse the micro-topography of the surface. The digitisation of the surface at different scales allowed the quantitative analysis and characterization of the features of the rock elements, i.e. anthropic marks such as engraving holes and natural grooves or micro-fractures caused by glacier drag or melting, and revealed the complex interactions between the anthropic engravings and the natural features of the rock, which is a crucial issue in the selection of optimal conservation measures.

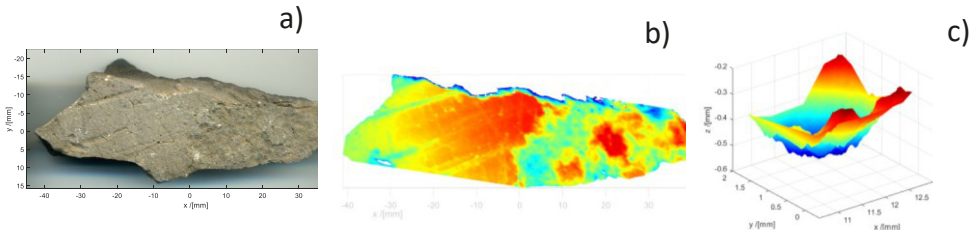

Figure: a) Image of the sample; b) Digitisation c)Analysis of an antropic engraving hole

Keywords: laser line sensors, surface analysis, petroglyphs, Valcamonica

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References:

[1] Freire-Lista, D.M. et al. "Building Granite Characterisation, Construction Phases, Mason's Marks and Glyptography of Nossa Senhora de Guadalupe Church, Mouçós e Lamares, Galicia-North Portugal Euroregion," Geoheritage 15, 24 (2023). https://doi.org/10.1007/s12371-023-00790-4
[2] Rock Art Research in the Digital Era: Case Studies from the 20th International Rock Art Congress IFRAO 2018, Valcamonica (Italy), BAR Publishing, 2022. https://doi.org/10.30861/9781407360119

Evaluation of deformation in aluminum plate under laser thermal stress using Shearography technique.

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ABSTRACT

Shearography, which measures deformation gradients, has established itself as a fundamental tool in non-destructive testing (NDT) across various industrial sectors [1]. This technique is noted for its use of the Michelson interferometer, which allows the observation of the object under study through two independent optical paths. In our experiment, we applied the Shearography technique using this interferometer to assess an aluminum metal plate subjected to different thermal loads. The main goal was to obtain the derivatives of the displacement field in the *x* direction, both for the in-plane displacement *u(x,y)* and out-of-plane displacement *w(x,y)*. To achieve this, we symmetrically illuminated the sample from two angles, thus capturing the deformation fields associated with the different thermal loads. This method also offers the possibility to evaluate the temperature linked to the imposed thermal stress. In the interferometer, one of the mirrors is equipped with a MDT694B piezoelectric device, which facilitates the application of a four-step phase shift. By integrating the deformation data, we generated a displacement map that provides a quantitative representation of how each specific point on the plate has physically varied due to the thermal loads. This map is crucial for visualizing the complete distribution of displacements across the plate. When a thermal load is applied to the metal plate, it expands or contracts depending on the achieved temperature, which can be uniform or vary according to the material properties, the presence of defects, or boundary conditions. Shearography is capable of detecting these variations precisely, offering a visual image of how the thermal load affects the material. This capability is essential for assessing structural integrity, identifying stress areas, and ensuring quality in manufacturing processes [2]. Over time, and with repeated thermal load cycles, additional changes may occur in the plate's topography, underscoring the importance of continuous evaluation to ensure long-term integrity. The ability of Shearography to detect thermal deformations without visible damage is particularly valuable for the ongoing monitoring of structures exposed to temperature fluctuations [3]. This has significant implications in asset management and the prevention of structural failures.

Keywords: Shearography, deformtions, temperature.

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References:

[1] L. Yang *et al.,* SPIE Press, (2016).
[2] W. Steinchen *et al.,* SPIE Press, (2003)
[3] N. Tao, *et al.,* NDT & E International,139, (2023)

Understanding the ocean using submarine optical fibre cables

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ABSTRACT

Oceans cover 70% of the Earth surface and are extremely important in many aspects of our life. For example, oceans play a significant role in regulating temperature: as water has a very significant heat capacity, it can potentially act as a very good heat sink. Understanding the role of the ocean in climate implies quantifying the process of ocean mixing, whereby the upper (warmer) layer of the ocean gets mixed with the lower (colder) layer. This process is mainly driven by tides, which excite internal waves (waves at the ocean interior) that then lead to small-scale mixing phenomena. The lack of good scientific instrumentation in the oceans leads to an evident lack of high-quality observations of these internal waves, which imply significant uncertainties in the determination of many oceanic parameters relevant for climate change such as ocean diffusivity. Also, the lack of significant geophysical instrumentation offshore makes it more complicated to have reliable early warning systems capable of mitigating some of the disastrous consequences of tsunamis [1].
In the last years, distributed acoustic sensors (DAS) have been proposed as an alternative to geophysical instruments in underwater scenarios. DAS systems allow for the fully distributed monitoring of temperature and seismic vibrations along a conventional telecom optical fiber in the sea-bottom [2]. In DAS, the optical fiber cable acts as a continuous array of temperature and strain meters, which are interrogated with a single opto-electronic unit located in one end of the cable. Conventional phase-measuring DAS systems generally show uneven sensitivity along the fiber and limitations in long-term measurements [3]. In 2016, we demonstrated a novel DAS architecture based on chirped pulses [4]. This method has proven capable of quantifying the magnitude of ongoing perturbations over the fiber with high and consistent sensitivity [5] and improved performance [6] over other traditional configurations. The use of distributed Raman amplification allows to extend the range of this technique beyond 70 km [7]. Combining the capacities of modern DAS technology with the availability of a vast network of fiber-optic cable deployed all over the planet, very often running across very deep underwater regions in the middle of the oceans, offers new opportunities for gaining new knowledge on offshore processes. This paper reviews our work on DAS for oceanography. We show that DAS measurements can provide a wealth of information on relevant oceanographic processes including ocean currents and internal waves.

Acknowledgements: This work was supported by MICIU/AEI/10.13039/501100011033 and the European Union NextGenerationEU/PRTR Program (Grant PSI ref. PLEC2021-007875 and TREMORS ref. CPP2021-008869), MICIU /AEI/10.13039/501100011033 and FEDER,EU (PID2021-128000OBC21, PID2021-128000OB-C22, PID2022-140963OA-I00), by the European Innovation Council (Grant SAFE: ref. 101098992), and MICIU/AEI/10.13039/501100011033, co-funded by European Commission (GA N°101069750) under the CETPartner- ship 2022 joint call (Project SEASNAKE + , ref: PCI2023-145978-2) and HORIZON-INFRA-2022-TECH-01-SUBMERSE-101095055.

References:

[1] Tsunamis revisited. Nat. Geosci. 12, 149, (2019).
[2] Williams, E. F., et al., Nat. Comm. 10 5778, doi:10.1038/s41467-019-13262-7 (2019).
[3] Gabai, H. and Eyal, A. Opt. Lett. 41, 5648-5651 (2016)
[4] Pastor-Graells, J. et al., Opt. Express, 24, 13121-13133 (2016).Pastor-Graells, J. et al., Opt. Express, 24, 13121-13133 (2016).
[5] Costa, L. et al., J. Lightwave. Technol. 37 4487-4495 (2019)
[6] Fernández-Ruiz, M. R. et al. J. Lightwave. Technol., 36, 5690-5696 (2018).
[7] Pastor-Graells, J. et al. J. Lightwave Technol. 35(21), 4677–4683 (2017).

Optical Sensorization for the Monitorization of Composite Parts on Manufacturing, Assembly, Integration and Testing Phases

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ABSTRACT

Composite materials are widely used in critical structures where the combination of high stiffness and low weight is crucial. Thus, in accordance to the criticality of the operation context, it is of high importance to thoroughly monitor the operational service life of these structures while in service, as well as to maintain strict control over their processing conditions. The incorporation of optical sensing systems during the production process represents an innovative approach that enables the production of smart components with integrated sensors into their structure, with the ability to monitor a wide range of physical variables relevant to evaluate the performance and quality of the product [1]. This new approach is highly disruptive, and composite materials are a broad field of application of this monitoring concept, due to the intrinsic characteristics of this type of materials and respective manufacturing processes.
In this study, it was considered the embedment of an optical FBG (fibre Bragg grating) sensor network, as shown in Figure 1, on: a) CFRP (Carbon Fibre Reinforced Polymer) composite curved panel, and b) on a COPV-Composite Overwrapped Pressure Vessel. The embedded optical sensorization system considered within the scope of this application case-studies was capable of multi-point and multivariable sensing (temperature and strain), enabling data monitoring throughout the entire production cycle and structural testing phases. In fact, the same optical network, embedded in the composite laminate, allowed to retrieve thermomechanical data essential to monitor the resin infusion process, cure kinetics and, finally, to assess impact events and, specifically for the COPV application case, also to monitor internal pressurization fatigue tests to resemble its operation service life.

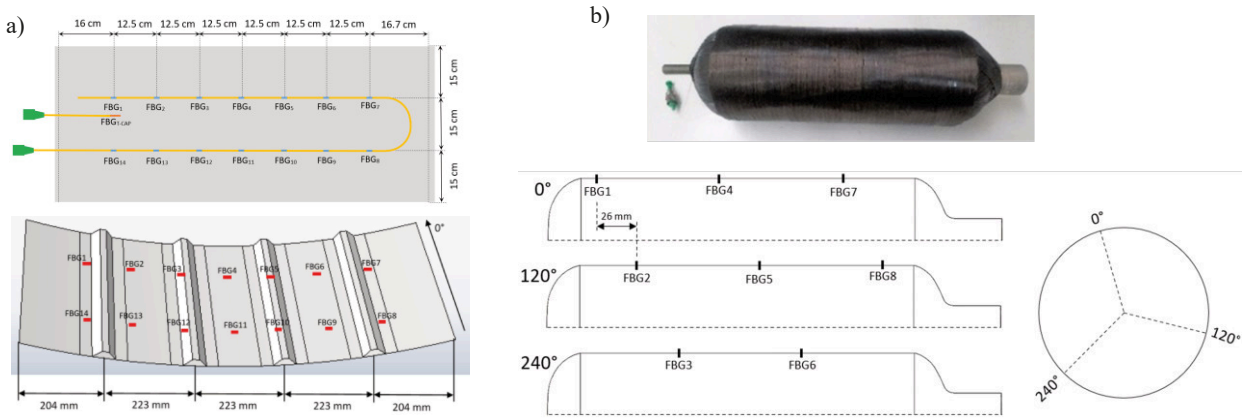

Figure 1. FBG sensor networks: a) 3D model of curved composite panel and indication of FBG sensors positioning, b) COPV and positioning scheme of FBG sensors.

Keywords: Composites, Optical sensorization, FBG, Manufacturing, Structural Health Monitoring.

References:

[1] Rocha Helena, Antunes Paulo, Lafont Ugo, and Nunes João P., "Processing and Structural Health Monitoring of a Composite Overwrapped Pressure Vessel for Hydrogen Storage," *Struct Health Monit*, vol. in press, 2023.

Optics and Photonics in Wind Industry: Challenges and Opportunities

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ABSTRACT

The wind industry has grown exponentially over the last 20 years, driven by the urgent need for clean, sustainable, and renewable energy sources to replace fossil fuels. To develop more efficient wind turbines in the shortest time possible, key players in the wind industry have invested substantial resources in manufacturing larger and more powerful turbines [1]. However, the increase in turbine size brings new challenges, such as maintaining structural integrity and addressing the environmental impacts these "giants" may have on their surroundings. Consequently, these complex challenges present opportunities for the optics and photonics fields, leveraging their unique characteristics. In this presentation, we will explore two of the most popular optical technologies used in the wind industry – optical fiber sensors and lasers. We will reveal how these technologies have been employed to mitigate some of the most complex challenges in wind turbines and how they are shaping the future of the wind industry.

Keywords: (Wind Turbine, Optical Fiber Sensor, Wind Industry, Laser)

References:

[1] D. Maradin, "Advantages and disadvantages of renewable energy sources utilization", International Journal of Energy Economics and Policy, vol. 11, 176–183, 2021. https://doi.org/10.32479/ijeep.11027.

Multimodal Spectral Imaging for Industrial Applications

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ABSTRACT

In modern industrial settings, the rapid and accurate sorting and identification of materials are critical for automating processes such as manufacturing and recycling. Achieving robust performance and reliability in these tasks is challenging due to the diverse nature of materials and the need for precise, real-time analysis. Single spectral techniques, while powerful, often face limitations. For example, Laser-Induced Breakdown Spectroscopy (LIBS) is highly accurate for elemental analysis but can be slow. In contrast, hyperspectral imaging offers high-speed data acquisition but may struggle with identifying certain materials due to its lower specificity.

Multimodal spectral imaging, which combines different techniques, can offer more capable solutions to these challenges. By integrating the capabilities of various methods, more robust identification or classification is often achieved. However, standard fusion techniques may introduce limitations, such as being constrained by the speed of the slowest technique in the tandem solution[1-3].

The Spectral Imaging team at INESC TEC is developing new solutions and methods for high-performance industrial applications using techniques such as LIBS, Raman spectroscopy, and hyperspectral imaging. Key developments include advancements in intelligent mapping algorithms, three-dimensional chemical element mapping, and enhanced mineral identification. A key innovation in our approach is the use of spectral knowledge distillation (SKD)[4]. This technique involves using one spectral method to train another, effectively transferring knowledge and enabling the second method to perform with enhanced capability.

This work provides an overview of new methodologies developed in multimodal spectral imaging, which will be discussed in the context of industrial case studies.

Keywords: LIBS, RAMAN, Hiperspectral imaging

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References:

[1] Motto-Ros, V. et al. Libs-based imaging: Recent advances and future directions. Spectroscopy 35, 34–40 (2020).
[2] Shaw, G. A. & Burke, H. K. Spectral imaging for remote sensing. Lincoln Lab. J. 14, 3–28 (2003).
[3] Piao, J., Chen, Y. & Shin, H. A new deep learning based multi-spectral image fusion method. Entropy 21, 570 (2019).
[4] Lopes, T., Capela, D., Guimarães, D. et al. From sensor fusion to knowledge distillation in collaborative LIBS and hyperspectral imaging for mineral identification. Sci Rep 14, 9123 (2024).

A LiDAR based obstacle detection framework for railway

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ABSTRACT

Obstacle detection on the railway, a crucial operational safety concern, is a complex task that encompasses a multitude of challenges. While Machine Learning (ML) algorithms are commonly employed in analogous applications such as autonomous car driving [1, 2], the railway field faces a significant barrier due to the scarcity of available data (particularly images), rendering conventional ML approaches impractical.
In response to this challenge, this study proposes and evaluates a framework which uses LiDAR (Light Detection and Ranging) data for obstacle detection on the railways. The framework aims to address the limitations posed by image data scarcity while enhancing operational safety in railway environments.
The developed methodology combines the use of a long-range LiDAR capable of detecting obstacles at distances of up to 500 meters, with the train's GPS (Global Positioning System) coordinates to accurately determine its position relative to detected obstacles. The LiDAR data is processed using a clustering algorithm, specifically DBSCAN (Density-based spatial clustering of applications with noise), to identify and classify potential obstacles at a pre-defined distance.
Tests of the proposed framework were conducted within the confines of a moving locomotive, specifically the CP 2600-2620 series, along a designated section of the Contumil-Leixões line. These tests served to validate the effectiveness and feasibility of the approach under real-world operating conditions.
Overall, the utilization of LiDAR data coupled with advanced clustering algorithms presents a promising avenue for enhancing obstacle detection capabilities in railway operations. By overcoming the challenges associated with data scarcity, this framework holds the potential to significantly improve operational safety and efficiency within railway networks. Further research and testing are warranted to validate the framework's performance across diverse railway environments and operating conditions.

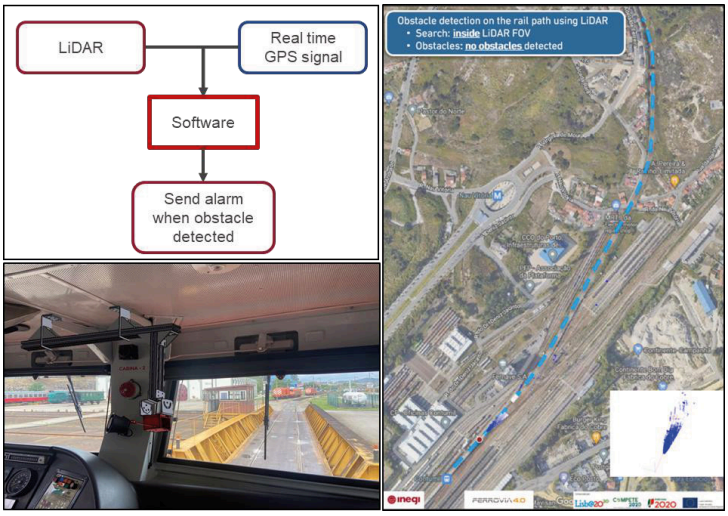

Figure 1. Obstacle detection on railway.

Keywords: LiDAR, obstacle detection, railway, clustering algorithm

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Low-cost Plasmonic Probes for single-molecule Detection

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ABSTRACT

Plastic Optical Fibers (POFs) can carry out several bio/chemical sensor configurations, exploiting their excellent flexibility, easy manipulation, great numerical aperture, large diameter, large number of modes, and the fact that plastic can withstand smaller bend radii than glass. In other words, extrinsic and intrinsic optical fiber sensing schemes can be realized using POFs' characteristics combined with cheap equipment [1-6]. The plasmonic regions of POF-based probes, realized via extrinsic and intrinsic schemes, can be combined with specific receptor layers, biomimetic (e.g., molecularly imprinted polymer layers or nanoparticles) or biological (e.g., antibodies and aptamers), which offer different sensing efficiencies when the receptor-analyte binding occurs. Therefore, the different efficiencies of the receptor layers and the several plasmonic sensitivities of the POF-based platforms (extrinsic and intrinsic schemes) can be combined to achieve the appropriate detection range for the substances of interest, as required in the considered application fields, such as medical diagnostics, environmental monitoring, industry, food safety, and security. In other words, the balance of the combination of POF platforms and receptors can produce the desired optimal performance of the plasmonic bio/chemical sensor in terms of substance and detection range of interest [4-6]. Several bio/chemical sensors have been developed for different application fields exploiting plasmonic D-shaped POF platforms combined with different kinds of receptors [1,5]. Our research group has recently designed, developed, and tested an unconventional plasmonic sensing approach to realize optical fiber sensors useful in several application fields [6]. Moreover, several plasmonic sensor configurations have been developed via extrinsic POF schemes, such as those based on 3D-printed waveguides [7], bacteria cellulose waveguides [8], Inkjet-Printed optical waveguides [9], spoon-shaped waveguides [10], PMMA slab waveguides [11], and ultra-sensing chips realized by a gold nanograting fabricated by electron beam lithography (EBL) on PMMA slab waveguides [12]. POFs connect the sensing chip to a light source and a spectrometer in these sensor configurations, with some benefits.

References:

[1] N. Cennamo, M. Pesavento, L. Zeni, "A review on simple and highly sensitive plastic optical fiber probes for bio-chemical sensing," Sensors and Actuators B, vol. 331, 129393, 2021.
[2] K. Anuj, R.J. Sharma, B.D. Gupta, "Fiber-optic sensors based on surface Plasmon resonance: a comprehensive review," IEEE Sensors Journal, vol. 7, 1118-1129, 2007.
[3] R.A. Mahmud, R.H. Sagor, M.Z.M. Khan, "Surface plasmon refractive index biosensors: A review of optical fiber, multilayer 2D material and gratings, and MIM configurations," Opt. Laser Technol., vol. 159, 108939, 2023.
[4] R.A. Kadhim, A.K.K. Abdul, L. Yuan, "Advances in Surface Plasmon Resonance-Based Plastic Optical Fiber Sensors," IETE Tech. Rev. vol. 39, 442–459, 2020.
[5] C. Leitão, et al., "Cost-effective fiber optic solutions for biosensing," Biosensors, vol. 12, 575, 2022.
[6] F. Arcadio, et al., "A Novel Approach to Realize Plasmonic Sensors via Multimode Optical Waveguides: A Review," Sensors, vol. 23, 5662, 2023.
[7] N. Cennamo, et al., "Microstructured Surface Plasmon Resonance Sensor Based on Inkjet 3D Printing Using Photocurable Resins with Tailored Refractive Index," Polymers, vol. 13, 2518, 2021.
[8] N. Cennamo, et al, "An Eco-Friendly Disposable Plasmonic Sensor Based on Bacterial Cellulose and Gold," Sensors, vol. 19, 489, 2019.
[9] N. Cennamo, et al., "Analysis of Low-Cost Inkjet-Printed Optical Platforms Covered by Molecularly Imprinted Polymers to Detect Furfural in Water," IEEE Sensors Journal, vol. 23, 22169-22179, 2023.
[10] N. Cennamo, et al., "Spoon-shaped polymer waveguides to excite multiple plasmonic phenomena: A multisensor based on antibody and molecularly imprinted nanoparticles to detect albumin concentrations over eight orders of magnitude," Biosensors and Bioelectronics, vol. 217, 114707, 2022.
[11] N. Cennamo, F. Mattiello, L. Zeni, "Slab Waveguide and Optical Fibers for Novel Plasmonic Sensor Configurations," Sensors, vol. 17, 1488, 2017.
[12] F. Arcadio, et al., "A Nanoplasmonic-Based Biosensing Approach for Wide-Range and Highly Sensitive Detection of Chemicals," Nanomaterials 11, 1961 (2021).

Non-intrusive monitoring of vital signs in the lower limbs using optical sensors

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ABSTRACT

Invisible and longitudinal health monitoring is currently a topic of global interest within the scientific community. By incorporating monitoring systems into everyday objects, valuable health information can be obtained without requiring any interaction or changes to people's routines [1,2].
The main goal of this work is to develop and test a health monitoring system that can provide quickly, continuously, and remotely monitoring of vital signs in the lower limbs, including heart rate (HR), oxygen saturation (SPO2), and respiratory rate (RR). The primary advantage of measuring vital signals in the lower limbs is the potential to integrate this system into different daily life objects, such as chairs, sofas, toilets, and fitness bands, and thus extend measurements to seated positions.
The system is based on two MAX30102 optical sensors, which obtain photoplethysmography signals from the back of the thigh. The sensor positions are shown in Figure 1. After acquisition, the signals are processed and analyzed through dedicated algorithms to obtain HR, RR, and SPO_2 data from the lower limbs, in real-time. For concept validation, user tests were conducted (17 volunteers, age group between 22 and 40 years old, 12 females, 5 males), and the obtained results present high levels of correlation with the reference measures, obtained using a pulse oximeter and a respiratory band. The results are promising and confirm the proposed system's viability for vital parameters monitoring, such as HR, RR, and SPO_2, in the lower limbs.

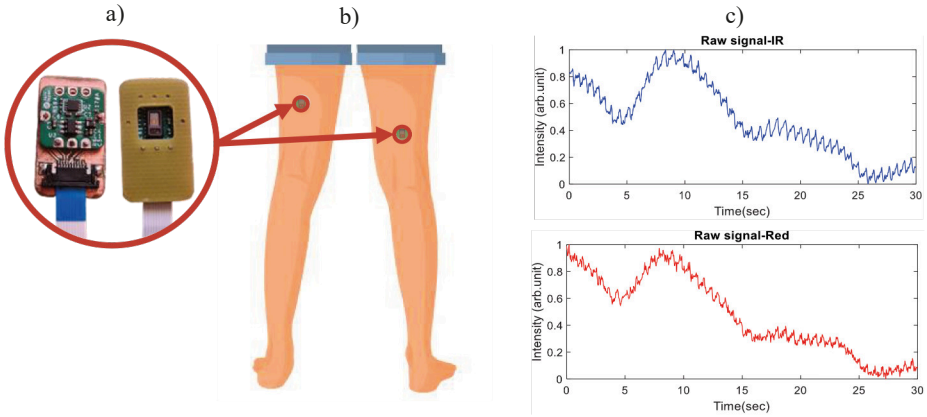

Figure 1. a) Front and back sides of MAX30102 sensor used in this work, b) sensor positioning/measurement sites c) raw signals of infrared (top) and red (bottom) LED from which the values of HR, RR and SPO_2 are calculated.

Keywords: Health Applications, Optical Sensor, Heart Rate, Oxygen Saturation, Respiratory Rate.

Acknowledgements: The present study was developed in the scope of the Project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46] – WP4 OLI Health, financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union; partially supported by project i3N (UIDB/50025/2020,UIDP/50025/2020 and LA/P/0037/2020) funded by national funds through the FCT and MEC of Portugal; by a grant (2022.09701.BD) to Regina Oliveira and by a CEEC contract (2020.00154.CEECIND) to Cátia Leitão, both funded by national funds through the FCT.

References:

[1] S. S. Gambhir et al Science Translational Medicine, vol. 10, no. 430. (2018). DOI: 10.1126/scitranslmed.aao3612.
[2] H. J. Baek et al., IEEE Transactions on Information Technology in Biomedicine, vol. 16, no. 1, pp. 150–158. (2012). DOI: 10.1109/TITB.2011.2175742

Synchrotron Radiation Fourier Transform Infrared spectroscopical analysis of biomolecules in MRC-5 fibroblast cells treated with biomass-derived carbon dots

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ABSTRACT

Synchrotron radiation Fourier transform infrared (SR FTIR) spectroscopy is a powerful tool for imaging and studying intracellular chemical changes on a single-cell level [1]. This technique achieves a high spatial resolution (3 to 10 μm) and a high signal-to-noise ratio. It has been used in biomedical applications and investigates structural biomolecular changes induced by external factors, like the interaction with a drug, light, or a combination [2]. Here, we have compared biomolecular structural changes in the MRC-5 fibroblast cell line induced by incubation with two biomass-derived carbon dots: black carrots (BC-CDs) and beetroots (BR-CDs). CDs are small nanoparticles with a diameter of about 10 nm, broadly utilised in biomedicine because of their optical properties [3]. We have analysed and statistically processed three significant regions in the SR FTIR spectra of cells treated with BM-CDs and found differences in all biomolecular areas compared to untreated control cells. The most expressed differences were identified in the signals corresponding to nucleic acids (phosphate vibrations) and proteins (Amide I region). These changes are illustrated in Fig. 1, in which the second derivatives of Amide I bands (a,c), and corresponding PC score plots (b,d) are given. The most expressed differences between the treatments are observed in the antiparallel and parallel β-sheets region. In contrast, a decrease in the total content of α-helices is detected in both treatments. Detailed inspection of other IR regions revealed that detected changes can be correlated with the composition and structure of CDs, which are, in turn, dependent on the fabrication source.

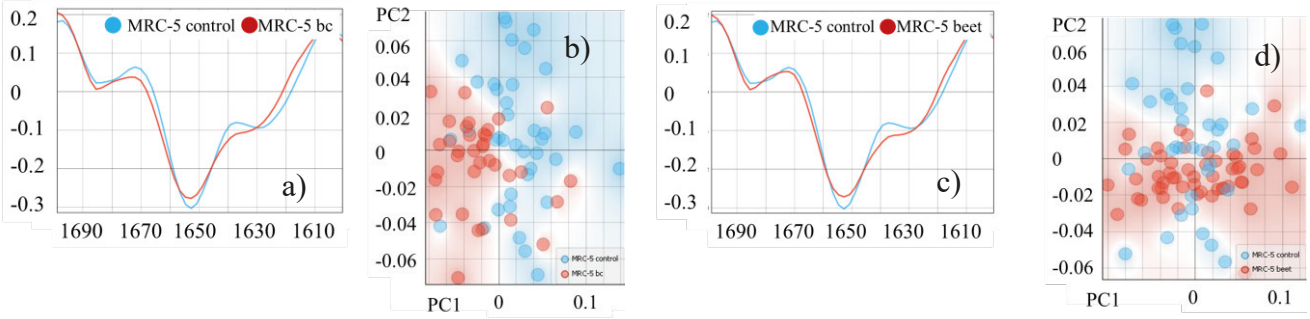

Figure 1. a) 2nd order proteins MRC-5 BC b) proteins BC MRC-5 scatter c) MRC-5 beet 2nd order d) MRC-5 beet scatter

References:
[1] I. Yousef, L. Ribó, A. Crisol, et al.,"MIRAS: The Infrared Synchrotron Radiation Beamline at ALBA", Synchrotron Radiat. News 30 (2017) 4–6.
[2] M. D. Nešić, T. Dučić, M. Gonçalves, et al., "Biochemical changes in cancer cells induced by photoactive nanosystem based on carbon dots loaded with Ru complex", Chemico-Biological Interactions 360 (2022) 109950.
[3] M. Algarra, C. Carrillo, M. D. Nešić, et al., "Testing of black-carrots-derived fluorescence imaging and anti-metastatic potential", J. Mol. Structure, 1300 (2024) 137245.

All-optical techniques for in-fiber excitation and interrogation of acoustic resonances

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ABSTRACT

Forward Brillouin Scattering (FBS) has been traditionally considered as an unwanted effect, but in the recent years its potential as a mechanism for optical fiber sensing has attracted great interest. The Transversal Acoustic Mode Resonances (TAMRs) excited by FBS provide high accuracy, allow sensing the external medium without the need of evanescent optical fields and they enable frequency-encoded techniques. Moreover, TAMRs can be both excited and interrogated using optical methods [1-2]. Conventional interrogation techniques based on interferometry do not provide axial resolution, since they need meters of fibers. In this contribution we present different techniques based on optical fiber devices that overcome this limitation and provide high Q-values for the measured TAMRs.

In this abstract we show two interrogation techniques which provide good axial resolution. Figure 1 (a)-(b) shows the temporal trace (up) and the correspondent radio-frequency spectrum (down) when a Long Period Grating (LPG) is used. In this case, the axial resolution is of several centimetres and the acoustic families detected by the LPG are radial (higher peaks in (b)) and torsional-radial. In the second example, Whispering Gallery Modes (WGMs) are used for characterizing the excited TAMRs, see Fig. 1 (c)-(d). WGMs are insensitive to torsional-radial TAMRs, thus the only family shown in (d) is the radial one. The axial extension of the used WGMs is lower than 1 mm; this enables a point to point measurement and high Q-values for TAMRs. In the contribution, we will show full detail of the excitation and characterization of TAMRs using both techniques, as well as some sensing applications.

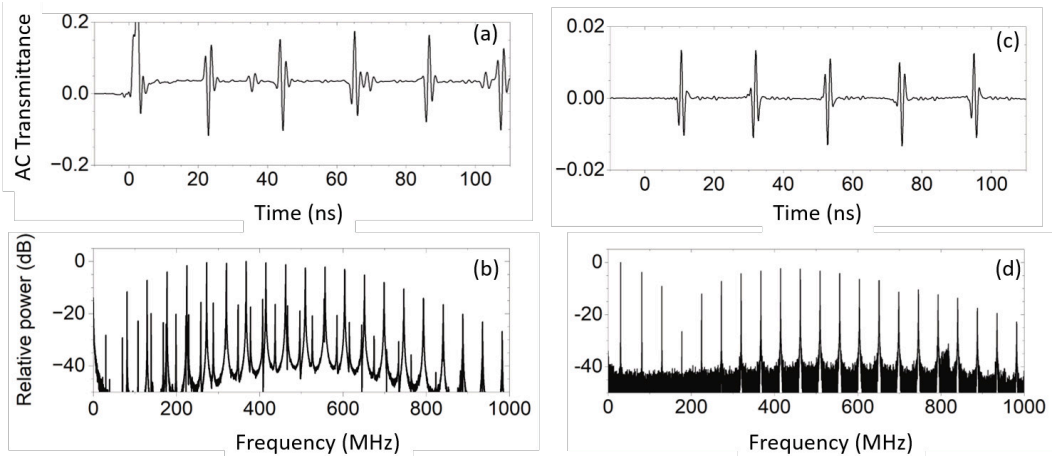

Figure 1. Results obtained by probing the TAMRs with the assistance of an LPG, (a)-(b), and with WGMs (c)-(d).

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References:

[1] A. Zadok *et al.*, Forward Brillouin scattering in standard optical fibers: single-mode, polarization-maintaining, and multi-core, Springer, 2022.
[2] L. A. Sánchez *et al.*, "High accuracy measurement of Poisson's ratio of optical fibers and its temperature dependence using forward-stimulated Brillouin scattering," Opt. Express 30, pp. 42-52, 2022.

Electrically pumped flipped-cavity nanoLEDs on InP membrane platform

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ABSTRACT

Room-temperature operation of the nanoscale electrically pumped light-emitting diodes (LEDs) is limited by the high series resistance and optical losses inherent to the small cavities. Despite that, practical demonstration of such devices is desirable for many applications due to their potential low-power high-speed operation, and small footprint [1]. In this work, the optical performance of a flipped-cavity metal-dielectric LED with sub-micron scale (~350 nm x 600 nm) is discussed. The measured nanoLED devices were fabricated on InP membrane on Si (IMOS) platform with double-side processing [2]. Direct optical characterization of the electrically pumped metal nanocavities was done with lensed fiber via an optical window. The results are compared with the Finite-Difference Time Domain (FDTD) simulation of the ideal device (Figure 1 Left).

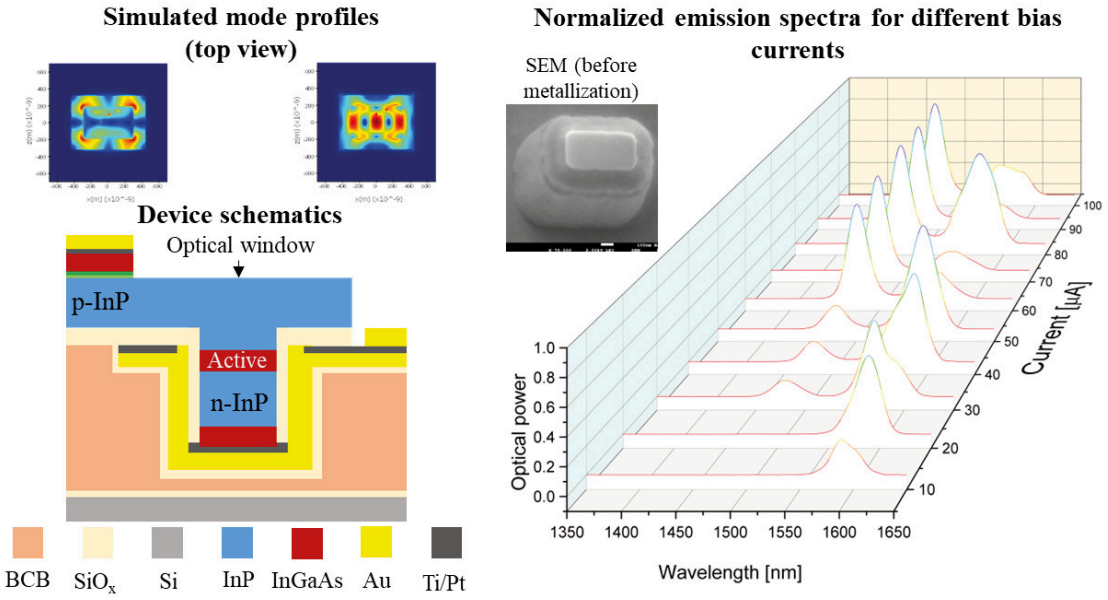

Figure 1. Left – Simulated electric field profiles and cross-section schematics of electrically pumped flipped-cavity nanoLED on IMOS platform; Right – Measured room-temperature spectra and SEM photo of the fabricated device.

The fabricated device shows a two-mode emission behaviour in the range between 4 and 44 kA/cm^2 of applied forward bias (Figure 1 Right). In this work, we discuss the impact of fabrication and current-induced changes (such as Joule heating and refractive index change) on the optoelectronic performance of nanoLED devices.

Acknowledgments: This project has received funding support from the European Commission, project ChipAI, with Grant 828841-ChipAI-H2020-FETOPEN-2018-2020, and Zwaartekracht Grant 'Research Center for Integrated Nanophotonics'. The authors would like to acknowledge Stuart Edwards for facilitating the supply of semiconductor wafers.

References:

[1] A. N. Chi-Yu, et al, "Theory of high-speed nanolasers and nanoLEDs", Opt. Express 20, pp. 450-470, 2012.
[2] E. D. Malysheva et al, "Towards spiking laser diodes on a III-V/Si nanophotonic platform for neuromorphic applications" in Abstract book of the 5th International Conference on Applications of Optics and Photonics, AOP2022 Guimarães, Portugal, July 18-22, 2022, p. 176

D-Shaped Photonic Crystal Fiber SPR Sensor for Oil Humidity Monitoring

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ABSTRACT

This theoretical study presents a D-shaped photonic crystal fiber (PCF) surface plasmon resonance (SPR) based sensor designed for humidity detection in transformer oil. This sensor leverages the unique properties of the coupling between surface plasmons and fiber guided mode at the Au-PCF interface to enhance the sensitivity to humidity changes in the external environment. The research demonstrated the sensor's efficacy in monitoring humidity levels ranging from 0% to 100% with average sensitivity measuring 1106.1 nm/RIU. This high sensitivity indicates a substantial shift in the resonance wavelength corresponding to minor changes in the refractive index caused by varying humidity levels, which is critically important in the context of transformer maintenance and safety. Transformer oil serves as both an insulator and a coolant, and its humidity level is a crucial parameter influencing the performance and longevity of transformers. Excessive humidity can lead to insulation failure and reduced efficiency and, therefore, the ability to accurately detect and monitor humidity levels in transformer oil can significantly enhance preventive maintenance strategies, reduce downtime, and prevent potential failures, ensuring the reliable operation of electrical power systems.

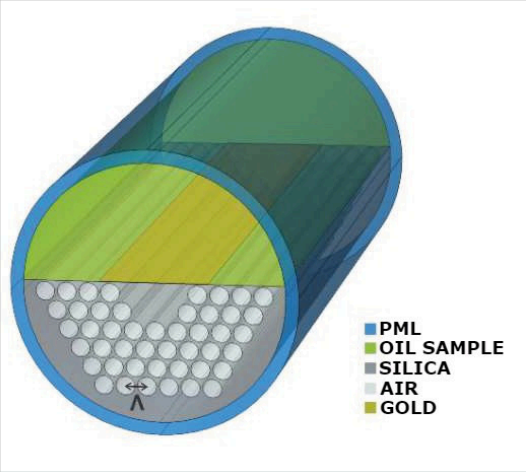

Figure 1. Schematic of the D-shaped PCF for oil monitoring.

Does Size Matter? Assessing Size-Dependent Performance of Gold Nanoparticles in Plasmonic Optical Fiber Sensors

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ABSTRACT

Since its revolution in the 70s, continuous research on Optical Fibers (OFs) has expanded their range of applications. Currently, one of its noteworthy uses lies on plasmonic based detection, where these filaments serve as miniaturized alternatives to bulky planar systems, offering cost-effectiveness, portability, capability for real-time remote operation and potential for *in vivo* measurements [1]. Gold nano-films and -particles (AuNPs) possess unique features such as biocompatibility, ease of production and biofunctionalization, and remarkable optical properties, making them ideal for developing highly sensitive plasmonic biosensors. The localized surface plasmon resonance (LSPR), characteristic of the AuNPs as transducers, exhibit higher sensitivity to the surrounding medium's refractive index (RI), compared to the thin films. The sensitivity of the OFs modified with AuNPs will be impacted by their diameter, morphology and density on the surface [2]. Therefore, developing high performance and reproducible OF-LSPR sensors is a major challenge.
The present work aims to optimize OF-LSPR probes coated with gold nanospheroids (AuNSs) varying in diameter: 20, 40 and 80 nm. For this purpose, silica OFs (600 µm core diameter) with an unclad tip configuration were manufactured. After hydroxylating the OF-tips, a silver mirror was synthesized on the extremity, followed by the silanization using (3-aminopropyl)triethoxysilane (APTES). Lastly, the AuNPs were immobilized on the surface by immersing the OF-tips in the respective colloids. Three OF-tips were modified with AuNPs of each diameter (n=9). RI sensitivity was evaluated resorting to glucose solutions with increasing concentrations, being all the OF-tips characterized 3 times. Additionally, scanning electron microscopy (SEM) was used to evaluate the NPs density and distribution onto the OFs surface.
The sensitivities of the 40 nm diameter AuNSs coated OFs displayed a linear behavior, each attaining the sensitivities of 0,66±0,11 AU/RIU (absorbance arbitrary units per refractive index units), 0,41±0,03 AU/RIU, and 0,21±0,02 AU/RIU. Moreover, the results revealed high repeatability ($\overline{CV}$ =15,6%), between assays, but low reproducibility (coefficient of variation (*CV*)=27,0%) between OFs. Similarly, the same methodologic studywas performed for the AuNSs with mean diameters of 20 and 80 nm.
These preliminary results not only evaluate the size-dependent performance of AuNSs, which is crucial for optimizing the performance ofthe biosensor, but also demonstrate the feasibility of this advanced approach that integrates the advantages of LSPR phenomena with the practicality of optical fiber-based biosensors for molecular sensing.

Keywords: optical fibers, refractive index, gold nanoparticles, LSPR, biosensing

Acknowledgements: The present study was supported by project i3N (UIDB/50025/2020, UIDP/50025/2020 and LA/P/0037/2020) funded by national funds through the FCT and MEC of Portugal. Cátia Leitão thanks the CEEC contract (2020.00154.CEECIND/CP1589/CT0019, https://doi.org/10.54499/2020.00154.CEECIND/CP1589/CT0019), funded by national funds through the FCT.

References:

[1] C. Caucheteur, T. Guo, and J. Albert, "Review of plasmonic fiber optic biochemical sensors: Improving the limit of detection," Analytical and bioanalytical chemistry, vol. 407, pp. 3883–3897, 2015. doi:10.1007/s00216-014-8411-6.
[2] V. Rivera, F. Ferri, and E Marega Jr, "Localized surface plasmon resonances: Noble metal with rare-earth ions," Plasmonics-Principles and Applications, vol. 1, no. 11, pp. 283–312, 2012. doi: https://doi.org/10.5772/50753.

Strategic Investigations for Soil Analysis and Monitoring Using Laser-Induced Breakdown Spectroscopy (LIBS)

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ABSTRACT

Improvements in soil and environmental quality, as well as the problem of global pollution, have become more difficult in recent years. Environmental monitoring is essential for an accurate and timely evaluation of the present situation. Studying the services offered by other sustainable ecosystems and the condition of the soil is also essential for understanding the relationship between terrestrial and marine settings.

Laser-induced breakdown spectroscopy (LIBS) is a well-known analytical technique that has an opportunity to be one of the potential technologies in the field of environmental analysis and biodiversity studies due to its numerous advantages, including the quick, real-time, in-situ, and simultaneous detection of multiple elements with minimal sample preparation.

As an important aspect of environmental management and protection, the research being presented develops the LIBS structural design, system architecture, and methodology for the rapid characterization of samples and their precipitates. In particular, the methodology focuses on the periodic monitoring of soil quality, which is vital, and on the qualitative and quantitative assessment of soil contamination, which is particularly significant.

The LIBS analytical data was utilized to qualitatively determine the constituents in the soils impacted by the fertilizers being studied, as shown in Figure 1(a). Therefore, extended field studies can offer an in-depth understanding of how effectively phosphorus (P) is monitored and controlled. The availability, qualitative, and semi-quantitative determination of P in soil as influenced by organic and inorganic fertilizers (no P, triple-superphosphate (TSP), compost, and compost+TSP) have been extensively investigated using the LIBS technique on a variety of soil samples established in Northern Germany, as illustrated in Figure 1(b).

Additionally, The proposed project can provide opportunities for sustainable development through the EU-CONEXUS network extension and related multidisciplinary joint research activities between the active universities and research centers by using an adaptable LIBS mode to measure the element concentrations in selected samples.

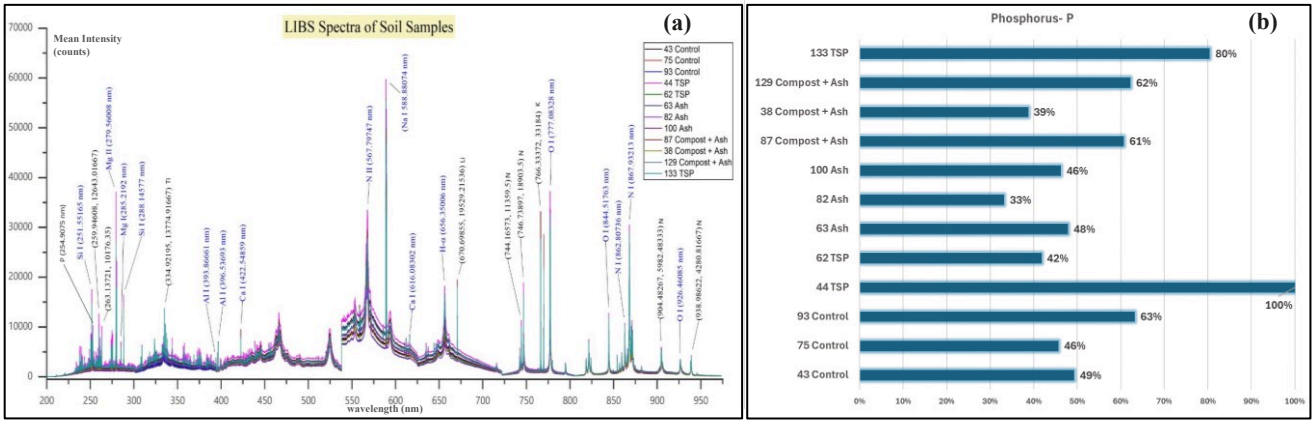

Figure 1. (a) LIBS spectrum for twelve of the investigated soil samples, (b) qualitative determination of P in targeted soil samples.

Keywords: laser-induced breakdown spectroscopy (LIBS), elements identification in soil, qualitative analysis.

References:

[1] Haider Al-Juboori, &T. McCormack. "Digital nanosecond imaging architecture & analytical tracking technique of colliding laser-produced plasma" Optic. & Quantum Electronics 54, 5 (2022):321. DOI:10.1007/s11082-022-03734-4.

Detection of Contaminants in Wood Waste Using Hyperspectral Imaging, X-Ray Fluorescence and Laser-Induced Breakdown Spectroscopy

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ABSTRACT

The use of recycled wastes in the wood industry for Particleboard and MDF production can significantly reduce the demand for virgin wood, minimize deforestation and play a crucial role for sustainable waste management. However, ensuring the safety and quality of recycled wood used for this end avoids environmental and health risks. Traditional methods for contaminant analysis are often time-consuming and lack precision. Spectroscopy techniques, such as Laser-Induced Breakdown Spectroscopy (LIBS) and X-Ray Fluorescence (XRF), are well-established methods that can enhance contaminant detection and Hyperspectral Imaging (HSI) has also gained significant attention in recent years. LIBS becomes a real-time technique that can quickly identify elemental composition with little to no sample preparation, making it perfect for field use[1]. Although usually limited to laboratory environments, XRF offers qualitative and quantitative elemental analysis[2]. HSI offers spatially resolved spectral information, enabling the identification of contaminants based on their unique spectral signatures[3]. For an industrial environment, the speed and the possibility of online implementation are crucial for the efficiency of the process.
Through a comparative analysis, this study highlights the strengths and limitations of each technique concerning hazardous detection in wood wastes. By comprehending these characteristics, it is possible to make informed decisions and select the best approach for the wood waste analysis.

Acknowledgments:
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References:
[1] Cremers, David A.; Radziemski, Leon J. Handbook of laser-induced breakdown spectroscopy. John Wiley & Sons, 2013.
[2] Roberts, Jessica, et al. A short update on the advantages, applications and limitations of hyperspectral and chemical imaging in food authentication. Applied Sciences, 2018, 8.4: 505.
[3] Beckhoff, Burkhard, et al. (ed.). Handbook of practical X-ray fluorescence analysis. Springer Science & Business Media, 2007.

Unlocking The Value Of Li Deposits Using Spectroscopic Techniques: Overview And Future Directions

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ABSTRACT

With the fast-paced continuous demand for lithium (Li) in the energy storage industry, spectroscopic techniques have emerged as indispensable tools in the modern Li exploration toolkit.
This work presents an overview of how we have been using spectroscopic techniques, including Laser-Induced Breakdown Spectroscopy (LIBS), X-ray Fluorescence (XRF), Raman Spectroscopy, and Hyperspectral Imaging (HSI), to improve identification and characterization of Li minerals. Case studies demonstrate how LIBS enables elemental mapping analysis with direct measurement of Li [1], while XRF provides hints on Li pathfinder elements that share similar geochemical behaviours [2]. Raman spectroscopy offers insights into the mineral structures, and hyperspectral imaging facilitates large-scale mapping.
Furthermore, we address the development of several machine learning and data fusion algorithms that will lead to a multi-modal approach for Li exploration [3]. This also includes a revolutionary new patented approach, knowledge distillation, where knowledge is transferred from a more complex to a simpler technique [4].
We also address future directions, emphasizing the use of digital twins and augmented reality to enable even more informed and efficient decision-making regarding resource extraction and processing.

Figure 1. Augmented reality for Li-bearing minerals

References:

[1] D. Capela, et al., "Robust and interpretable mineral identification using laser-induced breakdown spectroscopy mapping", Spectrochimica Acta Part B: Atomic Spectroscopy. 206, 106733, August 2023.
[2] R. Ribeiro, et al., "X-ray fluorescence and laser-induced breakdown spectroscopy analysis of Li-rich minerals in veins from Argemela Tin Mine, central Portugal". *Minerals*, *11*(11), 1169, October 2021.
[3] T. Lopes, et. al., "Multimodal approach to mineral identification: merging Laser-induced breakdown spectroscopy with Hyperspectral imaging". Journal of Physics: Conference Series, Vol. 2407, No. 1, pp. 012053, December 2022.
[4] T. Lopes, et. al., "From sensor fusion to knowledge distillation in collaborative LIBS and hyperspectral imaging for mineral identification". Scientific Reports, 14(1), 9123, April 2024.

WDM C-Band Four channel Using Cascaded Multimode Interference on SiN Strip Waveguide Structure

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ABSTRACT

Back Reflection losses are a significant issue that constrains the effectiveness of optical communication systems utilizing wavelength division multiplexing (WDM) technology with silicon (Si) Multimode Interference (MMI) waveguides [1-2]. To address this challenge, we introduce an innovative design for a 1×4 optical demultiplexer employing MMI within a silicon-nitride (SiN) buried waveguide configuration as shown in figure 1(b), optimized for operation within the C-band spectrum. Through simulations, we demonstrate that this proposed device facilitates the transmission of 4-channels spaced by 10 nm within the C-band, with a minimal power loss range of 1.96-2.36 dB, a broad bandwidth spanning 7.68-8.08 nm, and favourable crosstalk levels of 20.8-23.8 dB. Leveraging the low refractive index of SiN, we achieve a remarkably low back reflection of 41 dB, obviating the need for specialized angled MMI designs typically necessary in Si MMI technology. Consequently, this SiN demultiplexer MMI technology stands poised for integration within WDM frameworks, offering high data rates alongside minimal back reflection in optical communication systems. Figure 1(a) shows the transmission function of the four channels with large bandwidth ranging between 7.58-8.18 nm over the C-band range.

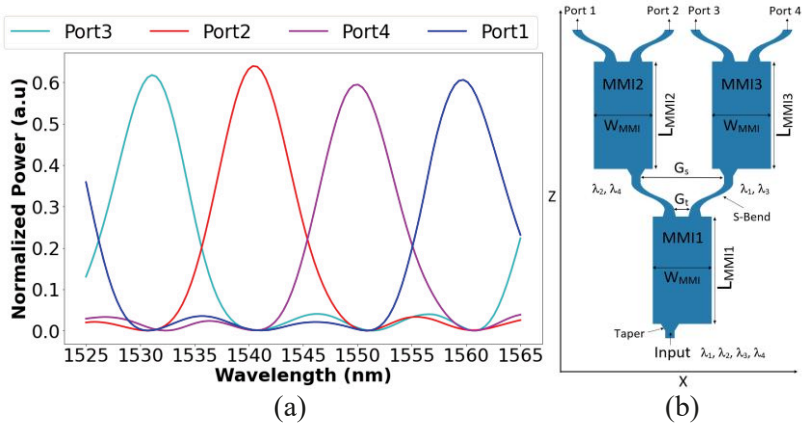

Figure 1. 1x4 wavelength demultiplexer. (a). C-band spectrum (b) Illustration in the x-z plane.

Results have shown the optimized parameters that should be used to divide four wavelengths of the MMI coupler using SiN buried waveguide. The wavelengths are 1530 nm, 1540 nm, 1550 nm, and 1560 nm. These results suggest that such a device could be useful in long-distance optical communication networks that use WDM technology in the C-band spectrum. Moreover, it is shown that the proposed device has a low back reflection loss ranging between 40-41 dB without using a special angled MMI design, and this is because of the use of SiN as the core material. The results show the promising potential for such a device to be implemented in WDM technology communications systems to increase the data bitrate.

Keywords: BPM; FDTD; MMI; WDM; Buried Waveguide; SiN.

References:

[1] Eyal Samoi, Yosef Benezra, Dror Malka, an ultracompact 3×1 MMI power-combiner based on Si slot-waveguide structures, Photonics and Nanostructures - Fundamentals and Applications, Volume 39, 2020, 100780, ISSN 1569-4410.
[2]Ioudashkin, Eduard, and Dror Malka. 2020. "A Three Demultiplexer C-Band Using Angled Multimode Interference in GaN–SiO2 Slot Waveguide Structures" Nanomaterials 10, no. 12: 2338.

Efficient generation of two coherent spectral lines using two mutually Injection locked DFB lasers

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ABSTRACT

Microwave photonics (MP) intertwines radio-frequency technology with photonics to generate and process RF signals in the optical domain. This field takes advantage of the fact that converting RF signals into the optical domain reduces the wavelength by three orders of magnitude, thereby enabling a decrease in the size, weight, and power consumption (SWaP) [1]. In such a context, perhaps the most important basic functionality that a MP circuit may provide is an RF signal generator [2]. In fact, there are many different techniques for building such a circuit.
Generating a single tone RF signal can be accomplished by beating two laser lines in a photodiode. However, beating two incoherent spectral lines generates an RF signal with unsteady RF frequency and strong phase noise. External modulation [3] enables producing two mutually coherent spectral lines, reducing phase noise. However, the power of the generated spectral lines is low due to insertion loss and low modulation efficiency. As a result, optical frequency combs [4] and mode locking lasers [5] have been proposed since they are able to generate several spectral lines with high modulation efficiency. However, these methods are power-inefficient whereas only two spectral lines are selected through optical filtering, resulting in a significant amount of energy being wasted on unused lines. Optical injection locking can be combined with external modulation to overcome its aforementioned shortcomings [3]. However, OIL requires optical isolation of the master laser, which cannot be achieved at least directly in photonic integrated circuits (PICs). In short, a method to efficiently generate two and only two coherent spectral lines with high power efficiency is still missing.
This work proposes a new energy-efficient methodology for the generation of two mutually coherent spectral lines, which combines mutual optical injection locking (MOIL) with external modulation produced by an electro-absorption modulator (EAM). The proposed concept is presented in Figure 1.

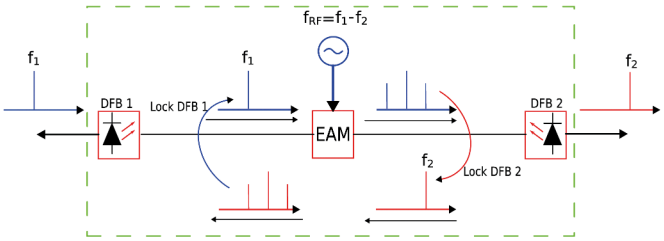

Figure 1. Proposed 2-tone generator.

Given that the RF frequency is identical to the frequency spacing between distributed feedback (DFB) lasers, i.e., $f_{RF} = f_1 - f_2$, DFB1 and DFB2 can be mutually optical injection locked through the generated RF sidetones. The main advantage of the proposed approach is that it does not require optical isolators, thus being implementable in a PIC. In this paper, we investigate the viability of the proposed concept using analytical and numerical assessment.

References:

[1] Marpaung, D., Roeloffzen, C., Heideman, R., Leinse, A., Sales, S., & Capmany, J. (2013). Integrated microwave photonics. Laser & Photonics Reviews, 7(4), 506-538.
[2] Seeds, A. J., & Williams, K. J. (2006). Microwave photonics. Journal of lightwave technology, 24(12), 4628-4641.
[3] Yao, J. (2009). Microwave photonics. Journal of lightwave technology, 27(3), 314-335.
[4] Wang, W. T., Liu, J. G., Sun, W. H., Chen, W., & Zhu, N. H. (2015). Multi-band local microwave signal generation based on an optical frequency comb generator. Optics Communications, 338, 90-94.
[5] Carpintero, G., Guzmán, R. C., Gordón, C., Kervella, G., Chitoui, M., & Van Dijk, F. (2015). Photonic integrated circuits for radio-frequency signal generation. Journal of Lightwave Technology, 34(2), 508-515.

Electrically Tunable Free Space Lithium Niobate Optical Filters

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ABSTRACT

The electro-optic and non-linear optical properties of Lithium Niobate (LN) have been well-known for decades. It has been widely used in applications such as waveguides [1], and modulators [2], however hardly in free space configuration. We present a LN-based optical filter. A 700nm thick LN film sandwiched between two highly reflective distributed bragg mirrors forms a Fabry- Pérot resonator with an electrically tunable cavity. The filter offers a stop band with a width of 400 nm while it becomes transmittive at the resonance frequency. The initial result in Figure 1.a shows the transmission notch measured with a reflectometer.
Applying an electrical field through planar electrodes and targeting the highest electro-optical coefficient of LN (r_{33}=30 pm/V), alter the optical length of the cavity and thus the notch wavelength. Figure 1.b indicates the simulation result with only ±1% optical path length difference. Experimental confirmation is in progress.

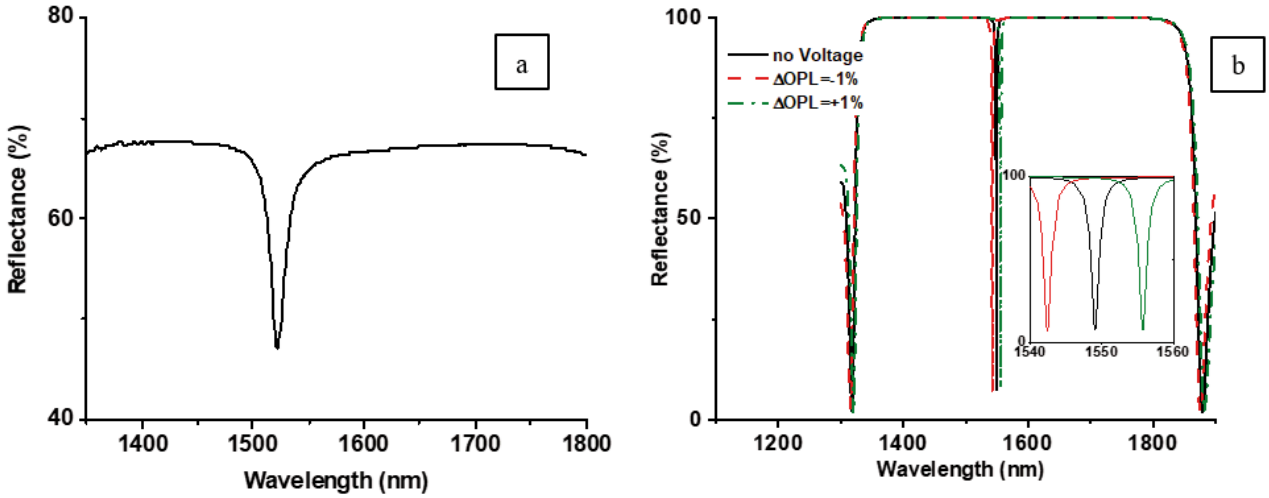

Figure 1. a) Notch filter at 1522 nm. b) Tunability of notch wavelength with the change of optical path length (OPL)-inset is a closer look at the notch wavelength

Fabrication process, optical characterization setup, and experimental results will be discussed with details in the main paper.

References:

[1] R. Schmidt and I. Kaminow, "Metal-diffused optical waveguides in $LiNbO_3$," Appl. Phys. Lett. 25(8), 458–460 (1974)
[2] A. Rao et al., "Heterogeneous microring and Mach-Zehnder modulators based on lithium niobate and chalcogenide glasses on silicon," Opt. Express 23(17), 22746–22752 (2015)

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Impact of Fast Power Fluctuations Caused by Atmospheric Turbulence On Polarization Measurements

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ABSTRACT

Continuous state of polarization (SOP) monitoring is essential for the correct implementation of quantum key distribution (QKD). In fiber-based polarization-encoded QKD systems significant SOP changes are mainly associated to environmental disturbances. During normal transmission the SOP variations over time are slow, being easily tracked with commercial polarimeters [1]. However, in free-space optics (FSO) links, effects such as atmospheric loss induced by turbulence, lead to rapid power fluctuations in the optical signal [2]. When using traditional SOP measurement techniques, intensity fluctuations can lead to errors in the SOP estimation.
One common method used by polarimeters to estimate the SOP is the rotating waveplate technique. Such device usually consists of a quarter waveplate (QWP), a linear polarizer (LP), and a photodetector. This method involves taking multiple intensity measurements while the QWP is rotated [3]. Then a truncated Fourier series can be used to derive the Stokes parameters [3]. However, typical rotation speeds of such waveplates are in the order of milliseconds, while the coherence time of intensity fluctuations in FSO channels is sub-millisecond [2], leading to potential errors in the SOP estimation. In this work, we carry out a simulation to assess the impact of such fluctuations on a polarimeter SOP estimation performing N intensity measurements. In that sense, we used experimental optical power measurements (see Fig. 1 a)), obtained during the transmission of an optical signal through an FSO channel with temperature-induced turbulence. We described the polarimeter transformation as a system of Mueller matrices, such that $S_{\text{out}} = M_{\text{LP}} M_{\text{QWP}}(\theta) S_{\text{in}}$, where S_{out} and S_{in} are the output and input signal Stokes vectors, and $M_{\text{QWP}}(\theta)$ and M_{LP} the Mueller matrices of the QWP and LP, respectively, with θ being the rotation angle of the QWP. This enables us to determine the intensity variation induced by the polarimeter components. Then, by summing the intensity fluctuation caused by the atmospheric turbulence we estimate its influence on the SOP measurement. For this simulation we considered a time of 10^{-3}s between intensity measurements of the polarimeter, and an input SOP defined by $\mathrm{S_{in}} = 1/\sqrt{2}[0, -1, 1]$. As shown in Fig. 1 b) and c), a low value of N induces high errors in the measurement during strong atmospheric turbulence. However, as N increases, the measurement error decreases, approaching levels seen in non-turbulent scenarios.

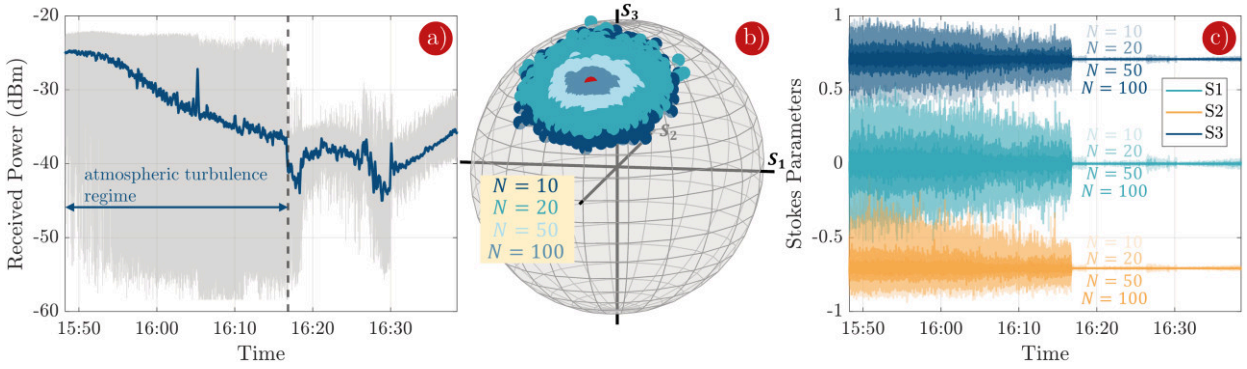

Figure 1. a) Optical power received during the transmission of an optical signal through a turbulent FSO channel; Stokes parameters for $N = 10, 20, 50$ and 100; b) represented on the Poincaré sphere; c) represented as a function of time.

Acknowledgements: This work was supported by the EU QuantERA program (GA 101017733), through the project QuantaGenomics, with national funding from FCT (QuantERA/0001/2021), by FEDER, through the COMPETE 2020, under the project QuantumPrime, (ref. PTDC/EEI-TEL/8017/2020) and by FCT/MCTES, through the project OptWire (PTDC/EEI-TEL/2697/2021). S. T. Mantey's and G. M. Fernandes's works were supported by FCT under Ph.D. Grant 2021.06085.BD, and under CEEC 2022.07168.CEECIND, respectively.

References:

[1] S. Mantey, et al, "AI-assisted polarization basis alignment for quantum key distribution system receivers," In proceedings of *2023 23rd International Conference on Transparent Optical Networks (ICTON)* conference, IEEE, 2023.

[2] F. Guiomar, et al, "Coherent free-space optical communications: opportunities and challenges," J. Light. Technol., vol. 40, no. 10, 2022.

[3] B. Schaefer, et al, "Measuring the Stokes polarization parameters," Am. J. Phys., vol. 75, no. 2, 2007.

Link Analysis for Satellite-Based Quantum Key Distribution

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ABSTRACT

Quantum Key Distribution (QKD) provides an information-theoretically safe solution to the key exchange in cryptographic protocols. Despite recent advances, scientific research is currently working towards the development of a global QKD network. As of now, fiber based QKD systems are well developed and documented, but are limited to a few hundred kilometers range, due to the exponential increase in attenuation with distance [1]. A solution for a global scale QKD implementation is the use of satellite nodes as part of its network, allowing for the establishment of long-range communication between parties. However, to achieve that goal, a detailed analysis of free-space quantum channels is necessary with a particular focus on the theoretical analysis for such long links and its security assessment. This requires a comprehensive understanding of the optical and turbulence effects that impact the signal's propagation through the atmosphere [2]. Such effects include geometric losses, atmospheric absorption and scattering, turbulence, tracking difficulties, and background noise due to the sun light [3].
In this work, we model a free space channel in an effort to summarize and characterize the contribution of these main propagation effects for further analysis on their security implications and QKD link performance, as well as to provide the basis for an optimization system of the experimental setup based on the available link margin. Figure 1 shows that employing a larger receiver telescope diameter, D_r, decreases the signal loss. It is also notable that a downlink suffers from less attenuation than an uplink, due to the higher turbulence effect experienced by the beam throughout the initial propagation of the signal in an uplink. For an elevation angle of 80º, the attenuation for the uplink is 26 dB higher than for the downlink. The total attenuation of the link increases as the elevation angle decreases and the satellite lowers into the horizon.

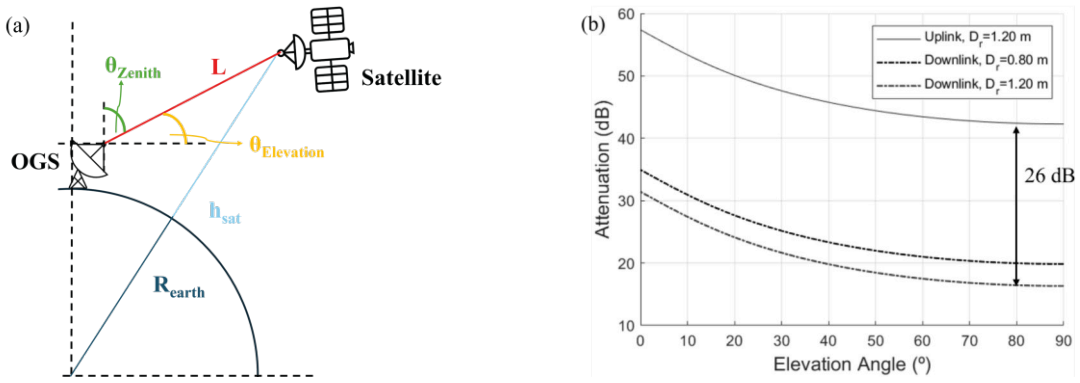

Figure 1. (a) Schematic diagram of ground-to-satellite link. (b) Total attenuation as a function of the elevation angle for uplink and downlink considering receiver telescope diameters of 0.80 m and 1.20 m.

Keywords: quantum key distribution, free-space, turbulence, link budget, secret key rate.

Acknowledgements: This work was supported by the EU DIGITAL-2021-QCI-01 Programme, through the project PTQCI (GA 101091730), and by the European Defence Industrial Development Program (EDIP), under the project DISCRETION (S12.858093).

References:

[1] L. de Forges de Parny et al., "Satellite-based quantum information networks: use cases, architecture, and roadmap," Commun Phys, vol. 6, no. 1, p. 12, Jan. 2023.
[2] D. Vasylyev et al., "Free-space quantum links under diverse weather conditions," Phys Rev A, vol. 96, no. 4, p. 43856, Oct. 2017.
[3] D. Vasylyev, W. Vogel, and F. Moll, "Satellite-mediated quantum atmospheric links," Phys Rev A, vol. 99, no. 5, p. 53830, May 2019.

Penrose Scattering in Quantum Vacuum

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ABSTRACT

We consider scattering of a probe laser pulse by an intense light spring in a QED vacuum [1]. This scattering configuration can be seen as the vacuum equivalent of Penrose superradiance, a process originally associated with the scattering of light by a rotating black hole.

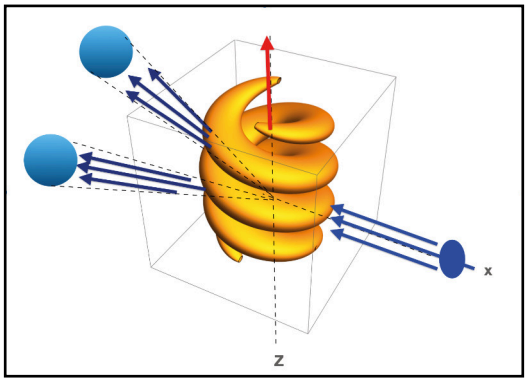

Figure 1. Caption goes here in 10 point font.

The rotating object here is an intense laser beam containing two different components of orbital angular momentum. Due to these two components having slightly different frequencies, the energy profile of the intense laser beam rotates with an angular velocity that depends on the frequency difference. The nonlinear properties of a quantum vacuum are described by a first-order Euler–Heisenberg Lagrangian [2]. In this configuration, the nonlinear photon–photon coupling leads to scattered radiation, showing frequency shift and angular dispersion. These two properties could eventually be favourable for observations in Petawatt laser experiments. In principle, this scattering configuration can also be reproduced in a nonlinear optical medium.

Keywords: nonlinear optics, quantum vacuum, Petawatt lasers, photon-photon scattering

References:

[1] J.T. Mendonça, “Penrose Scattering in Quantum Vacuum," Photonics, 11, 448 (2024).
[3] J.T. Mendonça, The Quantum Nature of Light: From Photon States to Quantum Fluids of Light, Institute of Physics Publishing, Bristol (2022).

Searching for Bias in Commercial Quantum Random Number Generators

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ABSTRACT

Quantum Random Number Generators (QRNGs) yield information-theoretically secure entropy by exploring the probabilistic nature of quantum measurements [1]. They are particularly important for cryptographic applications, as QRNGs offer a natural solution to the shortcomings of pseudorandom generators, which have already been implicated in successful cryptanalytic attacks [2]. In recent years, several commercial implementations have become available, with the most advanced solutions guaranteeing generation rates up to 1 Gbps and compliance with the NIST SP800-90 standards [1]. However, so far, these devices have followed a device-dependent approach, which forces users to trust the certification process claimed by the manufacturer. In this work, we have comparatively assessed the output statistical quality of the ID Quantique's Quantis PCIe-40M and Quside's PCIe 100 QRNGs by submitting their entropy source (ESs) to the extensive test batteries from the Dieharder, NIST SP800-22, and Testu01 (including FIPS_140_2, pseudoDIEHARD, Alphabit, Rabbit, Small Crush, Crush, and Big Crush) libraries [3]. While all other tests considered a continuous binary stream, Quantis's Big Crush used a limited 261 GB dataset that was rewound as needed due to limited data availability. For the Quside scheme, we tested both the raw ES and its output after randomness extraction (RE). Meanwhile, only the raw Quantis ES was provided by the manufacturer. Its output after the embedded deterministic generator was here not considered to allow a fair comparison of the ESs. As seen in Table 1, we report significant biases in the raw output of both implementations. While all cases successfully passed the FIPS_140_2 and pseudoDIEHARD tests, the raw Quside conclusively failed all other evaluations. This highlights its unsuitability for cryptographic applications without a RE algorithm. Meanwhile, none of the applied batteries could detect biases in its postprocessed variant, far surpassing the results seen for the Quantis QRNG. Our work highlights problems with standard self-reported certifications, which frequently report only the NIST and Dieharder batteries that may not easily detect biases identified by more rigorous assessments. This is particularly insidious given that manufacturers often provide limited implementation details and repeatedly promote their raw ES generation rates without clearly disclosing their secure throughputs. That could be catastrophic when, such as in the case of Quantis, the raw ES evades the typical batteries but is nonetheless conclusively biased.

	NIST	DieHarder	Rabbit	Alphabit	Small Crush	Crush	Big Crush
Raw Quside	✗	✗	✗	✗	✗	✗	✗
Quside	✓	✓	✓	✓	✓	✓	✓
Quantis	✓	✓	✗	✗	✓	✗	✗

Table 1. Summary decision for each of the batteries applied to the QuSide (raw and postprocessed) and Quantis output. Significance levels are respectively set as 0.001, 0.01 and 1×10^{-6} for the TestU01, NIST, and Dieharder's batteries.

Acknowledgements: This work was supported by the EU QuantERA program (GA 101017733), through the project QuantaGenomics, with national funding from FCT (QuantERA/0001/2021), and by FEDER, through the COMPETE 2020, under the project QuantumPrime, (ref. PTDC/EEI-TEL/8017/2020). Maurício' work was supported by FCT under Ph.D. Grant 2022.09584.BD.

References:

[1] V. Mannalatha, S. Mishra, and A. Pathak, "A comprehensive review of quantum random number generators: concepts, classification and the origin of randomness," Quantum Inf Process, vol. 22, no. 12, p. 439, 2023.
[2] M. J. Ferreira, N. A. Silva, A. N. Pinto, and N. J. Muga, "Statistical Validation of a Physical Prime Random Number Generator Based on Quantum Noise," Applied Sciences, vol. 13, no. 23, 2023.
[3] D. Hurley-Smith and J. Hernandez-Castro, "Quantum Leap and Crash: Searching and Finding Bias in Quantum Random Number Generators," ACM Trans. Priv. Secur., vol. 23, no. 3, Jun. 2020.

CTS-ISEL: Photonics and Optoelectronic devices for Cyber-Physical-Systems at the ISEL pole of the Center of Technology and System.

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The Centre of Technology and Systems (CTS) at the Instituto Superior de Engenharia de Lisboa (ISEL) is dedicated to advancing theoretical and applied research while promoting technology transfer and active participation in national and international R&D projects. Housed within the ISEL campus, benefiting from several laboratory facilities, the CTS-ISEL research pole specializes in thin film semiconductor materials, devices and systems for photonic and optoelectronic applications in next-generation Cyber-Physical-Systems. CTS-ISEL's R&D efforts are centered in semiconductor, optoelectronics, and photonics laboratories, focusing on developing innovative solution for Photonic Integrated Circuits (PICs), sensor systems in biomedical applications, and Visible Light Communication (VLC) systems for both indoor and outdoor use.

Key competencies of CTS-ISEL include:

- Preparation of materials and devices, utilizing techniques such as Plasma-Enhanced Chemical Vapor Deposition (PECVD) and various deposition methods for metals and oxides.
- Characterization of materials and devices, encompassing a range of techniques from conductivity and spectral response measurements to AFM and SEM microscopy.
- Modelling and Simulation of optoelectronic properties and devices, including PICs and VLC systems, employing tools such as Synopsys, RSOFT packages, PC-Spice and SUMO simulator.
- Design and implementation of VLC Systems for data transmission, positioning, vehicular communication, and urban traffic monitoring..
- Reinforcement Learning, Modelling, and Optimization of VLC systems, particularly in the context of intelligent urban traffic monitoring.

In addition to fundamental research, CTS-ISEL has developed practical solutions such as the PIC4PhotoAKI plasmonic interferometer for AKI detection, the Biocolor setup for LSPR sensor readout, and the LUMINA approach for portable Raman urine analysis. Furthermore, CTS-ISEL has contributed to adaptive traffic control strategies and indoor positioning and guidance systems using VLC technology.

Advanced Monitoring and Structural Integrity at INEGI

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ABSTRACT

INEGI's competencies and laboratory infrastructures related to the fields of Advanced Monitoring and Structural Integrity are particularly relevant in the evaluation of the structural behaviour of mechanical components, systems and structures, using numerical simulation tools for static, dynamic, fatigue and impact stresses and the competencies in the experimental validation of the behaviour of materials, components and structures. INEGI also works on the development of customized systems and solutions for monitoring and non-destructive inspection, with or without contact, both for the assessment of the structural condition and for predictive maintenance, competencies also relevant for the planned research work.
INEGI's team is composed of an interdisciplinary group of researchers with expertise in friction stir welding (FSW) processes, optics and laser metrology, experimental mechanics and multi-physics modelling, among others. It has the mission to contribute to the improvement of the reliability of mechanical systems, through focused R&D in applied mechanics.
INEGI has adequate technical resources and capabilities for mechanical characterization at quasi-static, medium and high strain-rate, within temperature-controlled environments at low to high temperatures, and under different, non-standard, loading conditions. INEGI also develops custom advanced monitoring and inspection solutions based on optical metrology and other non-destructive testing and inspection (NDT/NDI) technologies: Computer Vision, Fibre Optics e.g. Fiber Bragg Gratings, Distributed Fibre Optics; Electric Sensors, Laser Technologies (ESPI, Shearography), Non-Laser Technologies (Deflectometry, DIC), Thermography (Pulsed lock-in; TSA) and US-PAUT.

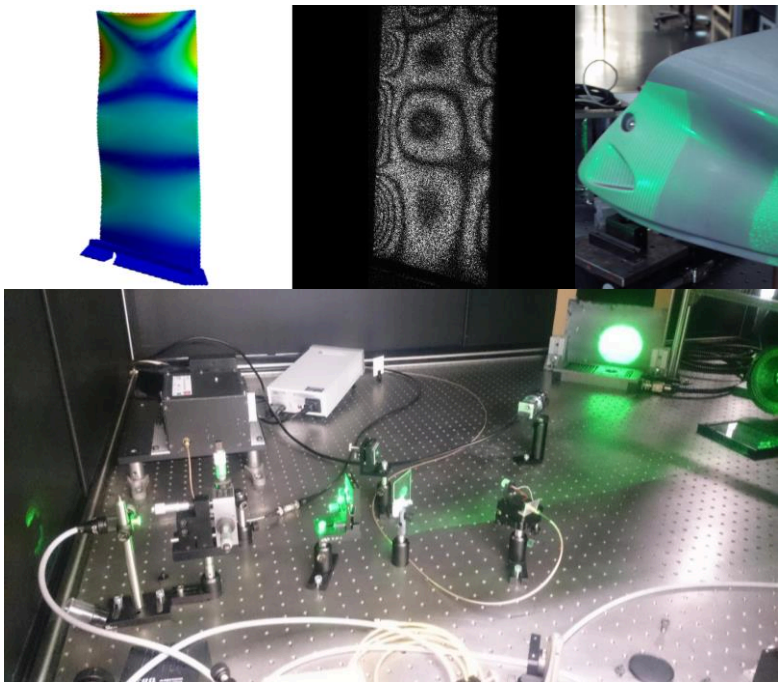

Figure 1. Optical metrology ay UMAI/INEGI

Optics and Lasers @ IBEB

João M. P. Coelho[1*], Tânia Ferreira-Gonçalves[1,2], Mariana Neves Amaral[1,2], Hugo A. Ferreira[1], Maria Manuela Gaspar[1,2], Catarina Pinto Reis[1,2]

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ABSTRACT

IBEB (*Instituto de Biofísica e Engenharia Biomédica*) is a research institute from *Faculdade de Ciências da Universidade de Lisboa*, that interfaces engineering with medicine and biophysics. Founded in 1992, it started researching into optics and lasers in 2009. Since then, two main areas emerged: the development of photothermal therapy for cancer, and the evaluation of the effects of laser dazzle. Regarding the first area, an irradiation procedure was tested considering a dedicated optical zoom system [1], besides using common direct irradiation. Currently, techniques capable of adapting to tumours' contours are being developed. Also, a proof of concept on feedback wavefront shaping was achieved by applying adequate algorithms for concentrating light inside the tissues. Implemented in transmission, it allowed to increase the beam's concentration inside a turbid media by 50% [2]. Experimental procedures were also implemented to support the development of metallic nanoparticles (NPs) capable of mediating the conversion of the energy from photons into heat. So far, the gold NPs showed to have a photothermal conversion efficiency up to 60% [3]. In addition, photoactivation of gold NPs has been tested on different types of superficial and localized cancers [4,5]. When using *in vitro* models, a reduction of more than 70% in cell viability was observed [3,5]. Regarding the 2nd main area, IBEB has participated in several study groups from NATO STO to evaluate the effects of laser dazzle. Within this topic, simulators have been developed [6] and the performance of subjects being dazzled whilst performing tasks requiring concentration, has been assessed using electroencephalography signals [7].

Keywords: IBEB; Biomedical Engineering; Phototherapy; Cancer; Laser dazzle.

Acknowledgements: The authors are thankful to *Fundação para a Ciência e a Tecnologia*, *I.P.* (FCT) for the financial support under project references UIDB/04138/2020, UIDP/04138/2020 and UIDB/00645/2020 (https://doi.org/10.54499/UIDB/00645/2020), the H2020 project ID 740736 "CAMELOT" (https://doi.org/10.3030/740736), and PhD fellowships SFRH/BD/147306/2019 and SFRH/BD/05377/2021 (https://doi.org/10.54499/2021.05377.BD). The authors also acknowledge the close collaboration with the Faculty of Pharmacy of *Universidade de Lisboa*, and *Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa*.

References:

[1] D. Garcia, J. M. P. Coelho, P. Vieira, "Optical design of a variable angle irradiation system for skin cancer laser phototherapy," EPJ Web Conf., vol. 238, 12010, 2020.
[2] J. Guerreiro, P. Vieira, J. M. P. Coelho, "Evaluation of Three Iterative Algorithms for Phase Modulation Regarding Their Application in Concentrating Light Inside Biological Tissues for Laser Induced Photothermal Therapy," Photonics, vol. 8, no. 9, 355, 2021.
[3] T. Ferreira-Gonçalves, D. Nunes, E. Fortunato, R. Martins, A. P. de Almeida, L. Carvalho, D. Ferreira, J. Catarino, P. Faísca, H. A. Ferreira, M. M. Gaspar, J. M. P. Coelho, C. P. Reis, "Rational approach to design gold nanoparticles for photothermal therapy: the effect of gold salt on physicochemical, optical and biological properties," Int. J. of Pharm., vol. 650, 123659, 2024.
[4] J. Lopes, T. Ferreira-Gonçalves, I. V. Figueiredo, C. M. P. Rodrigues, H. Ferreira, D. Ferreira, A. S. Viana, P. Faísca, M. M. Gaspar, J. M. P. Coelho, C. P. Reis, "Proof-of-Concept Study of Multifunctional Hybrid Nanoparticle System Combined with NIR Laser Irradiation for the Treatment of Melanoma," Biomolecules, vol. 11, no. 4, 511, 2021.
[5] M. Amaral, A. J. Charmier, R. A. Afonso, J. Catarino, P. Faísca, L. Carvalho, L. Ascensão, J. M. P. Coelho, M. Manuela Gaspar, C. Pinto Reis, "Gold-Based Nanoplataform for the Treatment of Anaplastic Thyroid Carcinoma: A Step Forward," Cancers, vol. 13, no. 6, 1242, 2021.
[6] J. M. P. Coelho, J. Freitas, C. A. Williamson, "Optical eye simulator for laser dazzle events," App. Optics, vol. 55, no. 9, 2240-2251, 2016.
[7] J. Santos, J. M. P. Coelho, P. Mendonça, H. A. Ferreira, "Assessment of light's dazzling effect on the EEG signal of subjects performing tasks that require concentration," in Proc. SPIE 11207, 4th International Conference on Applications of Optics and Photonics, 112072G (3 October 2019).

High peak and average power near and mid-IR lasers via ultrafast OPCPA

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ABSTRACT

The use of diode-pumped Yb-doped lasers as drivers of Optical Parametric Chirped Pulse Amplification (OPCPA) lasers has been identified as an approach that can support high average and peak power lasers [1]. The Laboratório de Lasers Intensos (L2I) is equipped with a 100 kHz, 1 ps, 1 mJ Amphos system, driving a 3.1 um OPCPA system from Fastlite delivering 60 µJ, 40 fs pulses, or an N2Photonics Multipass Cell (MPC) yielding 100 fs, 1030 nm 0.66 mJ pulses. Millijoule scaling of the mid-IR pulses [2] is currently underway, and a YCOB-based OPCPA [3] is being adapted with the MPC pulses as driver. These parameters rival the performance of several world-class facilities (see Fig 1), with the current mid-IR system being used to drive HHG in solids. The near-IR system has been used for fundamental physics, semiconductor defect production and localised annealing.

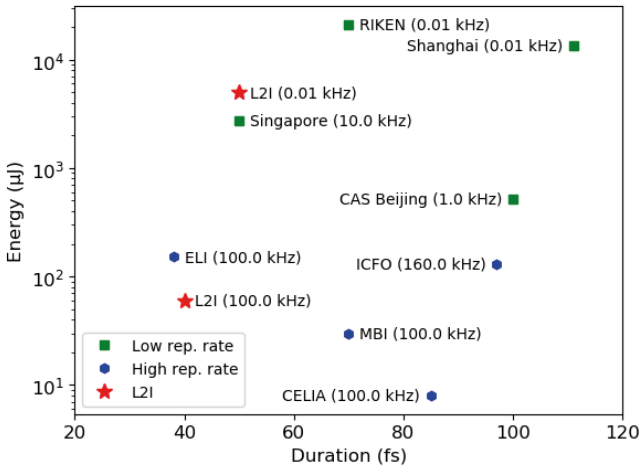

Figure 1. Positioning of L2I's current high repetition rate mid-IR laser system
(and low repetition rate system under development)

We present the current state of L2I and the near-term prospects for the OPCPA laser being developed, as well as ongoing collaborations and future directions for applications of the facility.

Keywords: ultrafast lasers, nonlinear optics, nonlinear amplification; ultrashort pulses; parametric amplification; high power laser

Acknowledgements: IPFN activities were supported by FCT - Fundação para a Ciência e Tecnologia, I.P. by project reference UIDB/50010/2020 and DOI identifier 10.54499/UIDB/50010/2020 (https://doi.org/10.54499/UIDB/50010/2020) and by project reference LA/P/0061/202 and DOI 10.54499/LA/P/0061/2020 (https://doi.org/10.54499/LA/P/0061/2020).

References:

[1] H. Fattahi et al. Third-generation femtosecond technology, Optica 1, 45-63 (2014).
[2] Alves, J. et al. Multi-mJ Scaling of 5-Optical Cycle, 3 µm OPCPA, Photonics 8, 503 (2021).
[3] Pires, H. et al. Ultrabroadband OPA in YCOB with a sub-ps pump source, Photonics 10, 253 (2023).

The Institute of Physics and Aerospace Sciences of the University the Vigo at Ourense (Spain)

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ABSTRACT

The creation of the Institute was approved at the end of 2022 by the University of Vigo. The institute, based in Ourense and with researchers at the Ourense and Vigo campuses, will be launched in early 2023. The aim of the institute is to develop its areas of work, integrating capacities to carry out cutting-edge scientific research, providing value to society, supporting the regional research and innovation strategy and structuring the transfer of the value developed in the academic institution to the industrial and business world.

Figure 1. Building of the Institute of Physics and Aerospace Sciences (IFCAE) at Ourense, Spain.

The mission of the Institute is to become and position itself as a research centre of excellence and sectorial R&D transfer of reference in the fields of physics, aerospace systems and other related disciplines, connected to the most relevant national and international networks. Th vision of IFCAE is to contribute to innovation in applied physics and in different aspects of the aerospace sector, promoting synergies between both fields through research excellence and an efficient transfer of research results in a responsible, recognised, multidisciplinary, competitive and committed way to promote the territorial, social and business development of the environment. One of the main axes is excellent and recognized research, developing multidisciplinary and competitive science of excellence, transferring value to the productive sector and promoting the professional career plan of the institute's researchers, attracting and retaining talent.

All the information about the institute and its activities can be found in its official website: https://ifcae.uvigo.es

An Easily Usable Device for Enhancing Geometrical Optics Instruction

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ABSTRACT

Geometrical optics is an experimental field closely related to human vision. Unfortunately, many textbooks fail to optimize their content to reflect these features and do not organize the principles logically or usefully. As a result, most students struggle to understand and remember how and why optical microscopes and telescopes function, even though the concepts are straightforward. Furthermore, when conducting experiments related to geometrical optics, students often cannot explain their observations based on textbook knowledge.
To address the shortcomings of textbooks and help students understand the basic principles of geometrical optics more easily, we first emphasize that an object in geometrical optics consists of numerous point sources of light. The human eye can perceive these point sources due to its design and function. When we see the point sources on an object, we see the object itself. Similarly, when we see point sources elsewhere, such as on a picture, screen, or created by a lens or mirror, we perceive an "object" composed of these visible point sources.
Second, concave mirrors and convex lenses can reflect or refract light from a point source towards a corresponding converging point in space. Engineers strive to perfect this function. These converging points are pivotal for reconstructing the point sources of an object. We can record these points using screens, film, or CCDs and then recreate the point sources of light based on these recorded points using various methods. Since light travels in straight lines, the converging points become new point sources of light in space, forming a real image that can be seen by the human eye.
Third, we conclude that a real image, like a real object, consists of numerous point sources of light and can be perceived directly by the human eye. However, each point source in a real image emits light within a constrained space defined by the size, shape, and potential obstructions of the lens or mirror, unlike the point sources of a real object, which emit light in all directions. These differences make real images appear intriguingly different from real objects in certain situations.
Based on these three key points, we can interpret and predict various phenomena in geometrical optics. For example, why can the Webb Space Telescope's primary mirror, made of 18 smaller concave mirrors, create a real image like a single large mirror? Why does a convex lens or concave mirror obstructed by objects create a real image with dark shadows? And why do these shadows disappear when viewed through an eyepiece, a short focal length convex lens? How and why do telescopes and optical microscopes work? In this speech, to promote our ideas for improving textbooks, we will utilize an innovative, portable device to conduct several key experiments exploring the mysteries of image formation, as well as how optical microscopes and telescopes function. Additionally, we will endeavor to illustrate new, concise, and more practical statements about the related field in geometrical optics.

Keywords: Real image, Concave mirror, Convex lens, Converging point, Point source of light.

Acknowledgements: We would like to thank the National Science and Technology Council for their financial support of Project No. 112-2410-H-238-001.

References:
[1] C. H. Chou, .Reflective telescopes: principles and geometric optics. Taipei, Taiwan (ROC): Straits Qianfeng Cultural Industry Co., Ltd., 2023.

Hands-on Optics: in and out

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ABSTRACT

Learning Optics by doing Optics is a challenge and a necessity, to bring this important field of Science and Engineering closer and more comprehensible, in particular to the students of our educational system and to Society in general. The hands-on component, which allows all the senses to be used to understand and establish relationships with the natural world, has long been recognised as a source of inspiration, motivation and learning [1]. This is why there are countless proven experiences of the benefits of the use and dissemination of active experiential learning in optics, thus having at our disposal a wide range of resources to be employed by teachers and students in an integrated way with the conceptual content to be taught inside and outside the classroom [2]. Well-structured experimental activities that can highlight, for example, the problems that gave rise to the knowledge, the employed methodology, past and recent advances and related technical applications, the influence of the content on the social and environmental level, the history of the content and the contribution of women to it. It is time for us to make use of the available information and to push, adapt, transform and modify the design and implementation of these powerful learning tools.

Figure 1. Hands-on Optics: in and out [4]

In this invited keynote lecture we will present our vision and experience, as well as an overview of available resources and suggestions for use. In particular, we will present some of our results of the use of these hands-on activities in formal (lecture experiences or interactive manipulative activities, mini-investigations in a project-based learning framework, interactive museums in schools, ...) and informal learning contexts (lectures, science week, citizen science, ...). Teaching contexts in the classroom and outside the classroom clearly related and to be related [3]. As happens, for example, in our masterclass conferences [4] with a very important hands-on component that link, in a transversal and interdisciplinary way, concepts of the secondary and high school curriculum (Light, Colour, Geometric Optics, Interference, Diffraction, Spectroscopy, Polarisation, ...) with everyday life and with our research in Applied Optics at the University of Vigo.

Keywords: Hands-on Optics, Optics Education, Outreach in Optics, Active Learning, Informal Learning

References:
[1] M.F. Costa and B.V. Dorrío, “Actividades manipulativas como herramienta didáctica en la educación científico-tecnológica”. Revista Eureka sobre enseñanza y divulgación de las Ciencias, vol. 7, no. 2, pp. 462-472, 2010.
[2] J. Blanco-García, and B.V. Dorrío, “Optics in engineering education: stimulating the interest of first-year students”, in Proc. SPIE 9289, 12th Education and Training in Optics and Photonics Conference, Porto-Portugal, July 2013, 92890Q.
[3] B. V. Dorrío and M. F. M. Costa, “Researchers promote science in school”, in Proceedings of the 9th International Conference on Hands-on Science, Antalya-Turkey, October 2012, pp 359-360.
[4] B. Vázquez Dorrío, "clickonphysics", Accessed: June 10, 2024. Available: https://www.clickonphysics.es/cms/en/charlas-2/

Art and Science at the formal and non-formal space

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ABSTRACT

Arte e Ciência is an extension project of the USP Physics Institute, whose main objective is to take the knowledge produced at the institution to the public, as a way of returning society's investment in Education. Held since 2006, this project involves the participation of undergraduate and postgraduate students interested in playful scientific dissemination. Contributing to the expansion of the population's scientific culture in an interactive way is also one of the purposes of the project, because when the public comes into contact with the experiments presented, they actively participate in the activities and take knowledge for themselves, making it part of their reality.

By taking knowledge to diverse spaces such as squares, schools or even parks, it aims to stimulate the interest of the general public, but especially young people and children, in science and technology. The project has around 70 experiments, involving physics, biology and mathematics. Scientific toy workshops are also proposed. To date, the project has attracted more than 100,000 visitors. The project's main activity is in public Basic Education schools and also at events at the University of São Paulo, such as Feira de Profissões and Semana Nacional de Ciência e Tecnologia.

This work will present the results of the activities carried out, as well as data regarding the public and their interaction with the experiments. Furthermore, during the presentation there will be a demonstration of experiments related to light and applications of optics in the contemporary world.

Optical Sensors for Resident Space Object Surveys

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ABSTRACT

Orbiting space objects have become in the last decade a major nuisance impacting orbiting space assets, from observatories to satellites and space stations. With the rise of the satellite population GEostationary Orbits (GEOs), space objects are becoming an even bigger threat and a strong problem to space observations. To tackle these threats several coordinated surveillance networks composed of dedicated sensors (telescopes, radars and laser ranging facilities) track and survey space objects, from debris to active satellites. As part of the Portuguese Ministry of Defense, Atlar is the company with a signed contract to control, operate and manage all the optical sensor network, consisting of a group of optical telescopes spread around Portugal, dedicated to the Space Situational Awareness (SSA) and Space Surveillance and Tracking (SST) domain. These optical systems will provide added value capabilities to the Portuguese SST network, complementing the optical telescopes of the EU-SST. These telescopes are optimized for GEO and MEO survey operations and besides the required SST operational capability, they will also provide an important development component to the Portuguese SST network.

Keywords: Space Debris, Automated telescopes, Optical observatories.

References:
[1] Bruno Coelho et al. New SST Optical Sensor of Pampilhosa da Serra: studies on image processing algorithms and multi-filter characterization of Space Debris. 2021. arXiv: 2107.02315 [astro-ph.IM].

Drone-suspended quantum gradiometer for detection of unexploded ordnance and geo-prospecting (QGrad)

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ABSTRACT

The QGrad project aims to develop quantum sensor technology for unshielded airborne use capable of detecting minute magnetic fields. The project focuses on optically pumped magnetometers, utilizing alkali vapour atoms and gradiometry to subtract signals from multiple magnetometers. This approach holds significance for uncovering hidden raw materials, pipelines, contaminated sites, foundations, and munitions, particularly addressing the challenge of locating land mines and explosive ordnance from past wars for safe clearance. Our collaboration includes academic partner Leibniz Institute of Photonic Technologies Jena, and industrial partners Asdro GmbH, Optikron GmbH, Supracon AG, and Toptica Photonics AG exploring the gradiometer scheme, developing necessary readout components, data processing capabilities and integration for flight use. In Europe, such quantum magnetometers are unavailable commercially, making QGrad a pioneering initiative. We report on the current status of the project and the gradiometer scheme in particular.

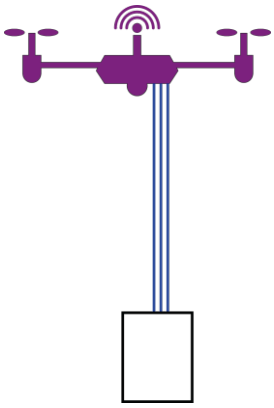

Figure 1. Drone-suspended gradiometer sketch

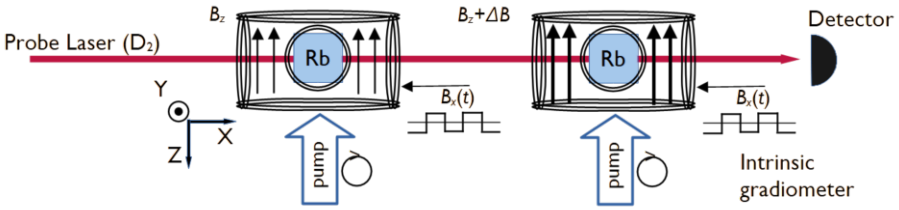

Figure 2. Optical magneto-gradiometer scheme

Keywords: magnetometry; optically pumped magnetometry (OPM); unmanned aerial vehicles (UAV); quantum sensing; alkali vapors

Some approaches for light and color on the surface of Mars

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ABSTRACT

Although D65 is the main CIE standard illuminant for colorimetric applications [1], it may be not a right choice to study colors of soils or objects on the surface of Mars. From COMIMART model [2] we have computed a set of 3139 total spectral irradiances on Mars surface, considering variations of two parameters: Zenith solar angle (range 0°-73°) and dust opacity (range 0.1-8.5). We found that these Mars lights had relatively low correlated color temperatures in the range 2100 K – 5900 K, and were mainly located below the Planckian locus, contrary to what happens on daylight in Earth (Fig. 1, left). Color fidelity indices [3] for Mars lights were higher than 93, but spectral irradiances on surfaces of Mars and Earth had obvious differences (Fig. 1, right). Therefore, we can compute color inconstancies for objects on surfaces of these two planets (e.g. samples of the GretagMacbeth ColorChecker) using some chromatic adaptation transform like CAT16 [4].

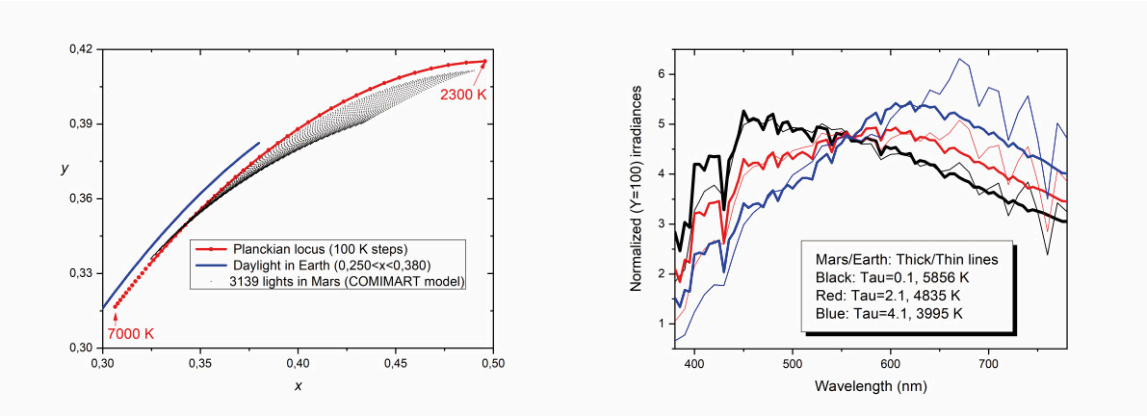

Figure 1. CIE *x*,*y* chromaticity coordinates for 3139 lights on the surface of Mars from COMIMART model in comparison with Planckian locus and Earth daylight (left). Normalized spectral irradiances (Y=100) on surfaces of Mars [zenith solar angle 36°, three dust opacity values (Tau)] and Earth with the same correlated color temperatures (right).

From mentioned 3139 spectral irradiances on Mars surface, we have used the method proposed by Judd et al. [5] and adopted by the CIE [1] to model relative spectral irradiances of lights on Mars surface, starting from a given value of correlated color temperature. Using two first eigenvectors from our model provided satisfactory results: Reconstructions had an average goodness of fit coefficient of 0.9841.

Keywords: Mars, daylight, colorimetry, correlated color temperature, principal component analysis.

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References:

[1] CIE 015:2018. Colorimetry, 4th Edition. CIE Central Bureau, Vienna (2018).
[2] A. Vicente-Retortillo, F. Valero, L. Vázquez, G. M. Martínez, "A model to calculate solar radiation fluxes on the Martian surface," J. Space Weather Space Clim., 5, A33 (2015).
[3] CIE 224:2017. CIE 2017 Colour Fidelity Index for accurate scientific use. CIE Central Bureau, Vienna (2017).
[4] CIE 248:2022. The CIE 2016 Colour Appearance Model for Colour Management Systems: CIECAM16.
[5] D. B. Judd, D. L. MacAdam, G. Wyszecki, "Spectral distribution of typical daylight as a function of correlated color temperature," J. Opt. Soc. Am. 54 (8), 1031-1040 (1964).

Emulation and Testbed Prototyping of Laser Beam Propagation Characteristics through Atmospheric Turbulence for Optical Satellite Feeder Links

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ABSTRACT

Two scenarios in space communications are classically examined in order to evaluate the link performance of free space optical communications (FSOC) and deep space optical communications (DSOC). These scenarios include the downlink and uplink between earth ground stations and near earth geostationary (GEO) satellites, as well as between the earth and spacecraft that are located a significant distance from the earth (i.e., one or more astronomical units (AU) away). Deep space is often defined as being more than 0.01 AU, or around 1,500,000 km, from Earth.

In the first part of this analytical research, various practical system characteristics for optical lasers, optical telescopes, transmitters, receivers, and atmospheric disturbances, including absorption and scintillation, are taken into consideration [1]. To validate and enhance the extended simulation model, the outcomes were compared to significant experimental data from DLR & JAXA's OICETS/Kirari-Japan, as shown in Figure 1(a). Additionally, this work will propose a synthetic effects-based optical turbulence generator in order to deeply investigate atmospheric turbulence disturbances in free-space optical communication systems and support the advancement of artificial intelligence processing-based mitigation solutions. The work objective is to relate the states of optical turbulence generators to turbulent properties and features in real time, making experimentation and testing accessible. Figure 1(b) shows schematics of a suggested artificial neural network used to understand and predict link degradation in turbulence and develop smart algorithms for an adaptive optics or intelligent systems model for turbulence mitigation.

Worth mentioning, the initial outcomes and analytical comparisons demonstrate the preliminary viability of the simulation model for the link budget and scintillation estimation for FSOC investigations, which can give deep insight into the development of the proposed testbed prototyping, machine learning-based laboratory measurement system, and possibility for enhanced DSOC project design and execution for long- and medium-term space mission planning.

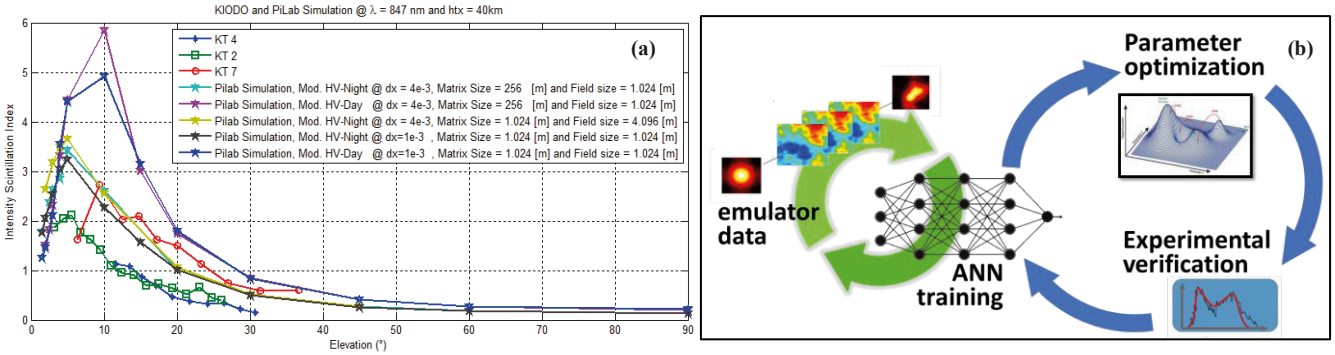

Figure 1. (a) Experimental and simulation results of intensity scintillation index of the downlink scenario. (b) Diagram of the proposed laboratory testbed-based disturbances for a novel wavefront aberration compensation technique..

Keywords: Free space optical communications (FSOC), low-earth orbit (LEO) satellites, downlink, and atmospheric disturbances.

References:

[1] Al-Juboori, Haider. "Exploration and Modelling of Atmospheric Turbulences Effects for Downlink Scenario of Free Space Optical Communications." In EPJ Web of Conferences, vol. 287, p. 09006. EDP Sciences, 2023. 10.1051/epjconf/202328709006

Optical frequency combs in distributed optical fiber sensing

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ABSTRACT

Distributed optical fiber sensing (DOFS) entails a set of techniques that turn an optical fiber into a long sequence of "virtual sensors," allowing small perturbations along the fiber length to be localized and quantified. Essentially, DOFS relies on the analysis of the weak return signal caused by optical scattering (Rayleigh, Brillouin, or Raman) when light propagates along the sensing fiber [1]. Among the approaches based on Rayleigh scattering, phase-sensitive optical time-domain reflectometry (φOTDR) has garnered great interest due to its ability to perform dynamic sensing of temperature and strain.
Since the turn of the century, optical frequency combs (OFCs) have revolutionized the field of optical metrology and have benefited a plethora of applications, such as high-resolution spectroscopy, parallel optical communications, laser ranging (lidar), and many others [2]. However, frequency combs have only recently begun to be harnessed for DOFS. Their first application in distributed acoustic sensing (DAS), known as time-expanded phase-sensitive OTDR (TE-φOTDR), was demonstrated in 2021 [3], bridging a gap between conventional φOTDR and optical frequency domain reflectometry [4]. TE-φOTDR involves the use of two densified electro-optic (EO) frequency combs with slightly different line spacings. The result is a dual-comb scheme that offers very high spatial resolution (cm scale) while requiring exceptionally low acquisition bandwidths (sub-MHz).
In this presentation, we review the fundamentals of TE-φOTDR and describe further progress to enhance its performance and extend its use to out-of-the-lab applications [5,6]. Other very recent DOFS approaches that exploit the properties of OFCs, especially those based on microcombs, are also briefly discussed [7].

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References:

[1] P. Lu, N. Lalam, M. Badar, B. Liu, B. T. Chorpening, M. P. Buric, and P. R. Ohodnicki, "Distributed optical fiber sensing: Review and perspective," Appl. Phys. Rev. 6, 041302 (2019).
[2] S. A. Diddams, K. Vahala, and T. Udem, "Optical frequency combs: Coherently uniting the electromagnetic spectrum," Science 369, eaay3676 (2020).
[3] M. Soriano-Amat, H. F. Martins, V. Durán, L. Costa, S. Martin-Lopez, M. Gonzalez-Herraez, and M. R. Fernández-Ruiz, "Time-expanded phase-sensitive optical time-domain reflectometry," Light Sci. Appl. 10, 51 (2021).
[4] M. R. Fernandez-Ruiz, M. Soriano-Amat, V. Durán, H. F. Martins, S. Martin-Lopez, and M. Gonzalez-Herraez, "Time Expansion in Distributed Optical Fiber Sensing," J. Light. Technol. 41, 3305–3315 (2023).
[5] M. Soriano-Amat, H. F. Martins, S. Martin-Lopez, M. Gonzalez-Herraez, M. R. Fernández-Ruiz, and V. Durán, "Time-expanded φOTDR using low-frequency electronics," Opt. Express 31, 843–852 (2023).
[6] M. Soriano-Amat, P. Guay, H. F. Martins, S. Martin-Lopez, M. Gonzalez-Herraez, M. R. Fernández-Ruiz, and J. Genest, "Millimetric spatial resolution time-expanded ϕ-OTDR," APL Photonics 8, 100803 (2023).
[7] J.-T. Li, B. Chang, F. Yan, L. Ran, and N. Wang, "Coherently parallel fiber•optic distributed acoustic sensing using dual Kerr soliton microcombs," Sci. Adv. 10, eadf8666 (2024).

From fibre design to fibre sensor: Preparation methods as key factor for high-quality coupled-core-fibre sensors

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ABSTRACT

During the last years, optical fibre-based simultaneous sensing of strain and temperature has attracted increased interest for different applications, e.g. in medicine, architecture, or aerospace. Specialized fibre designs allow to further enlarge the field of applications at much lower costs and easier handling. Today the performance of many sensors fabricated using conventional fibres suffers from cross-sensitivity to two parameters (temperature and strain) and quite high interrogation costs, while customized fibre architectures would allow to circumvent such sensor draw backs.
Here, we present the development of a high-quality coupled core fibre and its sensor performance from initial fibre design via elaboration of preform and fibre up to sensor evaluation (fig. 1). Coupled-core fibres with inscribed Bragg gratings are used as waveguides that comprise two or more cores close to each other. Such fibres exhibit unique features that can be exploited for sensing via changes in the Bragg grating characteristics: changes in reflectivity occur upon bending or vibration, while wavelength positions are changed with temperature. A compact, high-speed, and cost-effective interrogation unit could be developed using such fibre to monitor reflectivity changes, while even being able to distinguish the direction of the force or impact [1].

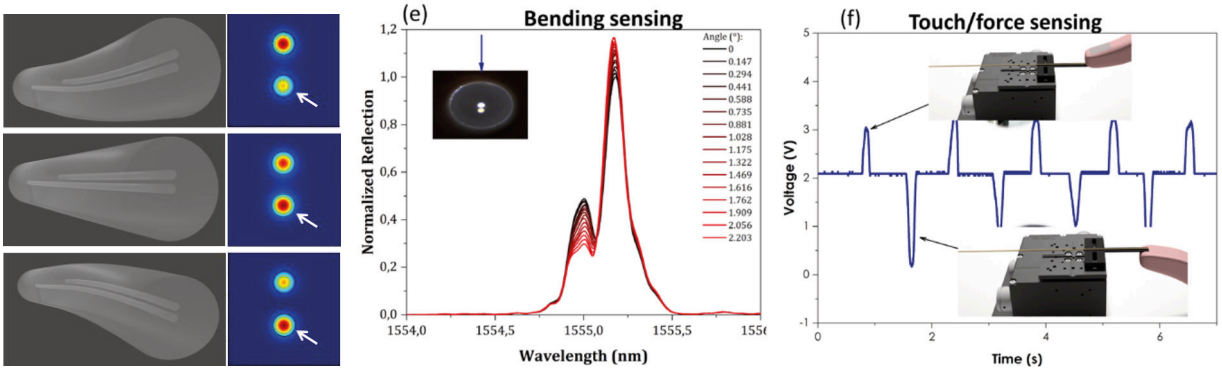

Figure 1. Dual-core fibre (left), sensor performance – bending (middle), and touch/force sensing (right) adapted from [1].

Several fibre core material techniques and approaches will be discussed that allow to obtain sufficient volume of material for required fibre core number, and specialized fibre core geometry in terms of core distances and radial refractive index profile whilst handling non-symmetrical fibre architectures of such modelled, complex structures and balancing resources and efforts.

Acknowledgements: This work has received funding from the European Union's Horizon2020 Programme for research, technological development and demonstration under Grant Agreement n°779472 ACTPHAST project (P2022-06); the authors further acknowledge funding from [quantifisens]

References:

[1] M. Alonso-Murias, D. Maldonado-Hurtado, J. A. Flores-Bravo, F. Lindner, J. Bierlich, K. Wondraczek, S. Sales, J. Villatoro, "Live Demonstration: Coupled-Core Fiber Bragg Grating Sensors," 2023 IEEE SENSORS, Vienna, Austria, pp. 1-1 (2023)

A Comparative Study of Surface Plasmon and Tamm Plasmon Polaritons for Hydrogen Sensing

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ABSTRACT

The need for alternative energy sources has arisen due to ecological concerns and growing energy consumption. Although green hydrogen (H_2) is a promising and environmentally friendly energy source, it must be continuously monitored for safer use due to its flammability[1]. Optical sensors have been developed to address these issues, providing high sensitivity, immunity to electromagnetic interference, and remote measurement[1].
Surface Plasmon Polaritons (SPP) and Tamm Plasmon Polaritons (TPP) are two methods that can be implemented and used for H_2 monitoring. The first one consists of the excitation of collective oscillations of free electrons at the interface between a metallic film and a dielectric medium through the electromagnetic evanescent field[2], while the latter corresponds to the electromagnetic resonance between metallic film and a distributed Bragg Reflector (DBR), excited with a normal incidence to the coating structure[3]. On the other hand, palladium (Pd) is a widely recognized metal renowned for its high ability and selectivity in absorbing H_2, leading to the formation of PdH_x. During the transition from Pd to PdH_x, the optical properties of the material change. It is possible to detect changes and monitor the hydrogen concentration by incorporating a thin layer of Pd above the metallic and dielectric layers. While SPPs are widely used for sensing, TPP offers advantages over conventional SPPs, which should be discussed. This work presents a comprehensive and systematic numerical study using the transfer-matrix technique to compare both methods, giving examples of possible applications.
For the SPP, the plasmonic material consists of Au, with a TiO_2 dielectric layer to enhance the optical response, and the sensitive layer is Pd. For the TPP, the DBR is composed of TiO_2 and SiO_2, with the metal layer comprising Pd. Adjusting the thickness of each layer and the incidence angle, it is possible to understand the influence on each resonance band's spectral position, full width at half maximum (FWHM), and sensitivity. Regarding the SPP structure, it was found that while the metallic layer influences the FWHM, the dielectric layer enables spectral tunability of the band, with the optimized band in the visible range. However, by expanding the dielectric layer to achieve a band in the near-infrared (NIR) range, the FWHM also increases. On the other hand, while TPP has lower sensitivity than SPP, it presents a very low and constant FWHM over the entire visible and NIR range, which can increase its figure-of-merit. In addition, the TPP can be excited at low incidence angles, allowing measurements of signals in reflection mode and easy interrogation.

Acknowledgements: This work is financed by Component 5 - Capitalization and Business Innovation, integrated in the Resilience Dimension of the Recovery and Resilience Plan within the scope of the Recovery and Resilience Mechanism (MRR) of the European Union (EU), framed in the Next Generation EU, for the period 2021 - 2026, within project ATE, with reference 56. Miguel Almeida acknowledges the support from FCT research grant 2023.00890.BD. Luís Coelho acknowledges the support from FCT research contract grant CEECIND/00471/2017.

References:

[1] A. K. Pathak, S. Verma, N. Sakda, C. Viphavakit, R. Chitaree, and B. M. A. Rahman, "Recent Advances in Optical Hydrogen Sensor including Use of Metal and Metal Alloys: A Review," Photonics, vol. 10, no. 2, p. 122, Jan. 2023, doi: 10.3390/photonics10020122.
[2] V. Yesudasu, H. S. Pradhan, and R. J. Pandya, "Recent progress in surface plasmon resonance based sensors: A comprehensive review," Heliyon, vol. 7, no. 3. Elsevier Ltd, Mar. 01, 2021. doi: 10.1016/j.heliyon.2021.e06321.
[3] Y. Chen et al., "Tamm Plasmon Polaritons Hydrogen Sensors," Advanced Physics Research, vol. 2, no. 8, Aug. 2023, doi: 10.1002/apxr.202200094.

Coil-shaped Optical Fiber Sensor for Compression Measurements

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ABSTRACT

This study investigated the effectiveness of a coil-shaped optic fiber interferometric sensor, with a diameter of 13 mm, for measuring compression. The sensor's design utilizes the principles of interferometry to create a pattern that changes with applied pressure. This configuration significantly amplifies the sensor's sensitivity to compression due to the extended optical path length within the compact form factor. The experimental results demonstrated that even small compressive forces caused detectable alterations in the interference pattern, allowing for precise quantification of pressure changes. The 13 mm diameter proved to be particularly advantageous, providing a balance between sensitivity and practical integration into various systems, from structural health monitoring to biomedical devices. This study also highlights the sensor's robustness against electromagnetic interference and environmental variations, attributing this to the intrinsic properties of optics fiber. Overall, the findings suggest that coil-shaped optic fiber interferometric sensors are highly effective for accurate and reliable compression sensing, with potential for broad application across multiple industries.

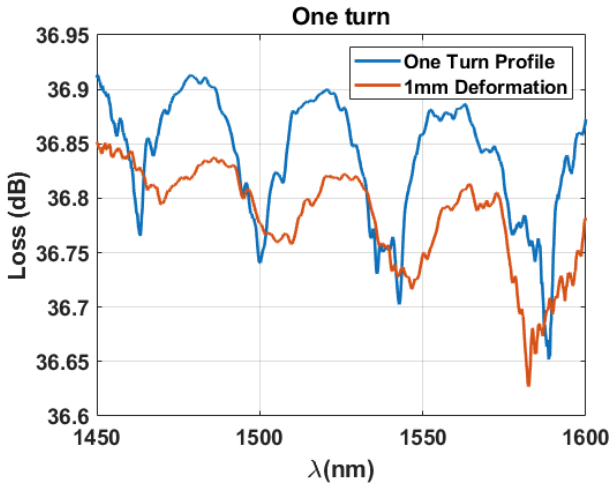

Figure 1. Spectral loss for the coil-shaped sensor and a 1mm deformation.

Monitoring Reinforced Concrete Structures Using Iron Thin-Film Coated Optical Fibre Sensors

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ABSTRACT

Reinforced concrete structures (RCS) are a cornerstone of human development, crucial to civil infrastructure, yet its usage accounts for 7% of global emissions [1]. Structural health monitoring (SHM) is essential for reducing this environmental impact, safeguarding human-life and fostering economic resilience [2]. Amongst the leading causes of early decay in RCS is rebar corrosion, which is heightened by the presence of carbon dioxide (CO_2) and chloride ions (Cl^-) [2]. Different types of optical fibre sensors (OFS) have been already employed in SHM due to rebar corrosion. A reflection probe based on an optical fibre tip coated with a thin layer of iron (Fe), provided a simple, robust and long-lasting solution [3]. As corrosion occurs, a drop in the measured signal is observed since the corrosion of Fe results in less signal being reflected at the fibre tip. In the present work, the reflection of a Fe thin film is studied to monitor corrosion in RCS, by observing the spectral changes that occur during the Fe corrosion process [4]. A multimode fibre tip, coated with a thin layer of Fe embedded in concrete, having the cement paste structure holding the iron and its corrosion products, allows spectral changes to be monitored through reflection. Iron thin films 100 nm thick were deposited on the polished tip of a multimode fibre using radio frequency magnetron sputtering. Corrosion was induced by applying drops of water with a 3.5% concentration of NaCl over several days and allowing the fibre tip to dry. The corrosion process was successfully monitored for tips exposed to air and those embedded in cement paste, with the results compared to reflection simulations of thin films composed of Fe, Fe_2O_3 and/or Fe_3O_4 [5]. This study paves the way for ratiometric monitoring at different wavelengths, enabling a more robust sensing system that is less susceptible to light source and coupling fluctuations, while remaining cost-effective.

Keywords: Reinforced Concrete Structures, Low-cost, Optical Fibre Sensors, Corrosion

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References:

[1] N. Darraj, G. Bender, Carbon Neutral Energy Intensive Industries, UNECE, Geneva, Switzerland, 2022. https://unece.org/sustainable-energy/cleaner-electricity-systems/carbon-neutral-energy-intensive-industries.
[2] L. Fan, Y. Bao, Review of fiber optic sensors for corrosion monitoring in reinforced concrete, Cement and Concrete Composites 120 (2021) 104029. https://doi.org/10.1016/j.cemconcomp.2021.104029.
[3] K.T. Wan, C.K.Y. Leung, Durability Tests of a Fiber Optic Corrosion Sensor, Sensors 12 (2012) 3656–3668. https://doi.org/10.3390/s120303656.
[4] P.L. Fuhr, D.R. Huston, Corrosion detection in reinforced concrete roadways and bridges via embedded fiber optic sensors, Smart Mater. Struct. 7 (1998) 217–228. https://doi.org/10.1088/0964-1726/7/2/009.
[5] O.S. Heavens, Optical properties of thin solid films, Dover Publ, New York, 1991.

Quantum Key Distribution

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ABSTRACT

We present quantum technologies, emphasizing the tremendous increase in computational power brought by quantum computing. While such computational power significantly benefits humanity, it also threatens Internet security. Two approaches have been developed to address this threat: post-quantum cryptography and quantum key distribution.

We highlight the foundational differences between these approaches and discuss quantum key distribution in detail.

We discuss the generation of random and prime numbers based on vacuum energy and the distribution of cryptographic keys using Fock and coherent states. Next, we introduce the concepts of symmetric and oblivious keys, explaining their role in supporting secure communication and computational services. We also explain how these keys can be derived from measurements performed on the exchanged quantum states. Finally, we discuss how these keys can be delivered to final applications through a key management system.

Acknowledgements: This work was funded within the DIGITAL-2021-QCI-01 Programme that has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 101091730

Keywords: quantum key distribution, quantum communications, quantum random numbers, cryptographic keys

Exploring new approaches to fabricate 2D layered materials supported gold nanoparticles for optical biosensing

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ABSTRACT

2D layered materials, such as transition metal dichalcogenides (e.g. molybdenum disulphide: MoS_2) have unique optical properties, well-defined architecture, and tunable surface chemistry, making them excellent platforms for optical sensing applications.[1] The combination of such 2D layered materials with metallic nanoparticles, such as gold nanoparticles (AuNPs), allows the fabrication of highly sensitive surface-enhanced Raman scattering (SERS) substrates for analytical purposes.[2] Herein, we report our research on the chemical strategies for producing 2D MoS_2/AuNPs composites with distinct morphologies. The resulting hybrid 2D materials have been investigated as SERS substrates to detect trace amounts of organic dyes (e.g. rhodamine B) and biological molecules of interest (e.g. adenine). Focus will be given to the preparation method of few-layer MoS_2 nanosheets and the incorporation of the AuNPs with distinct particle sizes. Finally, we will discuss the type of interfaces that result from coupling materials with distinct functionalities and morphologies, and their effects on the SERS performance using Raman imaging (Figure 1).

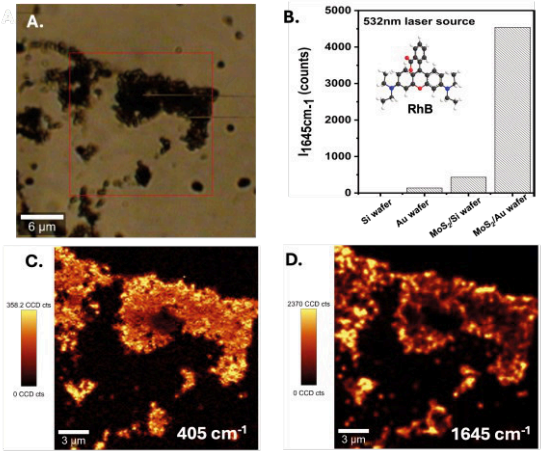

Figure 1: A. Optical image of MoS_2 deposited on Au wafer; B. Plot of the Raman intensity of the rhodamine B (RhB) band at 1645 cm^{-1} (100 µM) using Si wafer, Au wafer, MoS_2/Si wafer and MoS_2/Au wafer as SERS substrates; Raman images obtained by monitoring the MoS_2 Raman band (A_{g1}) at 405 cm^{-1} (C) and the RhB Raman band at 1645 cm^{-1}(D).

Keywords: Molybdenum disulphide; Gold nanoparticles, 2D Materials, SERS

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References:

[1] S. Joseph, J. Mohan, S. Lakshmy, S. Thomas, B. Chakraborty, S. Thomas, N. Kalarikkal, Mater. Chem. Phys. 297, 127332, 2023
[2] B. P. de Sousa, S. Fateixa, T. Trindade, Chem. Eur. J. 30, e202303658, 2024

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Optical spectroscopic insights into III-nitrides: rare-earth implanted nanowires for light-emitters and scandium-alloyed films for ferroelectrics

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ABSTRACT

III-nitrides (III-N) are among the most technologically relevant semiconductors for optoelectronics. Perhaps the leading example of this relevance is the efficient high-brightness blue light-emitting diodes (LEDs) that allowed the achievement of white LEDs [1]. In recent years, the focus has been on obtaining efficient III-N-based micron-sized LEDs (or micro-LEDs) across the entire visible range to produce full-colour displays that should outperform conventional displays in brightness, resolution, and operation lifetime.

However, micro-LED technology faces some challenges that must be solved for scale-up production: mass transfer/integration and full-colour implementation (efficiency drastically decreases for longer emitting wavelengths). A possible way to settle these issues is to implant III-N nanowires (NWs) with rare-earth (RE) ions. In this case, the transfer problem is prevented by directly growing high-quality NWs on cost-effective silicon substrates, allowing an easier integration with conventional microelectronics. Then, using lithographically defined masks, micro/nanoscale red-green-blue (RGB) emitters can be realized by implanting different RE ions in such NW structures. Depending on the implanted RE ions, the emitted colour is different; for example, Eu^{3+} is well-known for its characteristic red emission, Tb^{3+} or Er^{3+} have green emission lines, and Tm^{3+} has blue emission [2].

Recently, with the first demonstration of ferroelectricity in wurtzite (WZ) AlScN alloys [3], III-nitrides have also become promising as ferroelectric materials. By increasing the Sc-content in AlScN, the WZ structure softens and distorts (decrease in *c/a* lattice parameters ratio), reducing the polarization switching energy barrier to a point where the coercive field becomes lower than the dielectric breakdown threshold; this enables ferroelectricity with high spontaneous polarization values (120–150 $\mu C \cdot cm^{-2}$). However, for Sc-contents above ~50%, a cubic rock-salt (RS) phase becomes stable, compromising the growth of WZ AlScN with high Sc-content. Indeed, even for lower Sc-contents, WZ and RS phases can co-exist due to Sc segregation in Sc-rich AlScN cubic inclusions, which may compromise device performance.

This presentation will focus on the insights that optical spectroscopy techniques (e.g., UV/Vis transmittance, photoluminescence, and Raman spectroscopy) can give to optically and structurally characterize III-nitrides. In particular, two case studies will be presented and discussed: *i)* the realization of red micro-LEDs based on Eu-implanted AlN p-n junction NWs [4] and *ii)* the characterization of AlScN alloys grown by metalorganic chemical vapor deposition [5], aiming to establish which growth conditions allow the production of high-quality WZ AlScN films with enhanced Sc incorporation for future device implementation.

References:

[1] S. Nakamura and G. Fasol, The blue laser diode: GaN based light emitters and lasers. Germany: Springer-Verlag Berlin, 1997.

[2] K. P. O'Donnell, Rare earth doped III-nitrides for optoelectronic and spintronic applications. The Netherlands: Springer, 2010.

[3] S. Fichtner *et al*., "AlScN: A III-V semiconductor based ferroelectric," J. Appl. Phys., 125, 114103, 2019.

[4] J. Cardoso *et al*., "Europium-implanted AlN nanowires for red light-emitting diodes," ACS Appl. Nano Matter., 5, 972-984, 2022.

[5] N. Wolff *et al.,* "Demonstration and STEM Analysis of Ferroelectric Switching in MOCVD-Grown Single Crystalline $Al_{0.85}Sc_{0.15}N$", Adv. Physics Res., 3, 2300113, 2024.

NIR triggered elastic liposome containing magneto-plasmonic nanoparticles for treatment of skin

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ABSTRACT

Elastic liposomes (ELs) are excellent nanocarrier for topical applications due to their ultra-deformable properties. The integration of magnetic and plasmonic nanoparticles into these Els, forming magneto-plasmonic elastic liposomes, (MPELs) is a promising approach with potential to treat topical disease conditions. The combination of both magnetic and plasmonic components in a single system maximize the cell damage by increasing localized heat under a NIR laser [1,2], while being potential for magnetic hyperthermia and ideal as triggered drug delivery mediators.
In this work, we report the design, development, and characterization of MPELs of DPPC:SP80 (85:15) containing cubic shaped calcium/magnesium ferrite nanoparticles coupled with gold nanorods (figure 1), for photothermal therapy (PTT). The structural, morphological, magnetic and photothermal properties of both magnetic and plasmonic components were evaluated. A new methodology was employed to couple the magnetic and plasmonic nanostructures, using cysteine as bridge molecule [3]. The photothermal potential was evaluated for the magnetic nanoparticles, gold nanorods and the coupled magneto-plasmonic nanoparticles, displaying a maximum temperature variation of 28.9 ˚, 33.6 ˚C and 37.2 ˚C, respectively, under NIR-laser irradiation. A phase transition temperature (T_m) of 35 ˚C was estimated for MPELs by, ensuring high fluidity for enhanced skin penetration. These findings point to the development of thermos-elastic nanocarriers with suitable features as photothermal hyperthermia agents.

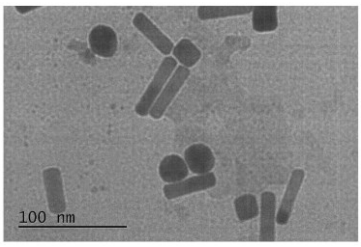

Figure 1. TEM image of the magneto-plasmonic nanoparticles. Scale bar: 100 nm.

Keywords: (calcium/magnesium ferrite, gold nanorods, elastic liposomes, photothermia

References:
[1] Ovejero, J.G., Casero, I.M., de la Presa, P., Mille, N., Carrey, J., Garcia, M.A., Hernando, A., Herrasti, P. "Hybrid nanoparticles for magnetic and plasmonic hyperthermia." Phys. Chem. Chem. Phys. 2018, 20, 24065–24073.
[2] Rodrigues, A.R.O., Santos, L.C.A., Macedo, D.O., Rio, I.S.R., Pires, A., Pereira, A.M., Araújo, J.P., Castanheira, E.M.S., Coutinho, P.J.G. "Plasmonic/magnetic liposomes based on nanoparticles with multicore-shell architecture for chemo/thermotherapy." J. Phys. D Conf. Ser. 2022, 2407, 012051.
[3] Pacheco, A.R.F., Barros, A.M., Amorim, C.O., Amaral, V.S., Coutinho, P.J.G., Rodrigues, A.R.O., Castanheira, E.M.S. "Elastic Liposomes Containing Calcium/Magnesium Ferrite Nanoparticles Coupled with Gold Nanorods for Application in Photothermal Therapy." Nanomaterials 2024, 14, 679.

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Optical Characterisation of Phase Change Materials Leakage in Coaxial Fibres after Cutting

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ABSTRACT

The need for climate-resilient infrastructure has become a crucial issue in the sake of citizens' quality of life. Building materials are used in large quantities in modern cities and can be directly related to urban heat islands (UHI) and energy management problems. Temperature variations, caused mainly by heat-absorbing materials, often results in higher energy consumption, an increase in heat-related illnesses and high heating/cooling costs. Mitigating the UHI effect and energy problems is key to curbing the adverse impacts of rising urban temperatures. Phase change materials (PCMs) have been incorporated into civil construction materials for thermoregulation. They can store and release heat in the form of latent heat, by adjusting the temperature through changes in phase states, thus reducing energy consumption of infrastructures by maintaining the composite temperature. However, it is known that their direct incorporation into civil engineering materials may compromise the change of structures after fusion, in the specific case of the solid-liquid PCMs, conditioning the mechanical behaviour of these materials. To mitigate this, PCMs have been encapsulated before their incorporation into civil engineering materials. Coaxial polymeric fibres (PCFs) have emerged as an innovative and safe alternative for encapsulating PCMs. In this study, coaxial fibres were produced by the wet-spinning method, with a sheath composed of commercial cellulose acetate (CA, Mn50,000) and a core made of polyethylene glycol (PEG2000). After production, PCFs were dried for 24 hours, and their morphologies were analysed using a bright-field microscope to confirm the presence of a well-formed core-shell structure. To verify the PCF sealing effectiveness at the fibre edges, thus preventing PEG leakage, the fibres were cut into small pieces using the hot cutting method, varying at three different temperatures, and then washed with distilled water. The resulting baths were analysed using UV-visible spectroscopy for potential PEG detection. In the end, PCFs were characterised by Fourier-transform infrared spectroscopy (FTIR) to evaluate the intensity of the PEG peaks before and after controlled washing. Although some leakage of PEG 2000 has been observed in unsuccessful cuts at high temperatures, the cut and sealed fibres can enhance its application in civil engineering materials.

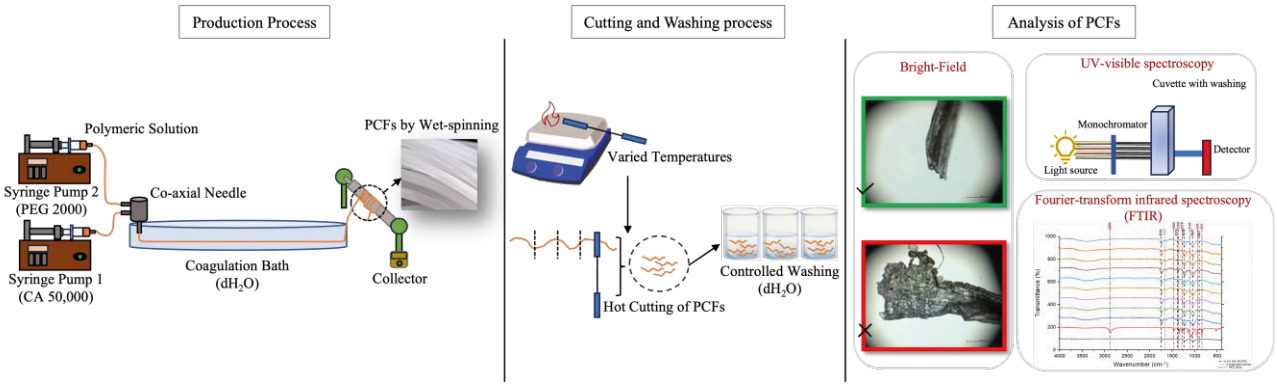

Figure 1. Graphical abstract of the cutting process and characterisation of PCFs.

High aspect-ratio Au@Ag plasmonic nanorods on optical fibers for remote glyphosate detection

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ABSTRACT

The localized surface plasmon resonance (LSPR) of metallic nanoparticles (NPs) creates an electromagnetic (EM) field enhancement extending a few nanometers outward from their surface, and is known to depend on their size, geometry, materials and the refractive index (RI) of the surrounding medium. In order to effectively use such NPs as plasmonic sensors, it is crucial to enhance their RI sensitivity which can be achieved by shifting their LSPR to longer wavelengths in the near-infrared (NIR). This opens new possibilities, as the combination of NIR plasmonic NPs with optical fibers sensor configurations at the optical telecommunication bands (from 1260 to 1625 nm), where typical single-mode optical fibers show the lowest attenuation coefficients (around 0.16 dB/km), encourage a sensor design for remote sensing applications.
This work presents the synthesis of colloidal Ag@Au nanorods (NRs) capable of operating at wavelengths ranging from 700 nm to greater than 2500 nm, by tuning their aspect ratio (AR). By increasing their AR, improvements in RI sensitivity and more efficient extinction cross sections were obtained, along with negligible band broadening. These results effectively demonstrate significant enhancements in sensing performance. Furthermore, the synthesized NRs exhibit the optical properties of Ag, outperforming Au NRs of equivalent dimensions, while retaining the chemical stability of Au. Thus, effectively combining the best properties of both materials. The performance of the complex Ag@Au NRs was tested, revealing RI sensitivity values ranging from 800 to 2000 nm/RIU as their AR increased from 4 to 9.
The optical fiber configuration developed was based on a side-polished configuration, where the polishing depth was optimized to preserve the fiber attenuation profile whilst maximizing the evanescent field interaction with the immobilized NRs. This, configuration was then applied as a real time aptasensor for glyphosate, a widely used and concerning herbicide, showing a ten-fold increase on the limit of detection (LOD) by shifting the wavelength of operation from the O to the C/L optical bands. These findings suggest that these Au@Ag NRs in conjunction with optical fiber configurations show great potential as a high-performance and real time solution for remote sensing.

Acknowledgements This work received funding from the European Union's Horizon Europe research and innovation program under the Grant Agreement through the project INNOAQUA. Paulo Santos acknowledges the support from FCT PhD grant SFRH/BD/146784/2019 and Luís Coelho from FCT research contract grant CEECIND/00471/2017.

Advancements in Graphene Oxide: Deposition Techniques, Sensing Applications, and Optical Fiber Integration

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ABSTRACT

Since the advent of graphene in 2004, its discovery has driven extensive scientific research [1]. Graphene oxide (GO) was initially considered a precursor to graphene due to its inferior electrical properties. But since, it has been recognized for its unique advantages, including solubility, processability in various solvents, and adaptability through chemical modifications. These properties, coupled with the potential for mass production, position GO as highly promising for technological applications [2]. This presentation focuses on GO, showcasing solutions for deposition, sensing applications, and laser fabrication in optical fibers. We provide an overview of graphene, GO, and reduced graphene oxide (rGO), emphasizing their material properties, synthesis methods, and characterization techniques. We then explore thin film assembly on optical fibers, demonstrating how the layer-by-layer technique effectively and easily addresses the complexities of fiber geometry, enabling multilayered structures for optical sensing. Furthermore, we present two novel Fabry-Perot interferometry-based sensors utilizing GO, capable of detecting changes in external refractive index and acoustic waves. Additionally, we examine the integration of GO with micro and nanofibers, detailing fabrication methods, real-time analysis, and the generation of ultrashort pulses through spray-coated GO films, highlighting the material's potential for advanced optical applications.

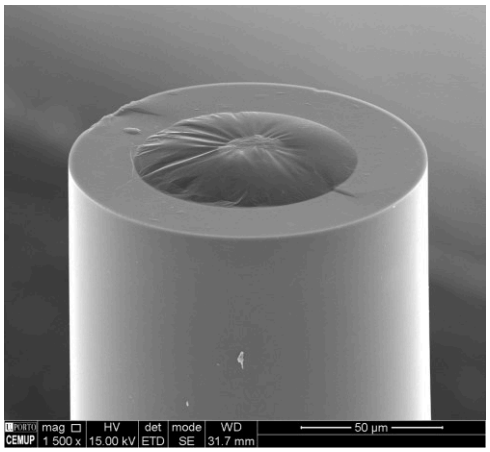

Figure 1. Thin film of graphene oxide deposited on the top of a silica capillary used for acoustic sensing.

Keywords: graphene oxide, optical fibers, fiber sensors, Q-switching, mode locking

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References:
[1] K. S. Novoselov et al., "Two-dimensional atomic crystals," Proc. Natl. Acad. Sci. U. S. A., vol. 102, no. 30, pp. 10451–10453, 2005, doi: 10.1073/pnas.0502848102.
[2] A. M. Dimiev and S. Eigler, Graphene Oxide. Chichester, UK: John Wiley & Sons, Ltd, 2016. doi: 10.1002/9781119069447.

Exploring the Refractive Index Sensitivity of Gold-Coated Optical Fiber Tips: The Influence of Key Parameters

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ABSTRACT

Optical fiber-based plasmonic sensors have shown exceptional versatility and performance in recent years, positioning the technique at the core of several innovative biosensing concepts. As regards to gold-coated optical fiber tips (Au-OFTs), they exhibit exceptional properties, namely high refractive index (RI) sensitivity and the possibility to be used as dip biosensors [1, 2]. The optimization of these probes is crucial for its wide application in biosensing. Therefore, in this work, the RI sensitivity of Au-OFTs is studied varying three key parameters: resonance wavelength (λ_{SPR}), sensing region length (SL) and OF core diameter.
For Au-OFTs characterization to RI, tests were made in glucose solutions with different concentrations (0-30% (w/v)), corresponding to a RI range between 1.3330 and 1.3685. The Au-OFTs spectral response to RI was monitored by tracking the λ_{SPR} and the sensitivity was determined as the slope of the data fitting.
Concerning initial λ_{SPR} (obtained in water), 600 µm Au-OFTs with resonances between 601.2 and 672.1 nm, were analysed. Results demonstrated a linear relation between λ_{SPR} and RI sensitivity, increasing from 1116.3 ± 86.9 to 2090.7 ± 102.5 nm/RIU. Also, SLs of 4, 6 and 8 mm were analysed, being the maximum sensitivity observed for greater SLs (1920.1 ± 121.3, 1997.9 ± 40.6 and 1761.7 ± 219.3 nm/RIU for 8, 6 and 4 mm, respectively, for 400 µm Au-OFTs). Regarding the Au-OFT core diameters, 200, 400 and 600 µm were studied, resulting in sensitivities of 1333.2 ± 114.9, 1466.7 ± 67.7 and 1652.2 ± 58.2 nm/RIU, respectively. As observed, the highest sensitivities are achieved for larger diameters, consistent with findings reported in the literature [2]. This work demonstrates that higher λ_{SPR}, longer SLs (at least 6 mm), and larger core diameters can contribute to the increased sensitivity of Au-OFTs to RI. These results provide valuable insights for optimizing Au-OFT envisaging a variety of sensing applications.

Keywords: Optical Fiber Sensor, Surface Plasmon Resonance (SPR), Spectral Changes, Sensitivity Variation, Biosensing Applications

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References:
[1] M. Loyez *et al.*, "HER2 breast cancer biomarker detection using a sandwich optical fiber assay," Talanta, vol. 221, Jan. 2021, doi: 10.1016/j.talanta.2020.121452.
[2] A. S. Assunção *et al.*, "Detection of NT-proBNP Using Optical Fiber Back-Reflection Plasmonic Biosensors," Biosensors, vol. 14, no. 4, p. 173, Apr. 2024, doi: 10.3390/bios14040173.

Wrapping optical fibers in a helical shape and exploring its sensing opportunities through fiber Bragg grating and multimode interferometer

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ABSTRACT

In this paper, it will be described the procedure that led us to create a multimode interferometer using two twisted silica single mode fibers (SMFs), inspired by the technologies developed by V. Kopp, et.al. [1]. A fiber Bragg grating (FBG) was written at this spirally twisted structure. In Fig. 1 it is shown a microscope image of one period of the twisted SMFs.
After the fiber post processing and FBG inscription we observed the transmission optical spectrum and verified the signature of both multimode interferometer and FBG. This innovative structure is simple to fabricate and allow us to simultaneously characterize two parameters, namely torsion and strain through amplitude and wavelength, as developed on [2].

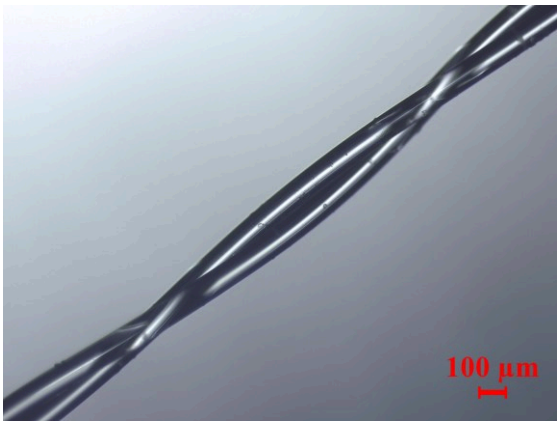

Figure 1. A single period of a dual twist SMFs.

Keywords: twisted optical fibers; multimode interferometer, fiber Bragg grating, torsion and strain sensors

Acknowledgements: This work was funded by Fundação para a Ciência e a Tecnologia (FCT) and FEDER funds through the COMPETE 2020 Programme and under the projects UIDB/50008/2020-UIDP/50008/2020 and by FCT/MEC under the project (PTDC/EEI-TEL/1511/2020). R. Oliveira acknowledges the FCT contract CEECIND2021.01066.

References:
[1] V. I. Kopp and A. Z. Genack, "Adding twist," *Nat. Photonics*, vol. 5, no. 8, pp. 470–472, 2011, doi: 10.1038/nphoton.2011.158.
[2] R. Oliveira, T. H. R. Marques, L. Bilro, R. Nogueira, and C. M. B. Cordeiro, "Multiparameter POF Sensing Based on Multimode Interference and Fiber Bragg Grating," *J. Light. Technol.*, vol. 35, no. 1, pp. 3–9, Jan. 2017, doi: 10.1109/JLT.2016.2626793.

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An Industry View of Automotive Lamps Engineering

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ABSTRACT

From bulbs and reflectors to LEDs and lenses – looking 25 years back, industrial development of vehicle lamps uses proven and robust designs along with trial and error loops. Ray tracing simulation software was starting. White LED was being invented and pure color LEDs with enough lumen for rear lamps were being developed. Bulbs, reflectors and pillow lenses were the norm. Materials characterisation was non-existent.
Now, automotive lighting development workflows use rayfiles of light sources, spectral characterised actors (materials and its shapes) and different sensors, all connected by powerful ray tracing simulation software. Luminance viewpoints, intensity maps, light flow maps, all in false and true color are obtained with each simulation. Optimisation of actors such as light guides are made in a few hours.
Demonstrating this evolution, an example of a rear stop lamp is given – from a traditional design to an example of an actual one. From a white light bulb, parabolic metalized reflector and a red array plastic filter to a pure color red LED with plastic lens and mini-pillows. From 10 to 100 lumen/Watt and from 21 to 2.1W of power consumption.
Evolution is all around: light sources miniaturisation with less electrical power but higher light emission, plastic materials optically characterized, different actor shapes allowing free-form optics, light guides and edge lights, BxDF optical surfaces characterisation, dispersive materials with good light transmission and high hiding power, light animations on lamps, and simulation software capable of handling all.
Before, homologation was a grant for the development of a lamp with no surprises. Now, homologation goes behind innovation, with discussion being held between industry and homologation bodies – industry is now pushing homologation and technology boundaries.
Looking 25 years back, automotive lamps development is more challenging than ever.

Keywords: Automotive lighting, Industry

Acknowledgements: Prof Luis Rino for the support.

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Automation Technologies to Scale PIC Testing from Lab to Fab

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ABSTRACT

Regularly testing photonic integrated circuits (PICs) at the wafer- and die-level requires high-precision alignments of test devices in multiple degrees of freedom (DOF). These tests are more complex than the traditional integrated circuits (ICs) testing because PIC testing often requires aligning optical components in addition to the alignment of a conventional probe card for electrical connections. These optical components, such as light sources and detectors, have much higher alignment sensitivities than electrical contacts and therefore require high-precision multi-DOF positioning systems during testing. Because of this added complexity, the precision motion systems required need to be more capable than those used in traditional IC testing. This is true for PIC testing at the lab-scale and for production-scale operations.
While the fundamental processes of PIC testing in labs or production environments are often similar, production-scale PIC testing presents a host of new challenges that need to be considered. The throughput and quality assurance goals of high-volume PIC manufacturing place additional demands on the test systems that include speed, reliability and scalability, in addition to the complex precision positioning requirements of lab testing. Optimizing a motion system to address all of these needs requires careful consideration of the system's architecture for both controls and mechanics. This presentation will cover the basics of precision motion systems for PIC testing and discuss the ways motion solutions can be specifically designed to address the production-scale test requirements for PIC manufacturing.

Keywords: photonic integrated circuits, high-precision alignments, from Lab to Fab.

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Fiber optic monitoring solution for predictive maintenance of pantographs and overhead powerlines

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ABSTRACT

The correct contact between the pantograph and the catenary is mandatory for efficient train operation. This can be ensured by monitoring forces and accelerations through sensors integrated in the pantograph. The proposed pantograph monitoring solution is a fully optical measurement system designed to be installed on regular operating trains, directly on the pantograph structure. It is based on force and acceleration fiber Bragg grating sensors that are passive and safe for accurate measurements on high-voltage conditions. These sensors can be used for contact force computation for pantograph control according to EN50317 standard. The system can thus be used for testing and homologation of pantographs and, in addition, to control the line contact force and perform predictive overhead line maintenance as part of a complete setup with map-based position analysis in a scalable overall monitoring solution.

Keywords: pantograph, contact force, fiber Bragg grating, accelerometer, force sensor

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Artificial Intelligence-Enhanced Colorimetric Assessment of Self-Cleaning Road Marking Paints

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ABSTRACT

Road Markings (RM) typically consist of two layers: a paint layer and a retroreflective layer. They play a crucial role in road safety by offering visibility and guidance to drivers. Over the lifetime, dirt particles, oils and greases are adsorbed on the RM surface, reducing their visibility and service life. The self-cleaning ability has been widely studied in substrates such as asphalt pavements, mortars, glasses, and paints (the latter mainly for architectural purposes). However, for RM, this represents a breakthrough and a sustainable advance, while having the potential to increase their service life and enhance road safety. In this context, nanotechnology can be a strong ally through the application of semiconductor materials, such as TiO_2, to develop self-cleaning ability. This is achieved due to their photooxidation capability, which enables the removal of pollutants adsorbed on the RM surface. In addition to this novelty in RM, quantifying this ability in terms of pollutant removal efficiency is also a challenge. Various techniques, including visual analysis, spectrometry, colorimetry, and digital image processing are used for this objective. In this sense, artificial intelligence and colorimetry can be combined to achieve improved results. The aim of the work herein reported is to assess the self-cleaning capacity in a RM paint through the mass incorporation of semiconductors and evaluate its efficiency by using traditional and modern colorimetry techniques. To this end, a water-based acrylic RM paint was modified by mass incorporation of 0.5%, 1%, 2%, and 3% of TiO_2 nanoparticles, and a pollutant model widely used, Rhodamine B, was applied onto their surface. The samples were irradiated with a light source that simulates sunlight for 60, 180, 360, 720, 1440, and 2880 minutes. Three techniques were used to evaluate the pollutant removal: i) visual analysis, ii) CIELAB color coordinates using a portable spectrophotometer, iii) digital image processing by artificial intelligence to gather average CIELAB color coordinates values from images covering the entire sample surfaces. This study allowed the evaluation of the self-cleaning capacity of a road element using qualitative and quantitative techniques. The results confirmed that RM paints with 2% and 3% TiO_2 incorporated have pollutant removal significantly higher. This work also enabled a comparison between conventional and modern techniques for quantifying self-cleaning.

Keywords: road markings, self-cleaning, colorimetry, digital image processing, artificial intelligence

Plasmonic Tilted Fiber Bragg Gratings: from refractometers to biosensors

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ABSTRACT

Tilted Fiber Bragg Gratings (TFBGs) typically utilize centimeter-long sections of fibers that are locally modified with a thin metal film to enhance their sensitivity to the surrounding refractive index through surface plasmonic resonance (SPR). These TFBGs are seen as a transposition of the Kretschmann prism configuration used in commercial SPR devices, facilitating the development of lab-on-fiber tools for diverse applications, such as biomedical diagnostics and environmental sensing where they offer unique advantages. This presentation provides an overview of the key achievements in label-free biosensing using SPR-TFBGs, covering *in vitro* bioassays to the *ex vivo* detection of biomarkers on the surface of cancer tissues. We examine their performance and outline potential improvements and future real-world applications.

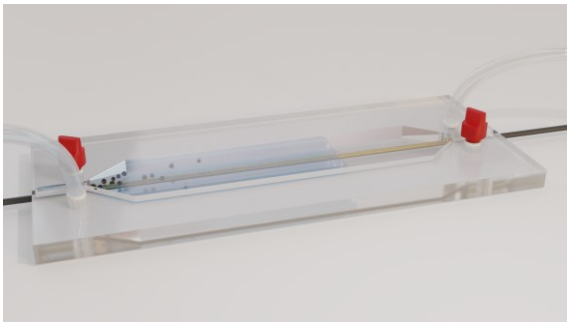

Figure 1. Artistic view of an SPR-TFBG embedded inside a microfluidic chip for biosensing purpose.

Over the last eight years, our group has developed biosensors against protein biomarkers and cells, aiming at their detection at low concentration and in complex media. Extensive tests were performed for lung cancer biomarkers detection, also with sensors embedded inside catheters to reach the upper-lobe region of lungs. They were assayed inside pig lungs and multiple resected human tissues to attest the presence of cytokeratin-17 biomarkers (CK17). [1-2] From these experimental works, promising results were achieved in detecting molecules at low concentration, down to the picomolar range. However, several challenges remain before these probes can be used in practical cases. Key areas requiring improvement include the robustness of the probes, particularly the stability of the gold layer, and ensuring reproducibility for consistent statistical analysis. It also requires automation of the manufacturing process, which is currently often performed manually. Enhancing field usability through portable systems will allow quick results without need for offline data processing. Recent advancements in spectral analysis such as the implementation of the Fourier Transformation of SPR-TFBGs spectra will be presented, leading to insights for user-friendly plasmonic interfaces. [3-4]

Keywords: Tilted Fiber Bragg Gratings, Optical Fibers, Plasmonics, Biosensing.

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References:

[1] C. Ribaut et al., “Cancer biomarker sensing using packaged plasmonic optical fiber gratings : Towards in vivo diagnosis,” Biosensors and Bioelectronics, vol. 92, pp. 449–456, 2017.
[2] M. Loyez et al., “In situ cancer diagnosis through online plasmonics,” Biosensors and Bioelectronics, vol. 131, pp. 104–112, 2019.
[3] C. Caucheteur and M. Loyez, Plasmonic Optical Fiber Biosensors. Artech House USA, 2023.
[4] H. Fasseaux, M. Loyez, and C. Caucheteur, “Machine learning unveils surface refractive index dynamics in comb-like plasmonic optical fiber biosensors,” Communications Engineering, vol. 3, no. 1, p. 34, 2024.

New strategies for multimodal cancer therapy based on plasmonic lipogels

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ABSTRACT

Enhancing the therapeutic efficacy of chemotherapeutic agents through sequential drug delivery holds immense promise. Natural polymer-based hydrogels present suitable properties for these applications [1]. Herein, we present a novel strategy aimed at improving the tunability and real-time control of nanogels, as well as enabling compartmentalization of drugs for on-demand release using NIR light [2]. We hypothesized that combining chitosan/alginate nanogel with lipid-gated mesoporous silica-coated gold nanorods, thus obtaining plasmonic lipogels [3], could enable both the drug loading in different compartments and the sequential release of two chemotherapeutic drugs (doxorubicin and methotrexate). Hence, mesoporous silica-coated gold nanorods (99 ± 11 nm) were loaded with methotrexate, and further coated with a thermoresponsive phospholipid bilayer that works as gatekeeper. These particles were then incorporated in a chitosan/alginate nanogel matrix containing doxorubicin (Figure 1). The nanogels exhibited high loading efficiencies of ~90% and ~85% for methotrexate and doxorubicin, respectively. Notably, the exposure to NIR laser irradiation led to an enhanced release of both drugs, in which doxorubicin released at a faster rate than methotrexate under acidic conditions. Besides, the plasmonic nanogels were found to be cytocompatible across different cell lines. Hereby, this design strategy presents a robust and multifunctional hydrogel platform for NIR-triggered sequential delivery that holds promise for advancing cancer therapy through different drug combinations against multiple targets in tumour microenvironment.

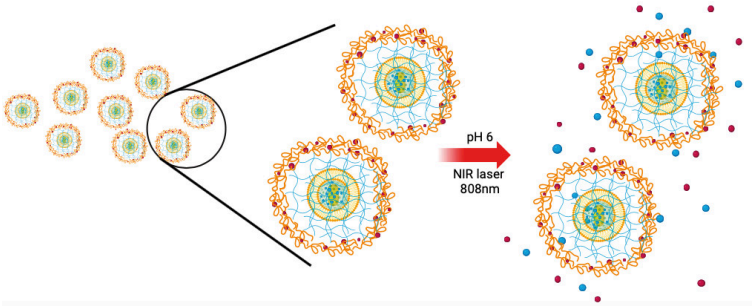

Figure 1. Scheme of the plasmonic lipogel based on silica-coated gold nanorods and chitosan/alginate nanogels.

Keywords: gold nanorods; plasmonic lipogels; drug release; photothermia; multimodal therapy.

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References:

[1] S.R.S. Veloso, E.S. Marta, P.V. Rodrigues, C. Moura, C.O. Amorim, V.S. Amaral, M.A. Correa-Duarte, E.M.S. Castanheira, "Chitosan/Alginate Nanogels Containing Multicore Magnetic Nanoparticles for Delivery of Doxorubicin", Pharmaceutics, vol. 15, no. 9, p. 2194, Aug. 2023, doi: 10.3390/pharmaceutics15092194.
[2] S.R.S. Veloso, V. Gomes, S.L.F. Mendes, L. Hilliou, R.B. Pereira, D.M. Pereira, P.J.G. Coutinho, P.M.T. Ferreira, M.A. Correa-Duarte, E.M.S. Castanheira, "Plasmonic lipogels: driving co-assembly of composites with peptide-based gels for controlled drug release", Soft Matter, vol. 18, no. 44, pp. 8384–8397, 2022, doi: 10.1039/D2SM00926A.
[3] F. Costa-e-Sá, M. Comís-Tuche, C. Spuch, E.M.S. Castanheira, S.R. S. Veloso, "Sequential release of drugs from dual-delivery plasmonic nanogels containing lipid-gated mesoporous silica-coated gold nanorods", J. Drug Deliv. Sci. Technol., vol. 96, p. 105723, Jun. 2024, doi: 10.1016/j.jddst.2024.105723.

Development and Validation of a Pulse Wave Velocity Monitoring Device

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ABSTRACT

Cardiovascular diseases are known to be the main causes of death worldwide. Although the number of deaths due to cardiovascular diseases decreased from 2000 to 2010, there was an increase in cardiovascular diseases-related deaths from 2010 to 2020 [1]. Comprising heart attacks, hypertension, diabetes, atherosclerosis, and other minor diseases, this group is associated with changes in arterial stiffness, which refers to the artery's ability to expand and contract as pressure varies during the cardiac cycle [2]. Recent guidelines from the European Society of Cardiology (2023) regarding the treatment of arterial hypertension recommend the use of pulse wave velocity measurement. This method is widely known as the most reliable way to assess arterial stiffness [3]. Pulse wave velocity measurement is considered the gold standard for monitoring arterial stiffness. Therefore, the development of new sensors capable of measuring pulse wave velocity has been a research focus in recent years, as commercial systems are often viewed as expensive and difficult to operate. In this context, our work presents the design of two arterial pulse sensors for detecting PWV and a validation setup to evaluate the proposed system. The body of the sensor consists of a tube made with 3D printing and a polymer optical fiber inside that ends in a cavity, the movement caused by the arterial distension changes the cavity dimensions increasing the reflected light in the fiber causing an increase in optical power Fig 1a. The electro-optic system represented in Fig 1b shows the optical components used to read the data in Matlab, while Fig 1c illustrates the bench setup for testing the sensor, the sensor probe was placed along a latex tube filled with water simulating the arteria. Pulses were created on one side of the tube by a piezoelectric actuator, on the other side of the tube, a manometer, a syringe and a commercial pressure sensor were placed to compare the data measured on the probe.

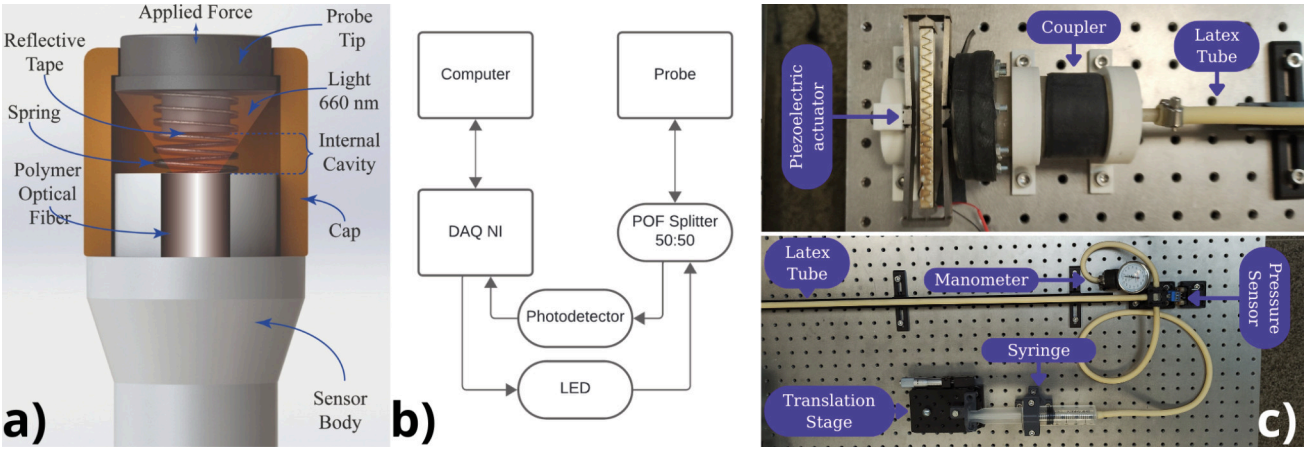

Figure 1. a) Sensor schematics. b) Data acquisition schema. c) Validation setup.

References:

[1] Martin, Seth S et al. "2024 Heart Disease and Stroke Statistics: A Report of US and Global Data From the American Heart Association." Circulation vol. 149,8 (2024): e347-e913. doi:10.1161/CIR.0000000000001209.

[2] Shirwany, Najeeb A, and Ming-hui Zou. "Arterial stiffness: a brief review." Acta pharmacologica Sinica vol. 31,10 (2010): 1267-76. doi:10.1038/aps.2010.123.

[3] Pereira, T., Correia, C. & Cardoso, J. Novel Methods for Pulse Wave Velocity Measurement. J. Med. Biol. Eng. 35, 555–565 (2015). https://doi.org/10.1007/s40846-015-0086-8.

Experimental study of the spatial and temporal coherence of a semiconductor laser with optical feedback

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ABSTRACT

Optical feedback can strongly reduce the linewidth of a semiconductor laser, but it can also cause line broadening (the so-called coherence collapse). While these effects on the temporal coherence are well known, the influence of feedback on the spatial coherence has received less attention. Here we use an experimental technique based on speckle analysis, to discriminate feedback effects on spatial and temporal coherence.
Speckle is a granular, noisy spatial structure produced by the interference of coherent waves. The contrast of the speckles decreases when the laser is under optical feedback or current modulation, which cause a chaotic, low coherence output [1]. To discriminate the effects of the excitation of temporal and spatial modes, we perform experiments with a multimode edge-emitting laser: we compare the contrast of speckle images (SC = $\sigma_I / \langle I \rangle$) recorded using either a multimode (MM) or a single-mode (SM) fiber and an optical diffuser (OD). We also compare the optical spectra after light propagates in the MM or SM fiber (see Fig. 1).
We find that: 1) the spectra measured using the MM or SM fiber are the same and 2) the speckle contrast (SC) measured using the MM fiber is significantly lower than that measured using the SM fiber. This difference is interpreted as due to the destabilization of spatial modes which lower the spatial coherence of the laser light and reduce the SC when the MM fiber is used, but which are filtered out by the SM fiber and therefore, the SC measured with the SM fiber is not reduced [2].
With the MM fiber, as expected, low SC is in general correlated with a broad spectrum. However, for some values of the pump current, this correlation does not hold and we observe a narrow spectrum and low SC. This can be interpreted as due to the fact that the laser emission switches between two regimes: stable emission (when the spectrum is recorded) and chaotic emission (when the speckle image is recorded). However, it can also be due to the emission of a single temporal mode (narrow spectrum) and several spatial modes (low SC).
With the SM fiber, the SC remains high after the laser turns on, regardless of the broadening of the spectrum. We interpret this as due to the filtering of the spatial modes done by the SM fiber: feedback excites temporal and spatial modes that would lower the SC value, but the spatial modes are filtered out by the SM fiber.

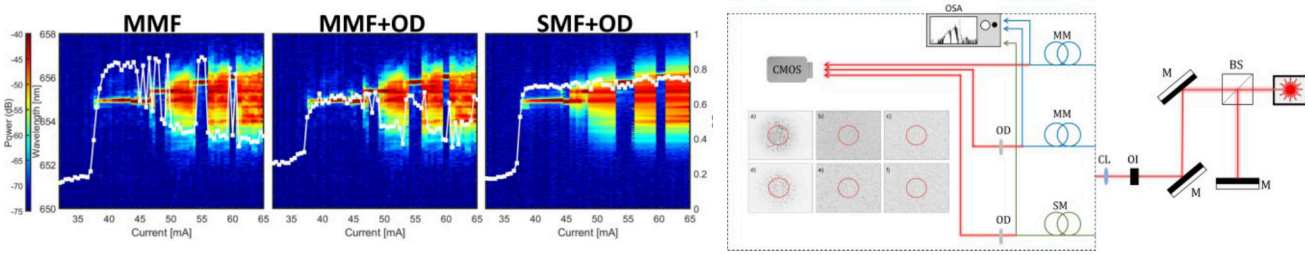

Figure 1. Top: SC (white) and optical spectra (color code) recorded with the laser with feedback (15% threshold reduction) by using the MM fiber (a), the MM fiber + OD (b) and the SM fiber + OD (c). Bottom: Experimental setup.

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References:

[1] M. Duque-Gijón, C. Masoller, and J. Tiana-Alsina, "*Abrupt transition from low-coherence to high-coherence radiation in a semiconductor laser with optical feedback*," Opt. Express 31, 3857–3864 (2023).
[2] M. Duque-Gijón, C. Masoller, and J. Tiana-Alsina, "*Experimental study of spatial and temporal coherence in a laser diode with optical feedback*," Opt. Express 31, 21954–21961 (2023)

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Modelling Investigation of Atmospheric Turbulence-Induced Beam Deviation for LEO/GEO FSO Communication Link

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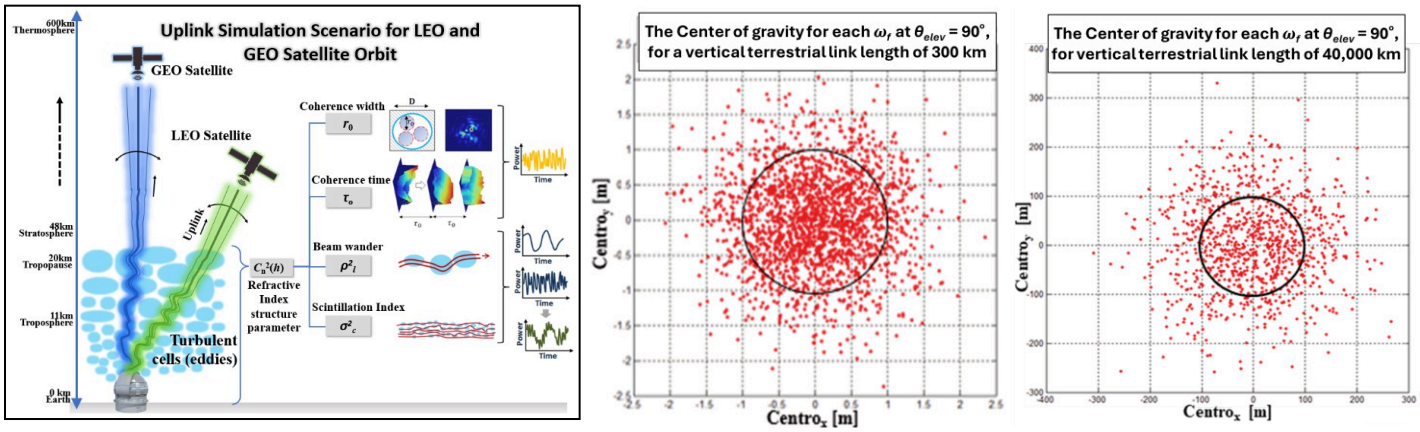
ABSTRACT

The uplink analytical simulation scenario of atmospheric turbulence-induced beam deviation can give the insight needed to understand and create the mitigation techniques that could support novel applications in the fields of free-space optical communications (FSOC) and the generation of laser guide stars. The main influence of atmospheric turbulence is in an altitude range of 20 km height, between the tropopause atmospheric layer and ground level, as Figure 1(a) explains. One of the significant challenges that causes wandering and fading of the beam from the receiver aperture is beam deviation. In this study, two uplink numerical modelling scenarios for low-earth orbit (LEO) and geostationary (GEO) satellites will be investigated and discussed. The simulation results of the beam wander effect were considered at λ = 1550 nm for beam waist = 50 mm and for LEO and GEO scenarios. In a moderate turbulence regime, Figure 1(b) shows the distribution of beam peaks throughout the aperture area using the suggested model at elevation angles (θ_{elev}) = 90° at a vertical terrestrial link length (L) of 300km , and Figure 1(c) shows simulate the beam wander effect for GEO satellites at L = 40,000 km. The work seeks to visualize the effective parameters and analytically simulate atmospheric optical propagation, especially for the wandering effect, which can give concrete milestones for developing a new scientific investigation era and deeper insight into the system theory of free-space optical communications.



(a) (b) (c)

Figure 1. (a) General scheme of the most optical uplink/downlink and well-known causes of atmospheric turbulences. (b) Random beam wandering over the receiver aperture for uplink LEO simulation scenario at L = 300 km, (c) at uplink GEO scenario and L = 40,000 km.

Keywords: Modelling atmospheric turbulence effects, beam wandering, free space optical (FSO) communication links, digital modelling-based simulation.

Passive imbalance fabrication effect on a linearly driven MZM in an oDAC-based PAM-4 Transmitter

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ABSTRACT

Photonic integrated circuit (PIC) is currently supporting high-capacity devices for large-scale production at reduced footprint and cost such as optical telecommunication transceivers. Due to the sensitivity of passive components in such devices, precision is not guaranteed. Therefore, any slight imprecision can alter the path of light entering the device and can lead to poor device performance after fabrication [1].
Programmable photonics offer a template to investigate the possible effect of such variation in PIC devices before fabrication. Using field programmable photonic gateway array (FPPGA), PIC devices such as unbalanced Mach Zehnder Interferometer (UMZI) filter and other passive based components can be emulated to study their fabrication tolerance and predict production yield in the face of several variations [2].
In this work, we have experimentally investigated the fabrication tolerance of an optical digital to analog converter (oDAC) based pulse amplitude modulation level four (PAM-4) transmitter. An oDAC-based PAM-4 transmitter is an alternative to the conventional electrical DAC (eDAC) based PAM-4 transmitter. This oDAC-based PAM-4 transmitter is based on passive devices such as couplers and splitters which make it very susceptible to any slight deviation during fabrication from its original design [3].
To model the oDAC-based PAM-4 transmitter, a hexagonal mesh FPPGA from iPronics is used [2]. The mesh is configured to model the required input splitter, output splitter, two MZM, acting as digital modulator and phase modulator, that are required to for the design. In addition, two binary non-return-to-zero (NRZ) are generated to modulate the two MZM as least and most significant bits. The input splitter with coupling factor (K_{in}) is subjected to passive variation by adding a random noise to K_{in} which implies $K_{in} = K_{in} + \sigma_n$, where σ_n is the fabrication standard deviation. Our initial findings where the modulation was done as rail-to-rail shows compression at level 00 and 11 of the PAM-4 signal levels when the design was repeated for 1000 times using Monte Carlo simulation as published in [1]. In this present work as an extension, the MZM is modulated within the linear region (0.04 to 0.3) of its transfer function to supress the compression instead of the rail-to-rail (0 to 1) modulation in [1]. A Monte Carlo emulation of 1000 oDAC-base PAM-4 transmitter chip is carried out. Gaussian profiles of the four levels of the PAM-4 signal exhibit similar spread and the compression we experienced on 00 and 11 amplitude level using the rail-to-rail modulation is eliminated, which may also affect expected production yield after fabrication.

Keywords: Fabrication imbalance, optical digital to analog converter, programmable photonics, linear modulated MZM

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References:

[1] A. E. Abejide et al. “Fabrication Tolerances' Impact on an oDAC-based PAM-4 Transmitter”, *MDPI Photonics journal*, accepted, (in press)
[2] Pérez et al. "Multipurpose silicon photonics signal processor core." *Nature communications* 8, no. 1 (2017): 636.
[3] Nazarathy et al. 2021. “Accurate Power-Efficient Format-Scalable Multi-Parallel Optical Digital-to-Analogue Conversion”, *Photonics* 8, no. 2: 38.

Beaconless Self-Alignment Method for Indoor Optical Wireless Communications

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ABSTRACT

Free-Space Optical (FSO) communications have emerged as a promising solution for future high-speed wireless communications, offering high-capacity transmission in an unlicensed spectrum, allied with its fast and easy implementation [1]. However, one of the primary challenges in FSO systems is achieving precise alignment between the transmitter and receiver without an initial pre-alignment or extensive manual configuration, which is crucial for enabling optical communication [2]. In this context, this study introduces a system capable of automatic alignment between transceivers, relying exclusively on camera information and Computer Vision (CV) frameworks, using a platform incorporating an arrangement of circles oriented through a gimbal-based Pointing, Acquisition, and Tracking (PAT) mechanism, as shown in Figure 1.

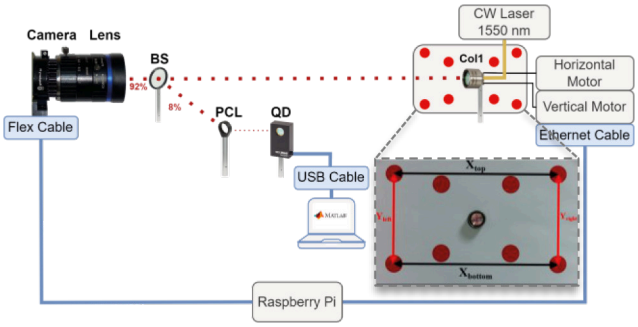

Figure 2. Experimental setup used for automatic beam alignment.

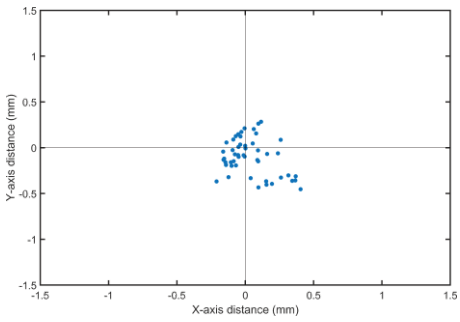

Figure 2. QD measurements for 1 m link distance.

The alignment process is achieved through the application of CV techniques, specifically to detect the center positions of the circles present in the transmitter's plane. Using this information, it was found that when the interconnection between the circle centers forms a quadrilateral with equal opposite sides (X_{top} equals X_{bottom} and X_{left} equals X_{right}), the FSO transceivers were aligned. Subsequently, a Gradient Descent (GD) algorithm was developed to adjust the platform's orientation using the stepper motors until the sum of differences between the opposite sides of the quadrilateral is zero, indicating system alignment. Through this method, successful alignments were demonstrated at distances of 1 meter and 1.5 meters across 50 alignment tests, consistently directing the beam to fall on the Quadrant Detector (QD), as depicted in Figure 2. The results obtained potentiate this automatic alignment to multiple applications in indoor FSO communication scenarios (e.g., inter-rack links in datacenter networks) or short-reach outdoor communications. By avoiding the need for additional pre-alignment PAT stages (e.g. GPS) or dedicated beacon lights, this alignment methodology might also be advantageous in terms of power efficiency, potentially enabling the use of low-power FSO transceivers for power-critical applications.

Keywords: Free-Space Optics, Optical Beam Steering, Computer Vision, Pointing Acquisition and Tracking Mechanisms.

Acknowledgements: This work was supported in part by FEDER through the CENTRO 2020 Programme funded by FCT/MCTES through Project OptWire under Grant PTDC/EEI-TEL/2697/2021, in part by FCT/MCTES through National Funds and when applicable co-funded EU Funds under Project UIDB/50008/2020-UIDP/50008/2020. The work of Gil M. Fernandes was supported by FCT through the Individual Scientific Employment Program under Contract 2022.07168.CEECIND.

References:

[1] P. K. Sahoo and A. K. Yadav, “A comprehensive road map of modern communication through free-space optics,” J. Opt. Commun., vol. 44, no. 1, pp. s1497–s1513, Feb. 2024.
[2] H. Kaushal and G. Kaddoum, “Optical Communication in Space: Challenges and Mitigation Techniques,” IEEE Communications Surveys & Tutorials, vol. 19, no. 1, pp. 57-96, 2017.

Spectral corrections in solid-state lighting measurements

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ABSTRACT

The relatively recent introduction of the Solid-State Lighting, based on LEDs, has made some of the traditional chromaticity appearance parameters to face new measurement challenges; arising from the remarkable difference between the spectral emissions of the LEDs and the Planckian radiator curves, Figure 1.

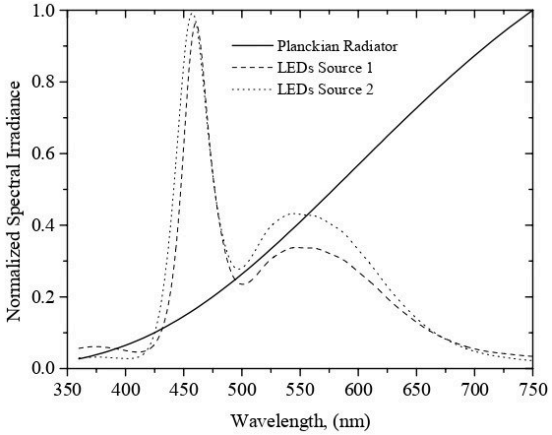

Figure 1. Emission spectra comparison between SSL sources and the Planckian radiator curves, [1].

Here I will discuss on the impact of these spectral differences on the measurement of some the key photometric quantities, as well as present the determination procedure for the spectral correction factors that need to be applied to the photometric detectors commonly used in the lighting industry.

Keywords: Solid-State Lighting, Photometers response, Correlated Colour Temperature.

References:

[1] A. Estrada-Hernández, I. Oidor, E. Rosas, "Correlated color temperature determination in FEL type incandescent lamps" in Proceedings of SPIE, Vol. 6046, 60461Q, (2006).
[2] A. Estrada-Hernández, L. P. González-Galván, H. Zárate-Hernández, R. Cardoso, E. Rosas, "Luminous flux and correlated color temperature determination for LEDs sources" in Proceedings of SPIE, Vol. 6422, 64220O, (2007).
[3] E. Rosas, A. Estrada-Hernández, "Effect of photometric detector spectral response quality on white LED spectral mismatch correction factors" in, Applied Optics, 55(19), pp. 5267-5272, (2016).

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Unlocking Traffic Control: Exploring Intersection Dynamics with Visible Light Communication

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ABSTRACTS

The landscape of transportation is evolving rapidly, driven by the convergence of emerging technologies such as smart sensors, Visible Light Communication (VLC), and artificial intelligence. These advancements hold promise for revolutionizing Smart Mobility solutions, offering innovative ways to address societal goals like reducing emissions and enhancing traffic safety.

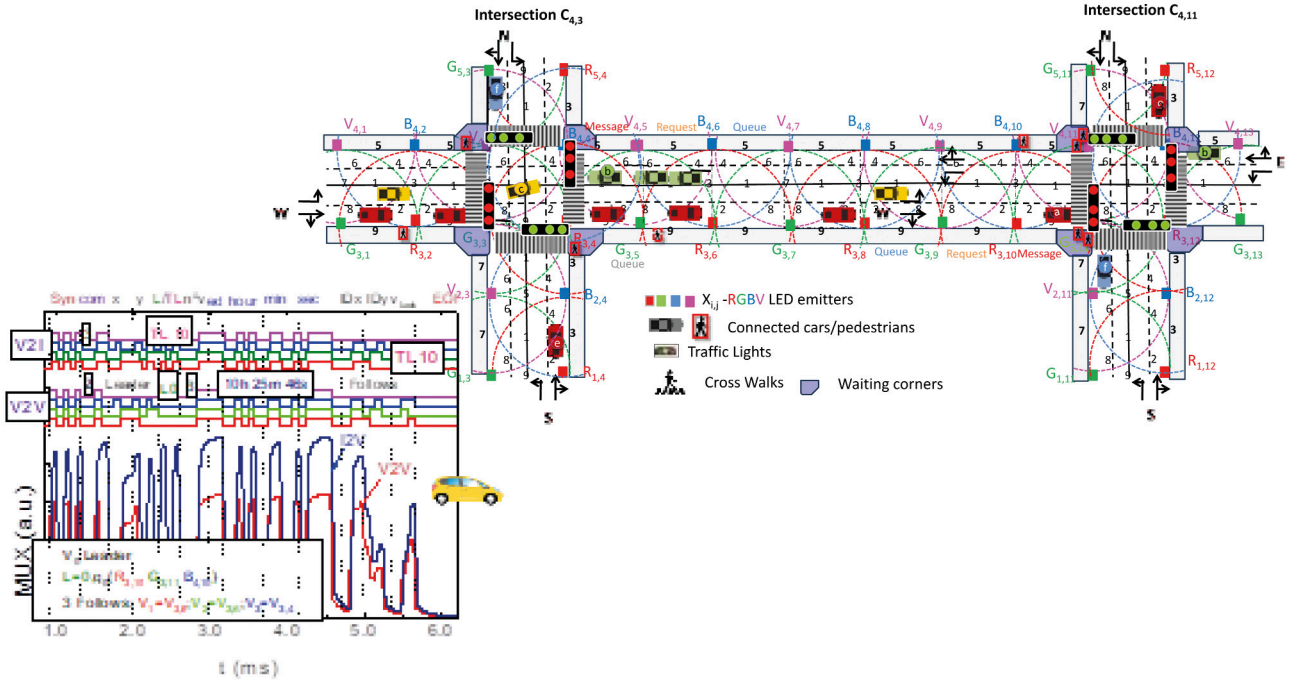

Figure 1. Simulated scenario: Four-legged intersection and environment with the optical infrastructure (Xij), the generated footprints (1-9) and the connected cars and pedestrians and MUX coded and decoded v-VLC signal.

This paper introduces Visible Light Communication (VLC) as an integrated approach to improving traffic signal efficiency and vehicle trajectory management at urban intersections. By combining VLC localization services with learning-based traffic signal control, a multi-intersection traffic control system is proposed. VLC utilizes light communication between connected vehicles and infrastructure, enabling joint transmission and data collection via mobile optical receivers. The system aims to reduce waiting times for pedestrians and vehicles while enhancing overall traffic safety. Flexible and adaptive, it accommodates diverse traffic movements during multiple signal phases. Cooperative mechanisms, transmission ranges, and queue/response interactions balance traffic flow between intersections, improving road network performance. Evaluated using the SUMO urban mobility simulator, the multi-intersection scenario demonstrates reduced waiting and travel times for both vehicles and pedestrians. A reinforcement learning scheme, based on VLC queuing/response behaviour's, optimally schedules traffic signals. Agents at each intersection control traffic lights using VLC-ready vehicles' communication, calculating strategies to enhance flow and communicate with each other for overall optimization. The decentralized and scalable nature of the proposed approach, particularly for multi-intersection scenarios, is discussed, showcasing its potential applicability in real-world traffic scenarios.

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The Critical Role of Exam Room Lighting in Presbyopia Correction

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ABSTRACT

Vision testing outcomes can be significantly affected by changes in measurement conditions, such as lighting, exam room size, and the type and presentation of test targets [1,2]. In research, these conditions are carefully defined and maintained, but in optometry exam rooms, they are often less monitored; therefore, deviations from expected conditions can occur. For presbyopia correction, additional inconsistency stems from factors such as near add estimation technique, endpoint for visual acuity, test distances, equipment used, and exam room conditions, including lighting [2,3]. Although there are guidelines for presbyopia evaluation [4], it is hard to maintain standardized care as exam room settings often differ (facilities, room size, lighting regulation options, and available equipment), leading to variability in clinical practices. In this study, we specifically analysed the impact of exam room lighting on presbyopia correction, aiming to highlight the critical role of appropriate lighting conditions.

In our study, 50 presbyopic patients aged 58 ± 11 years who attended regular eye exams participated. After balanced spherocylindrical subjective correction and binocular function evaluation at distance, near addition was measured using the plus build-up technique with refinement done on duochrome test at 40 cm (Essilor, Optoprox), aiming to achieve a near visual acuity of 1.0 (decimal units). For each participant, near addition, the range of clear vision, and pupil diameter were measured in the previously mentioned sequence under three defined illumination conditions: bright illumination (730-815 lux), medium illumination (415-500 lux), and low illumination (140-200 lux). We ensured a 3-minute adaptation period between changes in illumination.

Near addition differed significantly between the three illumination levels, $\chi^2(2) = 14.02$, $p = 0.001$. Specifically, near addition was significantly lower in bright illumination (median (IQR): 1.50 (1.00 - 1.75)) compared to moderate illumination (median (IQR): 2.00 (2.00 - 2.25), $p = 0.03$) and low illumination (median (IQR): 1.75 (1.50 - 2.00), $p < 0.001$). The difference in near addition between low and moderate illumination was not statistically significant ($p = 0.60$). The range of clear vision was also significantly influenced by illumination, with a shorter range observed in low illumination compared to bright illumination (10.00 (5.00 - 20.00) versus 15.00 (10.00 - 25.00), $p = 0.005$).

Our results demonstrate that exam room lighting significantly influences presbyopia correction outcome. Not adhering to the recommendation to measure near visual functions in bright illumination may result in prescribing a higher near addition, which corresponds to a shorter range of clear vision.

Keywords: presbyopia, near addition, the range of clear vision, illumination, lighting

Acknowledgements: I am thankful to bachelor student Sandra Sinavska and clinical optometrist Marika Kalnupa for their dedicated efforts in gathering the data for this study.

References:

[1] Y. Tsuneyoshi, S. Masui, H. Arai, I. Toda, M. Kubota, S. Kubota, K. Tsubota, M. Ayaki, and K. Negishi, "Determination of the standard visual criterion for diagnosing and treating presbyopia according to subjective patient symptoms," J. Clin. Med., vol. 10, 3546, 2021.

[2] J. S. Wolffsohn, L. N. Davies, and A. L. Sheppard, "New insights in presbyopia: impact of correction strategies," BMJ Open Ophthalmol., vol. 8, no. 1. 2023.

[3] E. K. Panagiotopoulou, K. Boboridis, I. Seimenis, and G. Labiris, "Impact of light conditions on visual performance following premium pseudophakic presbyopia corrections," J. Clin. Med., vol. 12, no. 13, 4324, 2023.

[4] J. S. Wolffsohn, D. Berkow, K. Y. Chan, S. K. Chaurasiya, D. Fadel, M. Haddad, T. Imane, L. Jones, A. L. Sheppard, M. Vianya-Estopa, K. Walsh, J. Woods, F. Zeri, and P. B. Morgan, "BCLA CLEAR Presbyopia: Evaluation and diagnosis," Cont Lens Anterior Eye, 18:102156, 2024.

UV-Vis-NIR persistent luminescence in Germanate-based materials

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ABSTRACT

Persistent luminescence (PersL) has attracted outstanding attention due to its noteworthy versatile functionality in applications ranging from anti-counterfeiting, safety signals, photocatalysis, and information storage, to bio-imaging, among others [1–4]. To exhibit PersL, materials need to possess two main types of centres, the emitter, which will dictate the spectral region/peak position of the emission, and trap centres within the host (e.g. intrinsic defects or impurities) that will capture the photogenerated carriers (storing energy during illumination), which will be then thermally (or photo) released, populating the optically active defects and resulting in light emission after removing the excitation source. As a result, this emission can last minutes, hours or even days [2,5]. Therefore, the selection of the host material is decisive. Among the different materials exploited for this purpose, wide bandgap germanate oxides have been standing out as an important class of PersL hosts [1,6,7].
In this talk, a brief overview of the PersL processes will be given and some of the results obtained so far will be presented. Emphasis will be placed on PersL in the ultraviolet (UV) spectral region that has been achieved with Bi-doped $LiYGeO_4$. This emission is peaked at ~350 nm, exhibiting an afterglow that extends for more than 7 h after ceasing the excitation (250 nm for 10 min). Interestingly, wavelengths longer than ~260 nm were seen to be inefficient for PersL in this material. On the other hand, visible and near-infrared (NIR) PersL were accomplished by nominally undoped (Mn and Cr as trace impurities) and intentionally Cr-doped Zn_2GeO_4, in which a green (~530 nm) afterglow of more than 8 h was observed for both samples. Moreover, an intentionally Cr-doped $Zn_{1+x}Ga_{2-2x}Ge_xO_4$ (deep-red) was produced, resulting in a PersL of more than 10 h when monitored at 694 nm, after excitation with 310 nm photons for 5 minutes. All materials were synthesized by solid-state reaction and characterized by electron microscopy, X-ray diffraction, Raman spectroscopy, diffuse reflectance, photoluminescence (PL), PL excitation and afterglow decay profiles. Particle-induced X-ray emission and nuclear reaction analysis were also assessed to determine the chemical elemental content. Thermoluminescence was conducted to get further insights into the defect state distribution and depth of the trap levels. These data highlighted the importance of the defects present in the host either as emitters or as trap centres responsible for PersL and allowed us to propose excitation mechanisms that play a role in the observed emissions.

Acknowledgements: This research was funded through the FCT–Portuguese Foundation for Science and Technology under the i3N project UIDB/50025/2020 & UIDP/50025/2020 & LA/P/0037/2020 and projects 2023.00054.RESTART and 2022.05329.PTDC (DOI: 10.54499/2022.05329.PTDC). J. Rodrigues acknowledges FCT for grant 2022.00010.CEECIND/CP1720/CT0023 (DOI: 10.54499/2022.00010.CEECIND/CP1720/CT0023). M. S. Batista thanks i3N and FCT for the PhD grant (UI/BD/152567/2022).

References:

[1] M.S. Batista, *et al.*, Optical Studies in Red/NIR Persistent Luminescent Cr-Doped Zinc Gallogermanate (ZGGO:Cr), Appl. Sci. 12 (2022) 2104.
[2] D. Poelman, *et al.*, Persistent phosphors for the future: Fit for the right application, J. Appl. Phys. 128 (2020) 240903.
[3] H. Shi, Z. An, Ultraviolet afterglow, Nat. Photonics. 13 (2019) 74–75.
[4] Y. Zhuang, *et al.*, Optical Data Storage and Multicolor Emission Readout on Flexible Films Using Deep-Trap Persistent Luminescence Materials, Adv. Funct. Mater. 28 (2018) 1705769.
[5] S. Wu, *et al.*, Recent Advances of Persistent Luminescence Nanoparticles in Bioapplications, Nano-Micro Lett. 12 (2020) 70.
[6] J. Shi, *et al.*, Super-Long Persistent Luminescence in the Ultraviolet A Region from a Bi^{3+} Doped $LiYGeO_4$ Phosphor, Adv. Opt. Mater. 7 (2019) 1900526.
[7] J. Dolado, *et al.*, Understanding the UV luminescence of zinc germanate: The role of native defects, Acta Mater. 196 (2020) 626–634.

Development of Multifunctional Liposomes Containing Magnetic/Gold Nanoparticles

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ABSTRACT

Multifunctional liposomes containing magnetic and plasmonic nanoparticles (magnetic/plasmonic liposomes) are a promising nanosystem for cancer therapy. Their structural and physical properties enable a synergistic behavior between dual hyperthermia (magneto-photothermia) and local chemotherapy, allowing overheating of cancer cells while increasing drug toxicity. [1-3].
In this work, multifunction liposomes based on magnetic/gold nanoparticles were developed (figure 1). To this end, cubic-shaped manganese ferrite nanoparticle clusters with a gold shell were synthesized. The growth of the gold shell on top of the magnetic nanoparticles clusters was monitored by UV-Vis-NIR, confirming the synthesis of the magnetic/plasmonic nanoparticles with a core-shell structure. Finally, the core-shell nanoparticles were coated with a surfactant/lipid bilayer using a previously described method [4], originating multifunctional liposomes with diameters around 200 nm. The structural characterization of the synthesized nanosystem was carried out by XRD, SEM, DLS and UV-Vis-NIR spectrophotometer. The heating capabilities of the obtained magnetic/plasmonic liposomes were evaluated under an 808nm laser (1W), due to the suitable absorption of the nanostructures at this wavelength (fig 1-B) and its biological window interest. Results show a significant temperature increase at the first 5 min of irradiation. Hence, the spectrophotometer plays a crucial role in the development of such nanosystems, allowing for rapid acquisition of data on their evolution and enabling precise selection of methodologies for subsequent protocols.

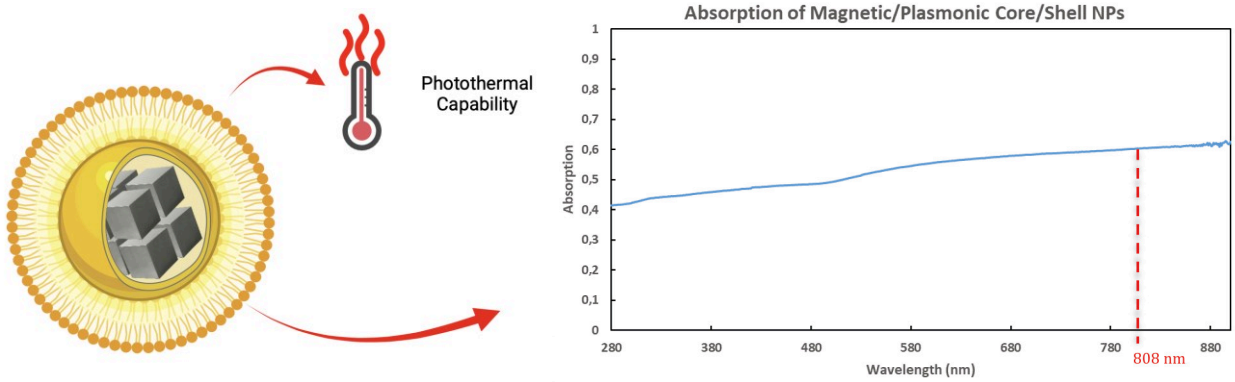

Figure 1. Schematic illustration of magnetoliposomes (A) and their absorption spectrum (B).

Keywords: Photothermia; Hiperthermia; Magnetic/plasmonic Nanoparticles; UV-Vis-NIR Spectrophotometer; Nanosystems;

References:

[1] E. Cazares-Cortes, “Recent insights in magnetic hyperthermia: From the “hot-spot” effect for local delivery to combined magneto-photothermia using magneto-plasmonic hybrids.” Advanced Drug Delivery Reviews, 138, 233–246, (2019).
[2] A.R.O, Rodrigues, “Development of Multifunctional Liposomes Containing Magnetic/Plasmonic MnFe2O4/Au Core/Shell Nanoparticles.” Pharmaceutics 11(1), 10, (2019).
[3] D. Titus, “Nanoparticle Characterization Techniques”. Green Synthesis, Characterization and Applications of Nanoparticles, 303–319 (2019).
[4] I.R.S. Rio, “Magnetoliposomes Based on Magnetic/Plasmonic Nanoparticles Loaded with Tricyclic Lactones for Combined Cancer Therapy.” Pharmaceutics 13(11), 1905, (2021).

High reflectivity band Distributed Bragg Reflector based on silicon-rich SiNx-SiOy at 80°C plasma-enhanced chemical vapour deposition

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ABSTRACT

Silicon nitride (SiN_x) is a tailoring material suitable for a large number of applications, like insulation layers, anti-reflective coatings and dielectric mirrors [1]. The aim of this study is to find the most convenient deposition parameters using plasma enhanced chemical vapour deposition (PECVD) at 80°C that provides to the SiN_x films the appropriate values in refractive index and mechanical stress to be used in the fabrication of self-supporting microelectromechanical systems (MEMS).
These devices consist of a concave movable mirror made of a SiN_x/SiO_y diffraction Bragg grating (DBR) that can find their application in tunable cavities or in vertical surface emitting lasers (VCSELs) [2, 3]. SiO_y, is a material that preserves its properties, as a compressive stress gradient (σ) and a refractive index n =1.45 while keeping an extinction coefficient k = 0 at 1550nm. This leads the investigation to focus the exploration and optimisation of silicon-rich SiN_x, searching for a high n at low k maintaining σ compatible with the curved shape of the MEMS that would provide an increased reflectivity and reflection band requiring less number of layers.
By using as precursor gases SiH_4 and N_2 with a flow ratio of 9.8:6 sccm, a pressure of 7.9 mTorr and a power of 200 W we could achieve thing films of silicon- rich SiN_x with n = 2.39 and k = 0.011 and a compressive σ = 135 MPa. The Young's Modulus E obtained by simulations in Comsol Multiphysics is between 56 and 90 GPa. Subsequently this silicon- rich SiN_x layers were used in the fabrication of concave DBRs together with SiO_y providing a reflectivity broader than 500nm measured with ellipsometry at 40°, Figure. 1, producing fully functional tunable mirrors.

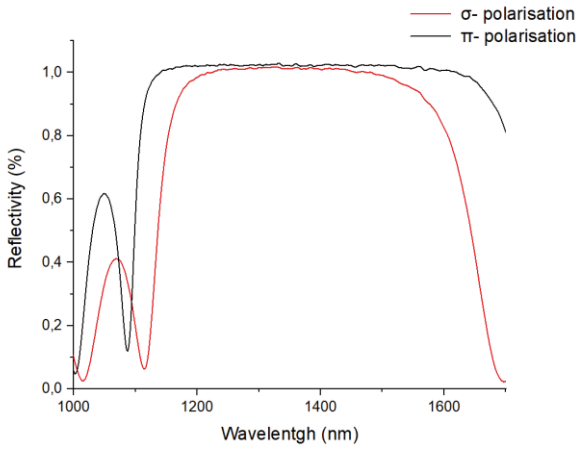

Figure 1. 6.5 layer pair SiN_x/SiO_y DBR for σ and π polarization under 40° incidence angle.

Keywords: MEMS, DBR, SiN_x, refractive index, Young modulus.

References:

[1] N. Hegedüs, K. Balázsi and C. Balázsi, " Silicon Niride and Hydrogenated Silicon Nitride Thin Films: A Review of Fabrication Methods and Applications", Materials, vol. 14, no. 5658, September 2021.
[2] Z. Shao, Y. Chen, H. Chen, Y. Zhang, F.Zhang, J. Jian, Z. Fan, L. Liu, C. Yang, L. Zhou and S. Yu, "Ultra-low temperature silicon nitride photonic integration platform," Optics express, vol. 24, no. 3, January 2016.
[3] C. Gierl, T. Gruendl, P. Debernardi, K. Zogal, C. Grasse, H. A. Davani, G. Bohm, S. Jatta,1 F. Kuppers, P. Meißner, and M.C. Amann, " Surface micromachined tunable 1.55 µm-VCSEL with 102 nm continuous single-mode tuning," Optics express, vol.19, no. 18, pp. 17336-17343, August 2011.

Refractive index analysis of planar interfaces by prism coupling technique

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ABSTRACT

For some years now, a number of foundries have made available the manufacture of integrated photonic structures for the visible spectrum and, as this technology makes its way into the market, a growing need will arise for accurate optical and dimensional characterization of such structures. To comply with this demand, we have developed a highly accurate optical characterization system based on the prism coupling technique [1] to investigate the optical properties of a-SiN:H planar waveguides deposited by plasma-enhanced chemical vapor deposition. The prism coupling technique is employed to excite waveguide modes resonantly in the waveguide through frustrated total internal reflection, using parallel or perpendicularly polarized light beams. Next, we calculate the waveguide's refractive index and thickness, and determine the interfaces' characteristics in terms of the refractive index gradient and roughness, through a developed mathematical model. Figure 1 presents the capabilities of our experimental optical setup in determining the effective refractive indexes of both transverse magnetic and electric modes of propagation within a planar waveguide of a-SiN:H, approximately 1 μm thick and which has been deposited over a substrate of optical glass (AF45).

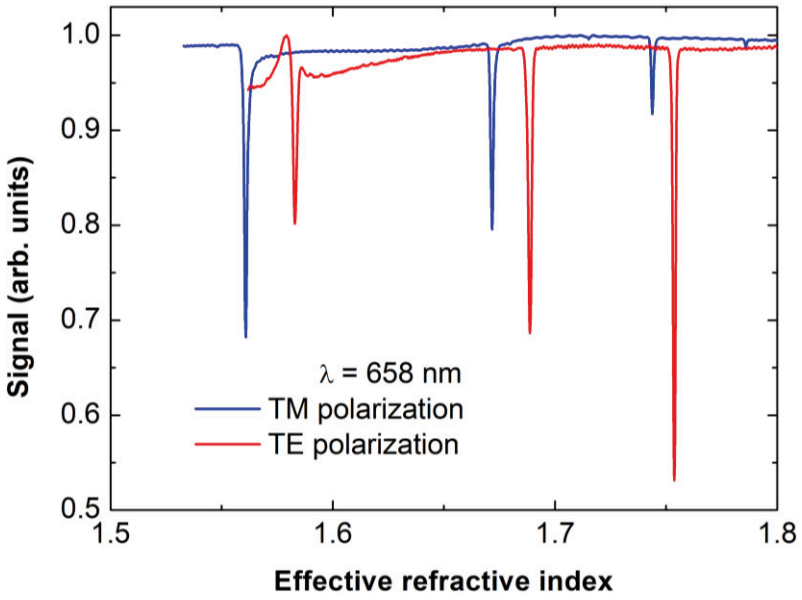

Figure 1. Experimental dependences for excitation of TM and TE modes in the a-SiN:H waveguide, where lower order modes correspond to higher effective refractive index in the graph.

Acknowledgements: This research was supported by Portuguese national funds provided by the Portuguese FCT program, Center of Technology and Systems (CTS) UIDB/00066/2020/UIDP/00066/2020, by FCT project ASER-META 2022.07694.PTDC and by IPL project IPL/IDI&CA2023/DETPREC_ISEL.

References:

[1] P. K. Tien, R. Ulrich, and R. J. Martin, "Modes of propagating light waves in thin deposited semiconductor films," *Appl. Phys. Lett.*, vol. 14, no. 9, pp. 291–294, 1969, doi: 10.1063/1.1652820.

Highly Efficient Deep Red-Emitting Mn^{4+} Phosphors for Enhanced Plant Growth and Advanced Optical Thermometry

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ABSTRACT

The present research focuses on the development of a highly efficient deep red-emitting Mn^{4+} phosphor [1], synthesized through a traditional solid-state reaction followed by ball milling, tailored for both temperature sensing and artificial plant growth applications. Structural analysis using Rietveld refinement of X-ray diffraction (XRD) data confirms the orthorhombic phase with a *Pbam* space group in the synthesized sample. High-resolution transmission electron microscopy (HRTEM) reveals the presence of small-sized particles lacking distinct shape or uniform size distribution.

Photoluminescence emission spectra demonstrate sharp peaks around 659 nm and 631 nm when excited by UV light at 317 nm and blue light at 417 nm, respectively. These emissions are attributed to the $^2E_g \rightarrow {}^4A_{2g}$ and $^2T_{1g} \rightarrow {}^4A_{2g}$ transitions of Mn^{4+} ions [2]. The red color purity of nearly 100% is confirmed from the color calculator software using the CIE coordinates under both UV and blue excitations. Additionally, calculations of absorption efficiency and internal and external quantum efficiencies under 417 nm blue excitation underscore the material's suitability for indoor plant growth applications [3].

A prototype red LED was created by coating the synthesized red-emitting phosphor powders onto a 410 nm blue LED chip. The electroluminescence spectra from this prototype overlap with the absorption spectra of key organic pigments in plants, making it ideal for promoting plant growth [4]. Moreover, a detailed assessment of the thermometric properties for fluorescence intensity ratio (FIR)- and lifetime-based thermometry reveals an impressive absolute sensitivity of 0.00326 K^{-1} at 373 K, coupled with excellent reproducibility and temperature resolution [5]. Due to its small particle size and high luminescent efficiency, this Mn^{4+} phosphor shows significant potential for integration into various devices that require high-performance, non-contact optical thermometry.

Keywords: Electroluminescence; Thermometry; Plant growth; LED chip; Quantum efficiency

Acknowledgements: The corresponding author Dr. Sudipta Som acknowledges the financial support from Shiv Nadar University Chennai to carry out this research.

References:

[1] H. Zhu, C. Lin, W. Luo, et al. “Highly efficient non-rare-earth red emitting phosphor for warm white light-emitting diodes”. Nat Commun 5, 4312 (2014).
[2] S. Adachi, S. “Review-Mn^{4+} activated Red and Deep Red-Emitting Phosphors”. ECS J. Solid State Sci. Technol. 9, 016001 (2020).
[3] X. Meng, Zhijun Wang, Zekang Yan, Dongxu Guo, Mengdi Liu, Jie Gong, Xiuxiu Feng, Ting Zhang, Xiaojie Lia, Panlai Li. “Flux induced highly efficient and stable phosphor $Sr_2ScSbO_6:Mn^{4+}$ for plant growth lighting”. J. Mater. Chem. C, 11, 5064-5072 (2023).
[4] Weixi Xia, Yulong Ye, Qinan Mao, Yang Ding, Xinyue Li, Meijiao Liu, Jiasong Zhong. “Engineering efficient blue and far-red dual-emitting phosphor for plant growth”. Materials Today Chemistry, 36, 101958 (2024).
[5] S. S. Liang, G. G. Li, P. P. Dang, Y. Wei, H. Z. Lian, J. Lin, “Cation Substitution Induced Adjustment on Lattice Structure and Photoluminescence Properties of $Mg_{14}Ge_5O_{24}:Mn^{4+}$: Optimized Emission for w-LED and Thermometry Applications”. Advanced Optical Materials 7, 1900093 (2019).

Structuring light with optical metasurfaces

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ABSTRACT

Metasurfaces are planar metamaterials consisting of nanostructures that allow to manipulate the phase, amplitude and polarization of light on a subwavelength scale with unprecedented control, representing the state-of-the-art in structured light [1]. This nanotechnology is not anymore an academic curiosity: today metasurfaces are being mass produced and can be fabricated with large areas (10 cm) using advanced lithography techniques [2]. These meta-optics are pushing the boundaries of structured light [3,4], allowing to exploit all of its degrees of freedom, even creating correlations between these resulting in complex multimodal forms of light, such as space-time beams [5]. In this contribution we will discuss the most recent advances in the field and where the most exciting opportunities lie ahead, in particular in the areas of nonlinear optics and structured laser-matter interactions.

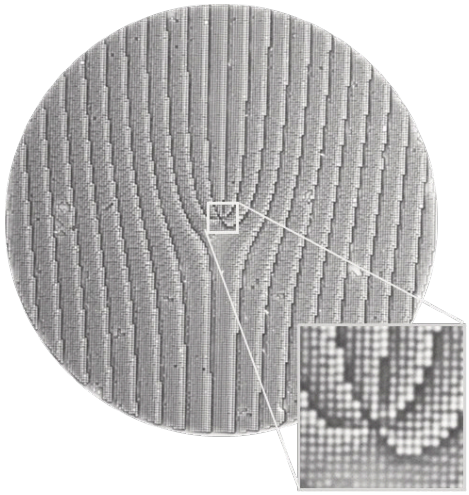

Figure 1. All-glass metasurface made of tall-vertical isotropic nanopillars producing a diffracted optical vortex.

Keywords: metasurfaces, structured light, space-time beams

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References:
[1] A.H. Dorrah *et al*., Tunable structured light with flat optics, Science 376.6591 (2022)
[2] J.S. Park *et al*., All-glass 100 mm Diameter Visible Metalens for Imaging the Cosmos, ACS nano 18, 3187 (2024)
[3] M. Piccardo *et al*., Arbitrary polarization conversion for pure vortex generation with a single metasurface, Nanophotonics, 0332 (2020)
[4] M. Piccardo *et al*., Vortex laser arrays with topological charge control and self-healing of defects, Nature Photonics 16, 359 (2022)
[5] M. Piccardo *et al*., Broadband control of topological-spectral correlations in space-time beams, Nature Photonics 17, 822 (2023)

Fully Connected Feedforward Neural Network for the Prediction of Amorphous Silicon Grating Couplers Efficiency

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ABSTRACT

Photonic circuits are an enabling technology for the development of novel solutions in different fields such as healthcare, quantum computing, neural networks, communications, and manufacturing. Interconnections between devices and systems require low-loss light coupling strategies. Grating couplers are a promising solution to couple light between photonic circuits and optical fibers due to their off-plane coupling capabilities. Hydrogenated amorphous silicon (a-Si:H), which can be deposited by PECVD over a substrate of silica or glass, is a suitable low-cost solution for the production of such light coupling devices. In this work we developed, trained and tested a fully connected feedforward neural network for coupling efficiency prediction in a-Si:H grating couplers. The light coupling gratings were simulated by two-dimensional finite-difference time-domain (FDTD) analysis and field distributions were analysed with the Finite Element Method (FEM). Simulated gratings include non-apodized, linear and quadratic refractive index variation designs featuring full or partial etching, operating at 1550 nm. Not featuring any type of bottom reflector, the couplers exhibit coupling efficiencies up to about 40 % (~ -4 dB). The neural network multiclass grating coupler efficiency classifier was trained with over 3000 simulation results, reaching an accuracy over 85%, for coupling efficiencies between 0 and 30%+.

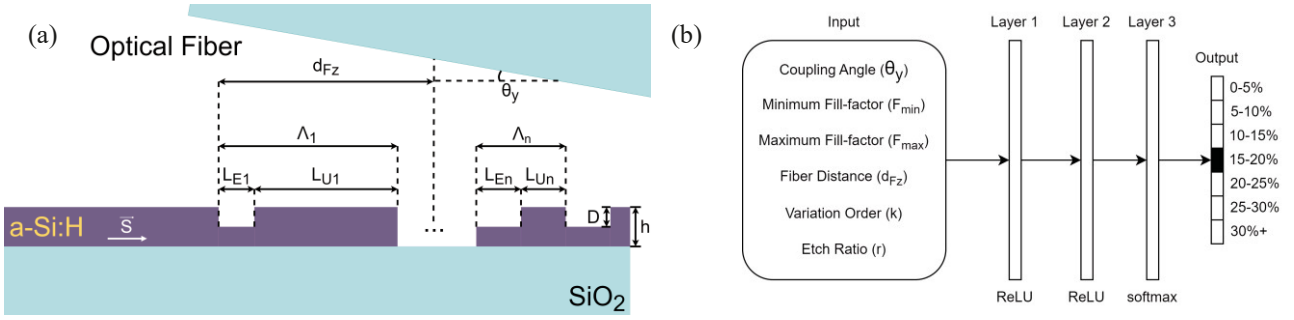

Figure 1. Grating coupler showing optimization parameters (a); Simplified neural network diagram (b).

Keywords: Grating coupler, light coupling, photonic circuit, amorphous silicon, neural network

Acknowledgements: This research was supported by Portuguese national funds provided by FCT – Fundação para a Ciência e a Tecnologia, through grant SFRH/BD/07792/2021 and funded by the Portuguese FCT program, Center of Technology and Systems (CTS) UIDB/00066/2020 / UIDP/00066/2020 and by FCT project ASER-META 2022.07694.PTDC

References:

[1] Miyatake, Y., Sekine, N., Toprasertpong, K., Takagi, S., & Takenaka, M. (2020). Computational design of efficient grating couplers using artificial intelligence. Japanese Journal of Applied Physics, 59(SG), SGGE09. Available: https://doi.org/10.7567/1347-4065/ab641c

[2] Almeida, D., Rossi, M., Lourenço, P., Fantoni, A., Costa, J., & Vieira, M. (2024, March). Amorphous silicon grating couplers based on random and quadratic variation of the refractive index. In Physics and Simulation of Optoelectronic Devices XXXII (Vol. 12880, pp. 125-133). SPIE. Available: https://doi.org/10.1117/12.3002858

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Manipulation of Microparticles in Optofluidic Devices Fabricated by Femtosecond Laser Micromachining

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ABSTRACT

In the past decade, micro-LOC (lab-on-a-chip) devices have proven to be a powerful and reliable biosensing technology for medical and healthcare applications, offering benefits such as point-of-care diagnostics, faster analysis, reduced reagent costs, and less chemical waste[1]. LOC technology enables the integration of multiple functions (fluidic, optical, electrochemical, …) onto a single chip with small dimensions, enhancing the automation, compactness, and portability of these devices.

One promising method for fabricating LOC devices is femtosecond (fs) laser micromachining. This technique, which can be applied to a wide range of materials transparent to the laser wavelength, relies on non-linear absorption of the pulsed laser beam and relaxation processes to alter the material properties at the laser beam's focal point. For instance, fs-laser exposure in fused silica can induce a refractive index increase or higher etching rate in HF acid[2]. This technique stands out from traditional planar microfabrication methods due to its capability for 3D machining and the integration of both optical and fluidic functions on a single chip. It enables the processing of fluidic samples—such as fluid mixing, particle functionalization, separation, or focusing—as well as their analysis through fluorescence, backscattered light, or optical trapping.

In this work, fs-laser micromachining is employed to fabricate optical waveguides and to create microfluidic channels and integrated micro-lenses in a fused silica substrate. Our main focus is to develop a flow cytometry device for optical manipulation and analysis of microparticles and cells. Precise control over particle movement and positioning within these channels is essential for achieving single-particle level sensing[3]. Despite particle flow being laminar, their distribution across the channel's cross-section is randomized, affecting the efficiency of the device. 3D fabrication enables the precise control over the distribution of microparticles inside the fabricated channels, both horizontally and vertically through hydrodynamic flow focusing (HFF). Just by adjusting the ratio between sheath and sample flow rates, we can control the spatial focusing of particles along the channel. As an example of horizontal HFF, 3 μm polystyrene particles were confined to a 10 μm layer across a 420 μm wide channel. The effectiveness of the device was demonstrated even with small flow rates as low as 1 μL/min. Laser writing of optical waveguides perpendicular to the microfluidic channel was also proven effective for manipulating particle positions within the flow or creating a dual-beam trap to capture microparticles. Further, integrated spherical micro-lenses with curvature radius as small as 100 μm and surface roughness below 100 nm have been fabricated to enhance the optical manipulation efficiency of the devices.

Keywords: fs-laser machining, hydrodynamic flow focusing, microfluidics, optical trapping, optofluidics

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References:

[1] Vashist, S. K., et al. " Emerging Technologies for Next-Generation Point-of-Care Testing." Trends in Biotechnology, Vol 33, no. 11, pp. 692-705, November 2015.

[2] Osellame, R., Femtosecond laser micromachining: photonic and microfluidic devices in transparent materials. Berlin: Springer, 2012.

[3] Storti, F., et al. "Simplified 3D hydrodynamic flow focusing for lab-on-chip single particle study." Scientific Reports, vol. 13, no. 1, Article 14671, 2023.

Smartphone Interrogation of Narrow Bragg Gratings in G.652 Fibre

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ABSTRACT

Fibre Bragg Grating (FBG) spectra using a smartphone have already been measured [1,2]. The first paper describes the interrogation of a chirped-FBG (FWHM ~ 6 nm) inscribed in multi-mode G.651 fibre and its strain sensitivity, whereas the second one describes the smartphone measurement of narrow FBG (FWHM ~ 0.2 nm) produced in standard G.652 fibre; their authors reported the shift of the central wavelength with temperature, replicating the FBG use as a thermal sensor. The authors of [1] state that FBG spectra in the visible should not be observed in single-mode fibres with the smartphone's LED source. However, that was previously reported in [3], using the light source of a smartphone, and replicated in [2]. The present work complements the measurement techniques of FBG in standard G.652 fibres with use of a smartphone, either in transmission or reflection set-ups.

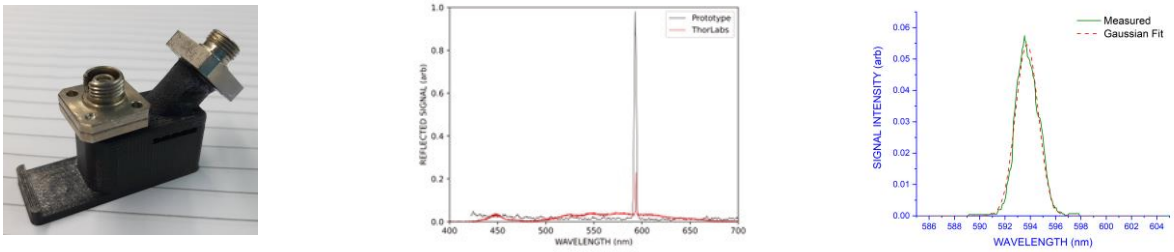

Figure 1. Left: Smartphone coupling device incorporating a transmissive diffraction grating. Centre: Reflection spectra of FBG measured with the apparatus, as compared to that obtained with a commercial spectrometer. Right: Detailed spectrum with Gaussian best-fit.

Fig. 1-centre shows the spectrum of a FBG measured with aid of the coupling device (Fig.1-left) as compared to that obtained with a commercial spectrometer. At the left side of the figure, an expanded view is presented, together with a Gaussian best-fit. Spectral calibration was achieved using narrow lines from fluorescent lamps and visible lasers in the green and red regions. The use of a transmission grating in the coupling device and the non-chirped FBG in the SMF helps to the excellent signal to noise obtained ratio, even with the narrow FBG (the observed linewidth is limited by the coupling device/CCD resolution).
Transmission spectra are also obtained. Results forecast dissemination of FBG sensor units in point sensing along distributed regions or consumer applications, profiting from the wider smartphone connectivity.

Keywords: Fibre Bragg Grating, Smartphone Spectroscopic Measurements

Acknowledgements: CNPq, FAPERJ (Brazilian Funding Agencies) and MULTI-FOTON (UTFPR) for providing the samples.

References:
[1] A.A. Markvart, L.B. Liokumovich, I.O. Medvedev, N.A. Ushakov, "Smartphone-based interrogation of a chirped FBG strain sensor inscribed in a multimode fiber," J. Lightwave Technol., vol. 39, no. 1, pp. 282–289, 2021.
[2] G.C. Mastrapa, A.A.C.O. Santos, G.G. Guimarães, H.J. Kalinowski, "Smartphone reading of standard Bragg gratings in single mode optical fiber," As. J. Phys., vol. 30, no. 5, pp.809–813, 2021.
[3] G.C. Mastrapa, G.C. Guimarães, P.L. Inácio, V. Oliveira, H.J. Kalinowski, "Fibre Bragg gratings in the visible: towards low-cost detection," in Photonics Europe Optical Sensing and Detection, Strasbourg, April 2018 (Proc. SPIE 1068, #106800N).

Study of photoelectric effect in gallium oxide-based sensors

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ABSTRACT

During the last decade Gallium oxide (Ga_2O_3) has emerged as a viable candidate for a number of power electronic and optoelectronic devices with potentiality to exceed existing technology based on well-established wideband gap semiconductors. This ultra-wide bandgap semiconductor with room temperature bandgap around ~4.8 eV (reported in the range 4.6-4.9 eV) has five different polymorph, namely, rhombohedral (α), monoclinic (β), cubic (δ), defective spinel (γ), or orthorhombic (ε) structures [1]. Among them, the β-polymorph phase is the most thermodynamically stable and bulk crystals have been successfully grown from various melting methods. As result, the β-Ga_2O_3 polytype is the most widely studied and utilized on the fabrication of testing devices. This semiconductor is typically semi-insulator or n-type conductor, depending on the concentration of intrinsic point defects (oxygen or gallium vacancies) and/or background impurities [2]. The goals of this work is to understand the deposition of high quality β-phase Ga_2O_3 films by Ion Beam Assisted Deposition (IBAD) method and its potential application as optoelectronic sensor. Our research was focused on the deposition of high quality β-phase Ga_2O_3 thin films on Si substrates at room temperature with optimize deposition conditions to produce films with improved structural, optical, and electronic properties. The Ga_2O_3 β-phase was verified by XRD analysis, while the bandgap value was obtained using the Tauc method.

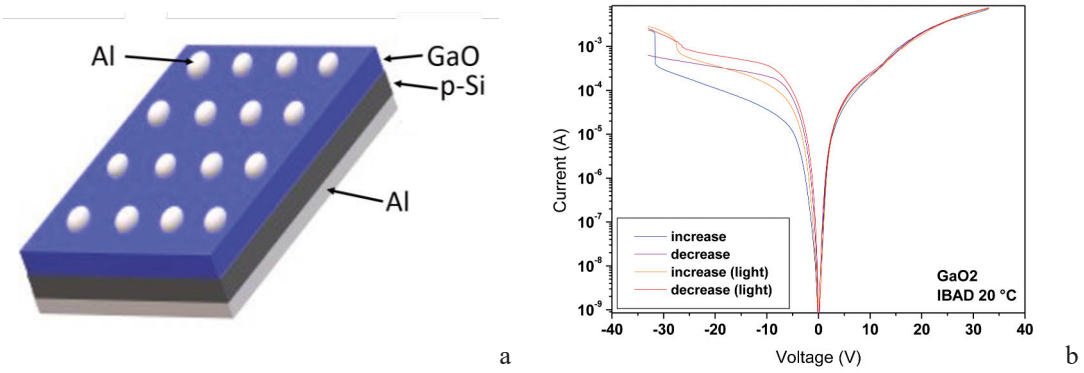

Figure 1. a) sensor device and b) IxV measurements.

Evaporated aluminium films at the top and bottom surfaces of the templates were employed as device contacts. A probed device structure is depicted in Figure 1a, which is comprised of four layers: Al/Si/Ga_2O_3/Al. RBS analyses indicate that thin silicon oxide interface layers were formed on p-type Si surface during the IBAD deposition process, which may results from oxygen ion beam falling on the substrate prior gallium oxide film deposition. There is still a process of formation of Ga_2O_3 doped with aluminium at the interface of the Al contacts and the insulating Ga_2O_3 layer. Current versus voltage (IxV) measurements were obtained using an HP 4140B picoammeter (Figure 1b). Data acquired under light soaking, using a halogen lamp, will be presented. The devices showed photoelectric effect and Schottky behaviour.

References:

[1] M. J. Tadjer, J. A. Freitas, J. C. Culbertson, E. R. Glaser, A. Mock, J. C. Gallagher, K. J. Schmieder, E. M. Jackson, N. A. Mahadik, B. N. Feygelson, A. Kuramata. "Structural and Electronic Properties of Si- and Sn-doped (-201) ß-Ga2O3 Annealed in Nitrogen and Oxygen Atmospheres" Journal of Physics D: Applied Physics 53 (2020): 504002-1-5040

[2] J. Zhang, J. Shi, D. Qi, L. Chen, K. H. L. Zhang, "Recent progress on the electronic structure, defect, and doping properties of Ga_2O_3", APL Materials, 2020.

Multidisciplinary applications for high power laser pulses: an update of the L2I facility

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ABSTRACT

The ongoing development of high repetition rate lasers sources such as those relying on diode pumped Yb doped media has led to commercial availability of mJ level pulses with pulse durations at the picosecond and at 100 kHz. These high average power lasers can drive high average and peak power laser systems via efficient nonlinear processes such as the use of MultiPass Cells (MPC) or Optical Parametric Chirped Pulse Amplification (OPCPA) chains [1]. Techniques such as MPC and OPCPA can also be used in tandem to allow for an extension of these high peak and average power sources towards the few tens of femtoseconds, with tunable wavelengths. The Laboratorio de Lasers Intensos (L2I) has a 100 kHz, 1 ps, 1 mJ Amphos system, this laser is used directly (as is or pulse-picked for repetition rate control) for several applications, but also drives a 3.1 um OPCPA system from Fastlite delivering 60 uJ, 40 fs pulses, or an N2Photonics MPC yielding 100 fs, 1030 nm 0.66 mJ pulses. mJ scaling of the Mid-IR pulses [2] is currently underway, and a YCOB based OPCPA [3] is been adapted with the MPC pulses as its driver.

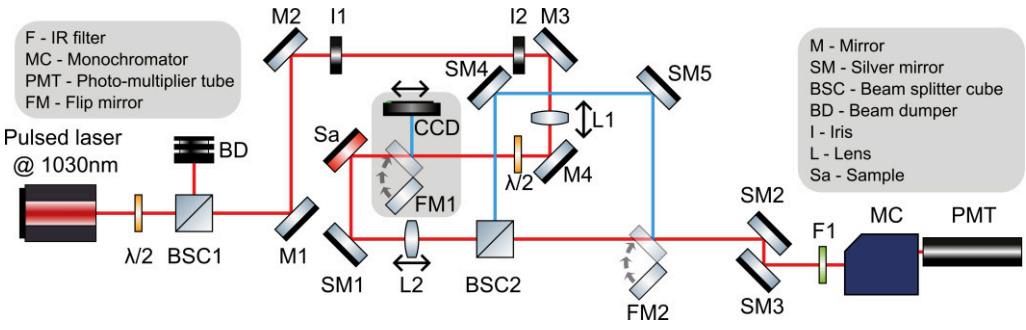

Figure 1. Diagram of the experimental setup

We present the current state of L2I, and of the multidisciplinary applications being driven with the available laser sources, as well as the near-terms prospects.

Keywords: ultrafast lasers, nonlinear optics, nonlinear amplification; ultrashort pulses; parametric amplification; high power laser

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References:

[1] H. Fattahi et al, "Third-generation femtosecond technology," Optica 1, 45-63 (2014).
[2] Alves, J. et al, "Multi-mJ Scaling of 5-Optical Cycle, 3 μm OPCPA". Photonics 2021, 8, 503.
[3] Pires, H. et al "Ultrabroadband OPA in YCOB with a sub-ps Pump Source" Photonics 2023, 10, 253

Abrupt transition to coherent emission in a semiconductor laser with optical feedback

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Semiconductor lasers are very sensitive to optical feedback, which reduces the laser threshold and can induce chaotic emission. While feedback effects have been extensively studied, how feedback affects the laser turn-on transition (from low-coherence radiation dominated by spontaneous emission to high-coherence radiation dominated by stimulated emission), had not yet been analysed. Here, we present the results of an experimental study using the speckle technique [1]. We show that the transition from low coherence (below threshold) to high coherence (above threshold) varies from smooth to abrupt as the amount of light fed back to the laser increases. Speckle is a granular, noisy spatial structure produced by the interference of coherent waves. When laser light propagates through a scattering medium, usable information can be obtained from the analysis of the speckle pattern. We demonstrate that the effect of optical feedback in the coherence of the light emitted during the turn-on is unveiled by the amount of speckle generated.
The experimental setup is shown in Fig. 1. The insets show examples of speckle images recorded below and above threshold. Figure 1(a) shows the LI curve for different feedback strengths, from which the threshold of the laser can be extracted for each feedback scenario. We note that shape of the LI curve is the same with and without feedback, and the only evident effect of the feedback is the lowering of the threshold current. For different pump current and feedback strength, we recorded several speckle images from which the speckle contrast, SC, was calculated in the center of the image, after subtracting the background. The SC is the ratio between the standard deviation of the values of the pixels, and the average value, $SC = \sigma_I / < I >$, that allows us to quantify the coherence of the light. Figure 1(b) shows the SC for different feedback strengths and pump currents conditions. Here we see that, the stronger the feedback, the more abrupt is the increase of the coherence of the laser light, when the laser turns on. To shed light on the mechanisms underlying the abrupt increase of coherence revealed by the SC, simulations using single-mode and multi-mode models are planned.

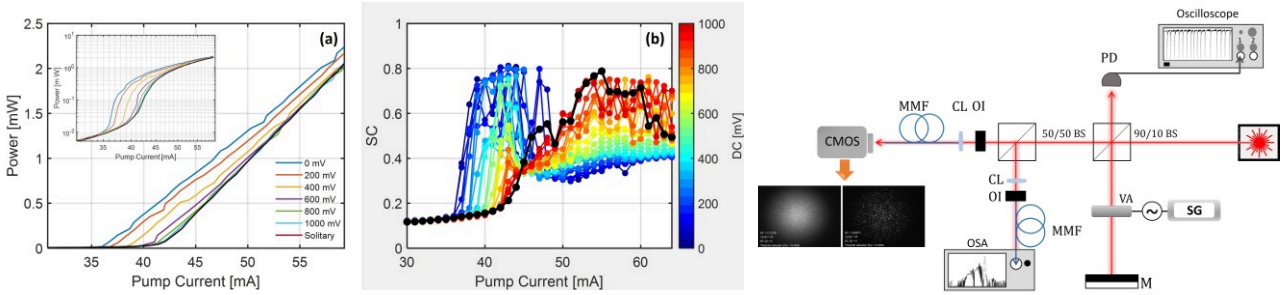

Figure 1. Right: LI curve (a) and speckle contrast (SC) (b) vs. pump current for different feedback strengths. The color code indicates the voltage in the Variable Attenuator (the higher the voltage-the lower the feedback). Left: Experimental setup. A: Manual Attenuator, VA: Variable Attenuator, MMF: Multi-Mode Fiber, BS: Beam Splitter, OI: Optical Isolator, OSA: Optical Spectrum Analyzer.

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References:
[1] M. Duque Gijón, C. Masoller, and J. Tiana-Alsina, "*Abrupt transition from low-coherence to high-coherence radiation in a semiconductor laser with optical feedback*", Opt. Express 31, 3857-3864 (2023).

Yb:YAG fibre laser applied to the conservation of built heritage: Preliminary results on the removal of black crusts from granite.

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ABSTRACT

Laser cleaning is a well-known technique in the heritage sector, where solid-state lasers are usually used to remove incrustations, patinas or vandal graffiti from granite and other building stones [1]; however, lasers based on Yb-doped fibres have become increasingly important in recent years. Compact and lightweight, they are easy to transport, even on scaffolding, and require relatively little maintenance. These fibre lasers can operate at repetition rates in the kHz range with a beam scanning system and can be coupled to robotic arms. Despite these features of laser systems, which make them attractive for heritage conservation applications, few studies have been reported on the removal of deposits from stone using these devices [2].
In this paper we present preliminary results of the use of a Yb:YAG fibre laser for cleaning granite samples from the František Palacký Road Bridge over the Vltava River in the historical centre of Nové Město (Prague), which is part of the cultural heritage of the Czech Republic. Small samples of black crusts on the granite ashlars of the bridge's piers and arches were selected and characterised using techniques including Raman spectroscopy, XRF mapping and scanning electron microscopy. The results show that most of the black crusts contain S, derived from fossil fuels, and under the microscope they appear to be deeply embedded between the crystals of the granite surface and are very irregular in thickness. To remove the crusts, different laser parameters were tested: power, pulse repetition rate, scanning speed and scanning pattern, in order to obtain the most suitable for efficient removal without damaging the substrate. These results, although preliminary, demonstrate the ability of this laser to be used in situ for the cleaning and conservation of granite in facades and monuments of cultural heritage.

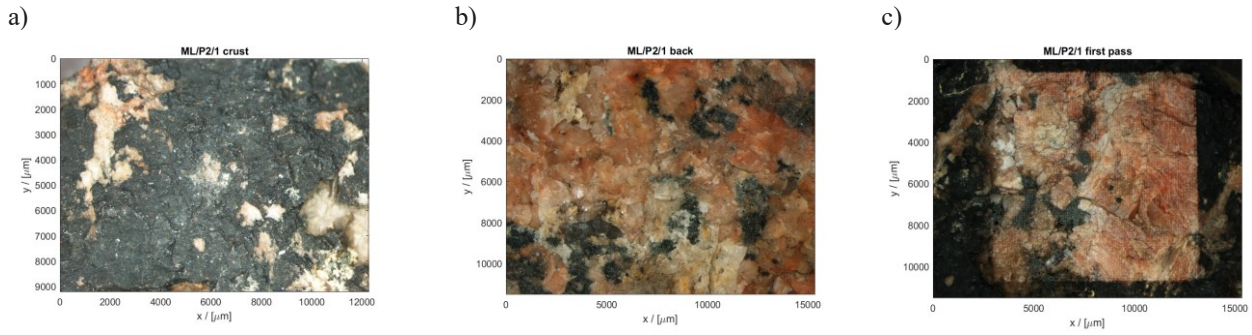

Figure 1. Images of a sample from the bridge´s pier: a) Black crust, b) Fresh granite, c) After Yb:YAG laser cleaning.

Keywords: Cultural Heritage, Fibre laser, Yb:YAG, granite, crust removal

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References:

[1] Lopez, Ana J., et al. Development of processing strategies for 3D controlled laser ablation: Application to the cleaning of stonework surfaces. Optics and Lasers in Engineering 126 (2020): 105897 https://doi.org/10.1016/j.optlaseng.2019.105897
[2] Suzuki, A., Riminesi, C., Ricci, M. et al. Testing of a new Yb:YAG fiber laser system for the removal of graphic vandalism from marble. Heritage Science 11, 132 (2023). https://doi.org/10.1186/s40494-023-00966-9

Quartic Soliton Solutions of a Mode-Locked Laser Distributed Model with Normal Fourth-Order Dispersion

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ABSTRACT

Quartic solitons (QSs) are shape-preserving wave structures which arise from the interplay of Kerr nonlinearity with fourth-order dispersion (4OD). In conservative media, QSs exist only for anomalous 4OD, but in optical media where energy exchange mechanisms are present, i.e. dissipative media, QSs also exist for normal 4OD [1-5]. Following our previous work [6], the formation and propagation of QSs in mode-locked lasers can be modelled through a distributed equation.

While numerical solutions of the evolution equation for anomalous 4OD showed a single type of solution, three types of solutions were found for normal 4OD, which were named as low, medium, and high-amplitude solutions (LASs, MASs and HASs respectively) and are represented in Fig. 1. LASs are never stable under propagation, evolving to MASs if the latter are stable in the working parameter region. We found parameter regions where MASs and HASs exist and are stable, finding that, within a short parameter space, these two types of solutions can coexist, and their evolution exhibits hysteresis. Both types of solutions were characterized by their energy and width, with HASs being much more energetic and MAS being significantly narrower.

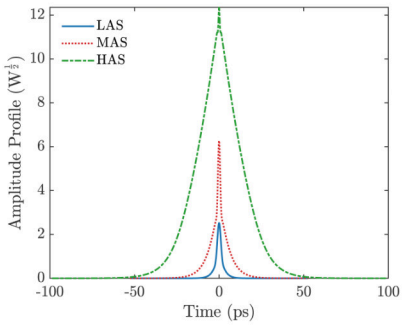

Figure 1. Amplitude profiles of the three types of quartic solitons obtained under the normal 4OD regime.

Keywords: Quartic Solitons, Dissipative Solitons, Normal Fourth-Order Dispersion, Mode-Locked Lasers

Acknowledgements: This work was developed under projects UIDB/50025/2020, UIDP/50025/2020, LA/P/0037/2020, UIDB/50014/2020 financed through national funds by FCT and the MEC of Portugal.

References:

[1] M. Karlsson and A. Höök, "Soliton-like pulses governed by fourth order dispersion in optical fibers," *Opt Commun*, vol. 104, pp. 303–307, 1994.
[2] N. Akhmediev, A. V Buryak, and M. Karlsson, "Radiationless optical solitons with oscillating tails," *Opt Commun*, vol. 110, pp. 540–544, 1994.
[3] A. Blanco-Redondo, C. M. De Sterke, J. E. Sipe, T. F. Krauss, B. J. Eggleton, and C. Husko, "Pure-quartic solitons," *Nat Commun*, vol. 7, Jan. 2016.
[4] A. F. J. Runge *et al.*, "Self-similar propagation of optical pulses in fibers with positive quartic dispersion," *Opt Lett*, vol. 45, no. 13, p. 3365, Jul. 2020.
[5] Z.-C. Qian, M. Liu, A.-P. Luo, Z.-C. Luo, and W.-C. Xu, "Dissipative pure-quartic soliton fiber laser," *Opt Express*, vol. 30, no. 12, p. 22066, Jun. 2022.
[6] D. Malheiro, M. Facão, and M. I. Carvalho, "Quartic solitons of a mode-locked laser distributed model," *Opt Lett*, vol. 48, no. 21, p. 5639, Nov. 2023.

Unlocking New Dynamics in Paraxial Fluids of Light with an Optical Feedback Loop

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ABSTRACT

In recent years, the exploration of optical analogues using paraxial fluids of light has gained significant interest [1-3]. However, experimental limitations, such as the fixed size of the nonlinear media, have often obstructed the observation of the desired dynamics, restricting access only to the output state and constraining the total temporal dynamics.
To overcome these challenges, we developed an optical feedback loop that involves measuring the output state using off-axis digital holography [4] and reconstructing it at the entrance of the medium using Spatial Light Modulators. This approach extends the analogue emulation time and provides access to intermediate states. This configuration also allows precise control over the amplitude and phase profiles of the beam at the medium input, allowing in the future the experimental realization of emulations with non-trivial initial conditions. With a photorefractive crystal as the nonlinear medium, we demonstrate the capabilities of this setup through various case studies.

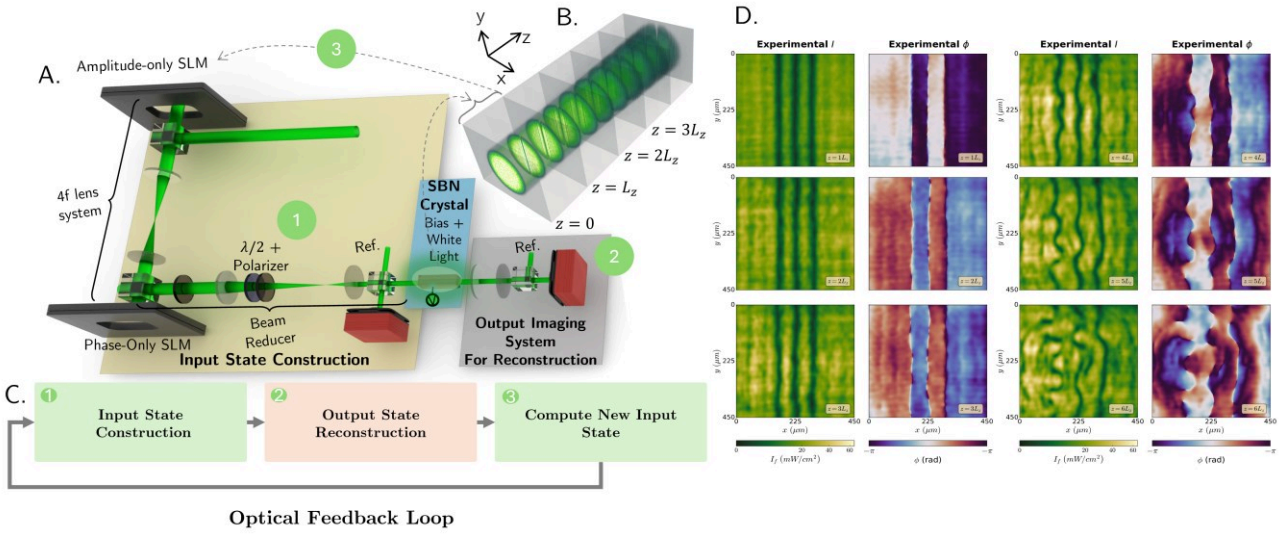

Figure 1. A. – Experimental setup implemented for the optical feedback loop. B. – Three-dimensional representation of a state evolving inside the crystal. C. – Feedback loop conceptual scheme. D. - Decay of 3 dark solitons for 6 feedback loop passages.

Keywords: Paraxial fluids of Light; Optical Feedback Loop; Optical Analogues; Analogue Quantum Turbulence; Photorefractive Material.

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References:

[1] Carusotto, Proceedings of the Royal Society A 470, 20140320 (2014).
[2] T. D. Ferreira, V. Rocha, D. Silva, A. Guerreiro, and N. A. Silva, New J. Phy 24, 113050 (2022).
[3] T. D. Ferreira, J. Garwola, and N. A. Silva, Physical Review A 109, 043704 (2024).
[4] E. Cuche, P. Marquet, and C. Depeursinge, Applied optics 39, 4070 (2000).

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Turbulence impacted wavefront corrections without conventional adaptive optics

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ABSTRACT

Conventionally there are several adaptive optics techniques for correcting the turbulence induced aberrations like i) phase conjugation, ii) deformable mirror based correcting adaptive optics system and iii) segmented mirrors based adaptive optics system [1]. Though one can correct the higher order turbulent induced aberrations using deformable mirrors/segmented mirrors/phase conjugate optics, we require additional precision optics and normally there are practical difficulties in achieving phase conjugation and other adaptive optics techniques. The main disadvantage in adaptive optics compensation is cost and complexity. So, it becomes necessary to design a new correction method for turbulence impacted wavefronts. In this paper we will be developing following new unconventional adaptive optics techniques for correcting turbulent affected distorted wavefront. i) Beam shaping after impact of turbulence ii) Beam cleaning using two wave mixing iii) Beam cleaning using enhanced back scattering respectively. In general, the atmospheric turbulence distorts the propagating beams resulting in scintillations (Intensity fluctuations), beam wandering and beam spreading. One has to reduce significantly these three parameters. In the first technique a laser beam is allowed to pass through a dynamic Pseudo Random Phase Plate (PRPP) which mimics the Kolmogorov type turbulent medium. The incident laser beam after spatial filtering will pass through the PRPP and is distorted due to the impact of turbulence which then is allowed to fall on a Vortex phase plate (VPP) which can shape the distorted beams in to different Laguerre Gaussian (LG) beams of different topological charges. Now, the turbulence impacted structured beams are allowed to pass through a 4f geometry where, the shape of beam is measured at 5 different planes. It is found that the beam shaping after the turbulence impact compared to propagating topological charged beams of different charges through turbulence reduces scintillation index significantly [2]. In the next method for the first time we have used a photorefractive Bismuth Titanium Oxide (BTO) crystal for beam cleaning using two wave mixing phenomena and photorefractive effect. In a typical two wave mixing geometry where both turbulence impacted beam and probe beam mix inside a photorefractive BTO crystal, significant reduction in scintillation index compared to turbulence impacted beam before two wave mixing is obtained. Finally in our third correction method, we use a double passage of aberrated beam through PRPP where a beam travels twice through turbulence and becomes more symmetrical. In this method our results show that, the Laguerre Gaussian (LG) and Bessel Gaussian beam passes through the same turbulence twice and in case of double passage of structured laser beams via a conventional mirror and retro-reflector we found that the scintillation index significantly is lesser for a Bessel Gaussian beam compared to Laguerre Gaussian beams when it is retro-reflected via the same turbulence impact.

Acknowledgement:
The author acknowledges SERB/DST, Govt. Of India (CRG/2020/003338) for funding and the Indian Institute of Space Science and Technology for the support.

References:
[1] R.K. Tyson, Principles of adaptive optics, 2nd ed, Academic Press, Boston, 19982.
[2] Shouvik Sadhukhan and C S Narayanamurthy "Turbulence Impacted Wavefront Corrections Using Beam Modulation Technique, Optics Communications (Elsevier), Accepted 2024
[3] Turbulence impacted wavefront correction using the photorefractive effect (To be Communicated).

Numerical evaluation of strain transfer model for steel-reinforced optical fiber cable embedded in a cylindrical concrete beam with two void inclusions

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ABSTRACT

The strain transfer in distributed optical fiber sensors is described through a simplified one-dimensional equation, derived from a more complex three-dimensional model based on continuum mechanics principles. This equation establishes a relationship between the measured longitudinal strain profile within the optical fiber and the real strain profile occurring in the host material, incorporating a parameter known as the strain-lag parameter. This parameter is influenced by the cable's geometric and mechanical characteristics. In the case of steel-reinforced optical fiber cables, valued for their resistance to breakage, a notable discrepancy between the measured and actual strain profiles is detected especially in the presence of a strain gradient, indicating that the ability to transfer strain from the host material to the optical fiber is restrained using this type of cable. This paper assesses numerically the strain transfer model for steel-reinforced optical fiber sensors in the presence of a strain gradient generated by two void inclusions in a concrete beam. The good accuracy of the strain transfer model is observed by the comparison with a 3D finite element simulation. However, the result points out the critical necessity of precisely determining the strain-lag parameter.

Keywords: Distributed optical fiber sensors, mechanical strain transfer, structural health monitoring

References:

[1] Pierre Ferdinand, “The Evolution of Optical Fiber Sensors Technologies During the 35 Last Years and Their Applications in Structure Health Monitoring”, 7th European Workshop on Structural Health Monitoring July 8-11, 2014. La Cité, Nantes, France.
[2] Barrias A, Casas JR, Villalba S. A Review of Distributed Optical Fiber Sensors for Civil Engineering Applications, Sensors (Basel), May 2016.
[3] Brian J. Soller, Dawn K. Gifford, Matthew S. Wolfe, and Mark E. Froggatt,” High-resolution optical frequency domain reflectometry for characterization of components and assemblies,” Opt. Express 13, 666-674 (2005).
[4] Farhad Ansari and Yuan Libo, “Mechanics of Bond and Interface Shear Transfer in Optical Fiber Sensors,” Journal of Engineering Mechanics, vol. 124, no. 4, pp. 385-394, 1998.
[5] Huaping Wang and Zhi Zhou, “Advances of strain transfer analysis of optical fiber sensors,” Pacific Science Review, vol. 7677, pp.8–18, Sep. 2014.
[6] Antoine Bassil, Distributed Fiber Optics Sensing for Crack Monitoring of Concrete Structures, PhD thesis, Université de Nantes, Nov. 2019.
[7] Arianna Piccolo et al., “Mechanical Properties of Optical Fiber Strain Sensing Cables under γ-Ray Irradiation and Large Strain
[8] Xing Zheng, Bin Shi, Cheng-Cheng Zhang, Yijie Sun, Lei Zhang, Heming Han, ”Strain transfer mechanism in surface-bonded distributed fiber-optics sensors subjected to linear strain gradients: Theoretical modeling and experimental validation”, Measurement, Volume 179, 2021.
[9] Xavier Chapeleau and Antoine Bassil, “A General Solution to Determine Strain Profile in the Core of Distributed Fiber Optic Sensors under Any Arbitrary Strain Fields,” Sensors, vol. 21, no. 16, pp. 1–33, Jan. 2021.

Towards All-Optical Extreme Learning Machines

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ABSTRACT

With the advent of neuromorphic systems, optical computing(OC) has found a new framework for highspeed and energy-efficient computing. In particular, we emphasize the Photonic Extreme Learning Machine(PELM) [1] framework as a versatile and easy-to-implement neural network architecture for OC, resulting in a series of implementations with a list of optical devices [2,3]. By leveraging a random mapping neural network [4], these configurations explore the high-dimensional hidden space as a playground to extract solutions to a series of tasks. Nevertheless, the lack of training in these systems currently implies an immediate limitation. Thus far, these systems have not found a suitable configuration to achieve an all-optical processing computing methodology.

In this work, we extend the PELM computing configuration towards enabling all-optical information processing. The proposed methodology leverages amplitude modulation by an output spatial light modulator (SLM), see Figure 1.a. Exploring an in silico training methodology via the mathematical model developed to train the physical system, in Figure 1.b we showcase the results obtained with the digital model. Additionally, Figure 1.c presents the initial results indicating the all-optical classification of points belonging to two ring-like distributions.

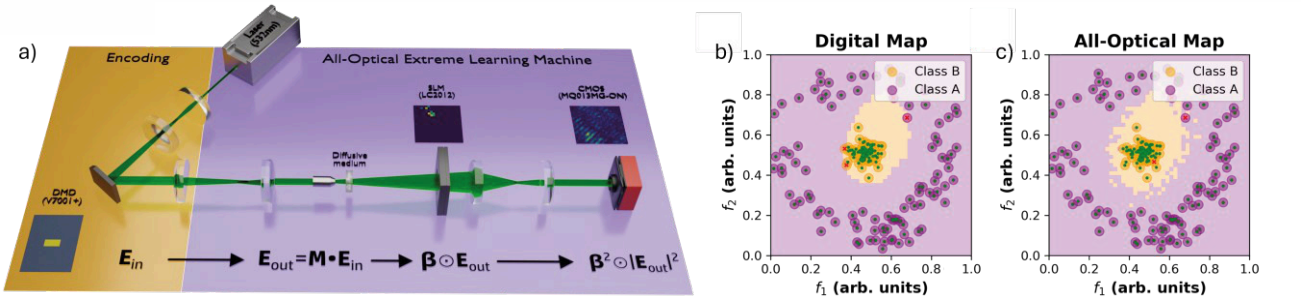

Figure 1. All-optical PELM methodology. a) Optical configuration used to extend the PELM towards all-optical information processing, featuring an output SLM. b) Classification test results from training the digital model using the developed mathematical framework. c) All-optical classification results achieved by transferring the trained digital model weight configuration to the SLM.

To conclude, our preliminary experimental results suggest that the proposed methodology can extend the capabilities of PELM towards all-optical processing. Furthermore, the agreement between the results obtained from the digital model used to train the system and the all-optical results supports the validity of our training method.

Keywords: All-optical Computing, Neuromorphic Computing, Reservoir Computing

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References:

[1] Pierangeli, D., Marcucci, G., & Conti, C. (2021). Photonic extreme learning machine by free-space optical propagation. Photonics Research, 9(8), 1446-1454.
[2] Zheng, M., Shi, L., & Zi, J. (2022). Optimize performance of a diffractive neural network by controlling the Fresnel number. Photonics Research, 10(11), 2667-2676.
[3] Yan, T., Wu, J., Zhou, T., Xie, H., Xu, F., Fan, J., ... & Dai, Q. (2019). Fourier-space diffractive deep neural network. Physical review letters, 123(2), 023901.
[4] Huang, G. B., Zhu, Q. Y., & Siew, C. K. (2006). Extreme learning machine: theory and applications. Neurocomputing, 70(1-3), 489501.

Accelerating Spectral Imaging with Optical Computing: A Fourier-Based Feature Extraction Approach

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ABSTRACT

Spectral imaging is a versatile tool in industrial and scientific realms, enabling spatial analysis of materials at various levels, e.g., LIBS for elemental compositions, hyperspectral reflectance for molecular compositions, and Raman spectroscopy for molecular structure. Yet, these detailed analyses produce large volumes of data [1], leading to complex data transfer requirements and complicating processing tasks. Based on these concerns, feature extraction techniques play a pivotal role in this field by allowing us to discriminate relevant spectral ranges for subsequent analysis.

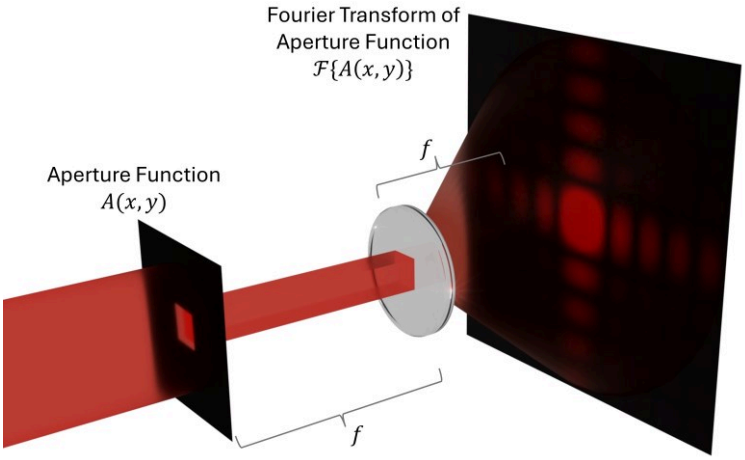

Figure 1. Illustrative image displaying the focal planes of a lens are related by the Fourier Transform.

While traditional feature extraction methods often include visual analysis, peak-finding algorithms, and mean signal analysis, these suffer from low signal-to-noise ratios or interference, in addition to personal bias leading to significant data loss which can be detrimental to proper analysis. In response, this work introduces a novel feature extraction approach utilizing an agnostic processing pipeline [2]. This method employs a spatial information ratio metric calculated in Fourier space for each wavelength, enhancing the robustness of identifying relevant spectral ranges. Furthermore, we explore an optical computing implementation of the algorithm to achieve faster and more energy-efficient data processing, aiming for real-time, in-line feature extraction. This development marks a significant advancement in spectral imaging by streamlining complex processes and mitigating typical analytical challenges.

Keywords: Spectral Imaging, Data Processing, Optical Computing

References:

[1] Ang, Kenneth Li-Minn, and Jasmine Kah Phooi Seng. "Big data and machine learning with hyperspectral information in agriculture." IEEE Access 9 (2021): 36699-36718.
[2] Lopes, Tomás, et al. "Identification of Relevant Spectral Ranges in Laser-Induced Breakdown Spectroscopy Imaging Using the Fourier Space." Applied Spectroscopy, 2024

Mixed Reality Meets Spectroscopy: Interactive 3D Visualization of Spectral Signatures

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ABSTRACT

Mixed reality (MR) is an emerging technology that connect humans with computers and the surrounding environment, enhancing our perception of reality by overlaying digital information onto the physical world [1]. However, the combination of this technology with spectroscopy techniques further improves our understanding of the world: on one hand, spectroscopy allows the detection of hidden features and properties of objects that are not visible to the naked eye, such as elemental and molecular compositions. On the other hand, mixed reality enables the visualization of this complementary spectral information in our environment, providing a user-centric extension of reality and effectively enhancing our senses.
Based on these opportunities, in this work, we present a mixed reality toolkit that combines 2D spectral imaging with 3D sample models constructed using photogrammetry techniques for display on the HoloLens 2 MR devices, aiming to create an interactive and immersive user experience. With this interface, the user can select a sample model and an elemental map from a preloaded asset library and see the map projected onto the sample model. To aid in the analysis and to properly explore features and properties in detail, interactions such as zoom adjustment, rotation, and pan of the models were added. Additionally, it is possible to readjust the position to an appropriated place by reading the information encoded in a QR code and superimposing the 2D spectral information onto a physical object instead of visualising this information on a virtual 3D model.
All these features allow for better contextual interpretation of the spectral data, the ability to visualize models and information without the need to travel to their location, and ease of decision-making through the provision of comparative tools.

Keywords: Augmented Reality, Spectral Imaging, Interactive Visualization

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References:
[1] R. Azuma; Y. Baillot; R. Behringer; S. Feiner; S. Julier; B. MacIntyre, " Recent advances in augmented reality," IEEE Computer Graphics and Applications, vol. 21, no. 6, pp. 34-47, 2001.

Numerical analysis of the impact of printing angle on the performance of 3D-printed optical components

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ABSTRACT

Nowadays, digital light processing and stereolithography are being commonly used for 3D-printing optical components due to their high resolution, precision, and low cost [1, 2]. These techniques use a photosensitive resin that is cured layer-by-layer through ultraviolet (UV) exposure. Each printing layer experiences varying light intensity, with the regions closer to the UV source being more exposed, resulting in a gradient refractive index across the layer [3]. This work numerically evaluates the impact of the printing angle on the imaging performance of a 3D-printed lens using a ray tracing algorithm in COMSOL Multiphysics. For this, the influence of the gradient refractive index across each printing layer was taken into consideration, using a "sawtooth" transition zone with a thickness of 50 µm. This layer thickness aligns with the range of printing resolutions commonly used to print optical components, which range between 10 and 50 µm [4, 5]. The results revealed that the printing angle significantly influences lens performance, particularly affecting the spot size and the deviation of the focal point relative to the optical axis. Printing layers parallel to the optical axis yielded the worst imaging performance, while those perpendicular to it achieved better results (see Figure 1).

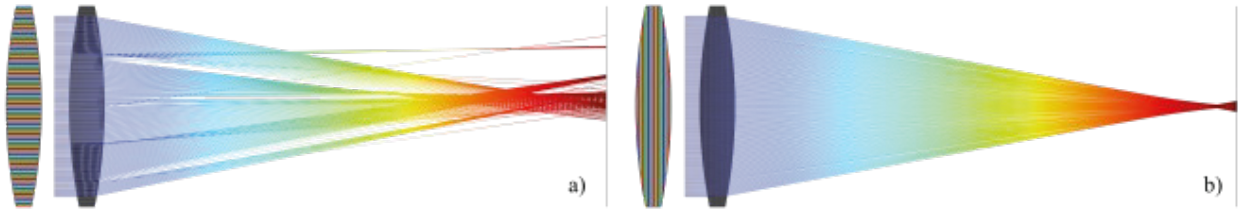

Figure 1. Ray diagram of a double-convex lens with two different printing layer orientations: (a) parallel to the optical axis and (b) perpendicular to the optical axis. The lens image shows printing layers with a thickness of 500 µm for visualization purposes.

Keywords: 3D printing, digital light processing, numerical model, optical components, stereolithography.

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References:

[1] G. D. Berglund and T. S. Tkaczyk, "Fabrication of optical components using a consumer-grade lithographic printer," Optics Express, vol. 27, no. 21, pp. 30405-30420, October 2019.
[2] L. D. Vallejo-Melgarejo, R. G. Reifenberger, B. A. Newell, C. A. Narváez-Tovar, and J. M. Garcia-Bravo, "Characterization of 3D-printed lenses and diffraction gratings made by DLP additive manufacturing," Rapid Prototyping Journal, vol. 25, no. 10, pp. 1684-1694, July 2019.
[3] R. Oliveira, R. Nogueira, and L. Bilro, "Do-it-yourself three-dimensional large core multimode fiber splitters through a consumer-grade 3D printer," Optical Materials Express, vol. 12, no. 2, pp. 593-605, February 2022.
[4] G. D. Berglund and T. S. Tkaczyk, "Enabling consumer-grade 3D-printed optical instruments – a case study on design and fabrication of a spectrometer system using low-cost 3D printing technologies," Optics Continuum, vol. 1, no. 3, pp. 516-526, March 2022.
[5] K. Swargiary, P. Jarutatsanangkoon, P. Suwanich, R. Jolivot, and W. S. Mohammed, "Single-step 3D-printed integrated optical system and its implementation for a sensing application using digital light processing technology," Applied Optics, vol. 59, no. 1, pp. 122-128, January 2020.

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Modifying Optical Properties of β-Ga_2O_3 by Ion Implantation and Irradiation

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ABSTRACT

β-Ga_2O_3, a semiconductor with a wide band gap of approximately 4.9 eV, has attracted a significant interest over recent years. In addition to its unique electrical properties, such as an electric breakdown field of about 8 MV/cm, this semiconductor combines excellent transparency to visible and ultraviolet light, making it ideal for use in the development of optoelectronic devices such as optical modulators, saturable absorbers for passively Q-switched lasers, waveguides, solar blind photodetectors, and light-emitting Schottky barrier diodes, among others. Many of these applications exploit different types of optical centers associated with intrinsic defects or those intentionally created by doping. In this context, ion implantation and irradiation, which allow precise control over the concentration and distribution of defects in semiconductors, are among the most promising techniques for modifying the optical properties of these materials.

In this context, this presentation will provide an overview of various studies on the incorporation and optical activation of technologically significant optical centers based on rare earths and transition metals in single crystals, nanowires, and thin films of β-Ga_2O_3 through ion implantation and irradiation. It will be demonstrated how energy transfer and radiative recombination processes involved in the optical activation of implanted europium depend on the local environment and the concentration of intrinsic defects promoted during the implantation process. In particular, it will be demonstrated how the implantation conditions, such as temperature and fluence, as well as post-implantation processes like thermal annealing, play a crucial role in the activation of optical centers created by ion implantation [1,2,3].

Furthermore, it will be shown that beyond keV heavy ion implantation, controlling defect concentration through MeV light ion irradiation has significant potential not only in altering electrical properties but also in enhancing the activation and efficiency of energy transfer processes from the host to the optical center. Recent studies performed by our group on the optical activation of chromium ions in highly electrically conductive β-Ga_2O_3 samples through defect creation by proton and alpha particle irradiation will be presented [4,5].

Finally, to highlight the potential of ion beam-based techniques for modifying the optical properties of semiconductors, a recent and innovative study on the potential of ion implantation for the formation of gold and silver nanoparticles in this semiconductor will also be presented. Due to their plasmonic properties, these metallic nanoparticles show great potential for applications such as photodetectors and sensors for environmental, biomedical, and chemical detection.

Keywords: Proton irradiation, Ion implantation, Defects, Optical centers, Plasmonic applications, β-Ga_2O_3, Europium, Chromium, Silver and Gold nanoparticles

References:

[1] K. Lorenz, M. Peres *et al*., " Doping of Ga_2O_3 bulk crystals and NWs by ion implantation", Proc. SPIE 8987, Oxide-based Materials and Devices V, 89870M, (2014).

[2] M. Peres *et al*., " Doping β-Ga_2O_3 with europium: influence of the implantation and annealing temperature", J. Phys. D: Appl. Phys. 50, 325101 (2017).

[3] M. Peres *et al*., " Eu Activation in β-Ga_2O_3 MOVPE Thin Films by Ion Implantation", ECS Journal of Solid State Science and Technology, 8 (7) Q3097-Q3102 (2019).

[4] M. Peres et al., "Enhancing the luminescence yield of Cr3+ in β-Ga_2O_3 by proton irradiation", Appl. Phys. Lett. 120, 261904 (2022).

[5] D. M. Esteves, K. Lorenz, M. Peres et al., "Probing the Cr^{3+} luminescence sensitization in β-Ga_2O_3 with ion-beam-induced luminescence and thermoluminescence", Sci. Rep., vol. 13, no. 4882, (2023).

Studies on characterization of pH-dependent synthesis of Zn_2GeO_4:Mn persistent luminescence nanomaterials, morphology, optical properties and SARS-CoV-2 protein surface modification.

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ABSTRACT

Class of luminescent materials, which once excited can preserve absorbed energy and emit in delay way, is described as persistent luminescent particles [1]. Such phenomena is related to the choice of specific host lattice, electron excitation, absorbing energy, internal interactions and processes, luminescence centres and finally, release of previously stored energy [2]. Long afterglow emission of nanomaterials found great interest in biomedical applications such as imaging – as its optical properties make it possible to avoid damaging tissues and reduce their autofluorescence [3]. Zn_2GeO_4:Mn (ZGO:Mn), long lasting green phosphor, is presented as capable for the applications indicated [4]. In order to enhance the functionality of the use of such materials in bioimaging, the surface in the next step can be functionalized, for example with SARS-CoV-2 proteins – additionally it may serve a purpose of studying virus-cell interactions [5].
This study shows our results in the terms of microwave-assisted, pH-dependent synthesis of ZGO:Mn nanomaterials, its characterization of morphology by transmission electron microscopy, crystal structure by X-ray powder diffraction and optical properties via spectrofluorimetry. ζ-potential was examined via electrophoretic light scattering method. We also present the results related to the surface modification with SARS-CoV-2 proteins.
Our work provide therefore (i) the characterization of the influence of pH during the synthesis on morphology of obtained nanoparticles, (ii) its effect on optical properties, and (iii) surface modification of the material showing best luminescence characteristics with virus proteins. Currently, our focus is on further research related to the biocompatibility assessment of ZGO:Mn modified via SARS-CoV-2 antibodies, characterization of enhanced cellular uptake by cancer cells, as well as persistent luminescence properties.

Keywords: bioimaging, ZGO:Mn, persistent luminescence, SARS-CoV-2

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References:

[1] J. Wang *et al.*, "One-Dimensional Luminous Nanorods Featuring Tunable Persistent Luminescence for Autofluorescence-Free Biosensing," *ACS Nano*, vol. 11, no. 8, pp. 8185–8191, Aug. 2017, doi: 10.1021/acsnano.7b03128.
[2] Z. Cui *et al.*, "Controllable Synthesis and Luminescence Properties of Zn2GeO4 : Mn2+ Nanorod Phosphors," *ChemistrySelect*, vol. 6, no. 39, pp. 10554–10560, Oct. 2021, doi: 10.1002/slct.202102822.
[3] V. Castaing, E. Arroyo, A. I. Becerro, M. Ocaña, G. Lozano, and H. Míguez, "Persistent luminescent nanoparticles: Challenges and opportunities for a shimmering future," *Journal of Applied Physics*, vol. 130, no. 8. American Institute of Physics Inc., Aug. 28, 2021. doi: 10.1063/5.0053283.
[4] R. M. Calderón-Olvera *et al.*, "Persistent Luminescence Zn2GeO4:Mn2+ Nanoparticles Functionalized with Polyacrylic Acid: One-Pot Synthesis and Biosensing Applications," *ACS Appl Mater Interfaces*, vol. 15, no. 17, pp. 20613–20624, May 2023, doi: 10.1021/acsami.2c21735.
[5] W. Andrzejewska *et al.*, "SARS-CoV-2 Virus-like Particles with Plasmonic Au Cores and S1-Spike Protein Coronas," *ACS Synth Biol*, vol. 12, no. 8, pp. 2320–2328, Aug. 2023, doi: 10.1021/acssynbio.3c00133.

Optical, Morphological, Chemical, Structural, and Photocatalytic Effects of Iron Modified Nano-TiO_2

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ABSTRACT

Titanium dioxide nanoparticles (nano-TiO_2) are widely used to promote the oxidation of organic and inorganic pollutants in the atmosphere. This process begins when this semiconductor material absorbs light energy, creating an electron-hole pair that initiates photocatalytic reactions. These reactions degrade harmful pollutants into less harmful by-products. Previous studies recognize the advantages of using nano-TiO_2, such as its non-toxicity, low- cost, and high stability. However, the pollutant degradation rate is limited to the absorption of the energy fraction corresponding to the ultraviolet (UV) range, which represents only 3-4% of the solar spectrum. This limitation is attributed to the large band gap of nano-TiO_2 (E_g > 3.0 eV), covering the wavelength of light below 400 nm. To overcome this issue, the literature highlights the potential of modifying TiO_2 with metals such as iron (Fe^{+3}), nickel (Ni^{2+}), cobalt (Co^{+2}) and others. Modifying nano-TiO_2 creates an intermediate band within the band gap, enabling the absorption of lower-energy photons and enhancing the material's ability to utilize a broader spectrum of light. This increases light absorption to higher wavelengths within the visible range (400 nm - 700 nm), enhancing the degradation rate of pollutants in outdoor applications since around 48% of sunlight falls within this range. Specifically, Fe^{+3} has a similar ionic radius to Ti^{+4} and is highly compatible for incorporation into the crystal lattice of TiO_2. Therefore, this work aims to investigate the effect of Fe^{+3} modifying in nano-TiO_2 on optical, structural, chemical, and morphological properties, as well as photocatalytic activity. To this end, using the co-precipitation method, different aqueous solutions of $FeCl_3$ were added to aqueous suspensions of TiO_2 concentrations of 0.1%, 0.5%, 1% and 10% (relative to the mass of TiO_2). Modified and unmodified nano-TiO_2 were characterized by diffuse reflectance spectroscopy (DRS) followed by band gap calculation, X-ray diffraction (XRD), energy dispersive X-ray spectroscopy (EDS) and scanning electron microscopy (SEM). The photocatalytic activity was investigated by decolorizing Rhodamine B (RhB) aqueous solutions under similar sunlight irradiation. The results by DRS indicate that modifying improved light absorption in the UV range for all iron concentrations; however, only the concentration of TiO_2: $FeCl_3$ (10%) shifted the absorption to the visible region. Also, the inclusion of Fe^{+3} in TiO_2 decreased the band gap energy from 3.14 eV to up to 2.80 eV. XRD analysis showed variations in the estimated crystallite size (20-25nm). The nano-TiO_2 morphology by SEM analysis showed that it did not change significantly after iron modification. EDS showed $FeCl_3$ peak only higher concentration (10%). In addition, the 0.1% Fe-modified TiO_2 exhibited the highest activity in the photocatalytic degradation of RhB with an efficiency of 90% after 3 hours of irradiation.

Nanoparticles Enhanced Laser Induced Breakdown Spectroscopy of Gemstones

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ABSTRACT

Nanoparticles Enhanced Laser Induced Breakdown Spectroscopy (NELIBS) has proven to improve the effectiveness of laser induced breakdown spectroscopy (LIBS) by minimising the sample damage and enhancing the spectral features. LIBS is an excellent technology for rapid on-site investigations that attracts interest from diverse areas of research. Gemmology is no exception. Gemstone characterisation is a crucial aspect within the field of gemmology, necessitating precise analytical techniques. The application of LIBS for Gemstone characterisation is limited due to ineffective ablation and crack formation even more with cost-effective, non-gated LIBS systems. Therefore, in this study, we explore the advantage of NELIBS, with ungated LIBS system, for characterising gemstones and probable identification based on spectral differences. Our objective is to amplify the spectral features and do a comparative analysis with conventional LIBS. We deposited two layers of 2μL drops of 20nm Gold Nanoparticles (AuNPs) colloidal solution on the surfaces of Sapphire and Opal gemstones. Targeted areas were shot with 3 pulses of Nd:YAG laser (~50mJ, 10ns, 1064nm, 1Hz) for recording NELIBS spectra with OceanOptics HR4000 spectrometer, as illustrated in Fig 1. Similar procedure was repeated without NP layers for recording conventional LIBS spectra for comparative analysis. Results have shown significant enhancement in spectral features i.e. emergence of new spectral lines, and intensification of the existing ones. The UV-Vis spectral regions which were devoid of any spectral information in conventional LIBS spectra showed prominent spectral lines in NELIBS spectra. Several folds enhancement is observed in spectral lines, see Fig 2. These enhancements have notable improvements for characterisation of Gemstones. In this preliminary investigation we demonstrate the potential of NELIBS for characterisation and possibility of onsite identification and authentication of Gemstones.

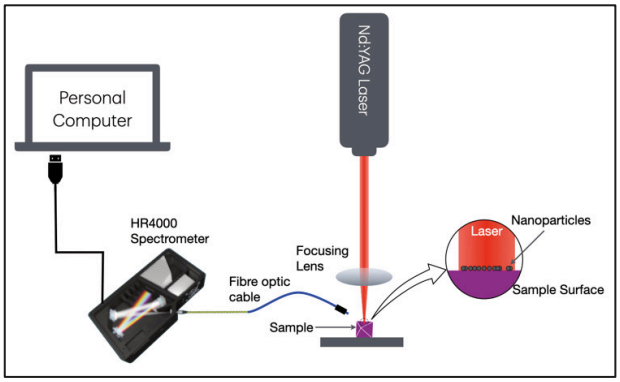

Figure1, Schematic Illustration of Experimental Setup

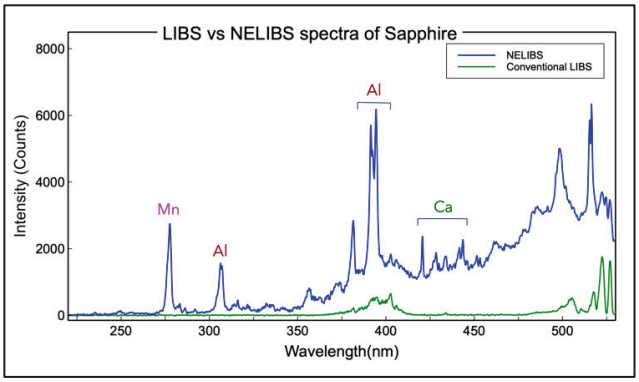

Figure 2, Enhanced spectral features in Sapphire spectrum using NELIBS

Keywords: Laser-Induced Breakdown Spectroscopy (LIBS), Gemstones, NELIBS, Signal Enhancement.

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Towards cost-effective interrogation techniques to monitoring metropolitan optical fiber networks: The GT_OnE approach

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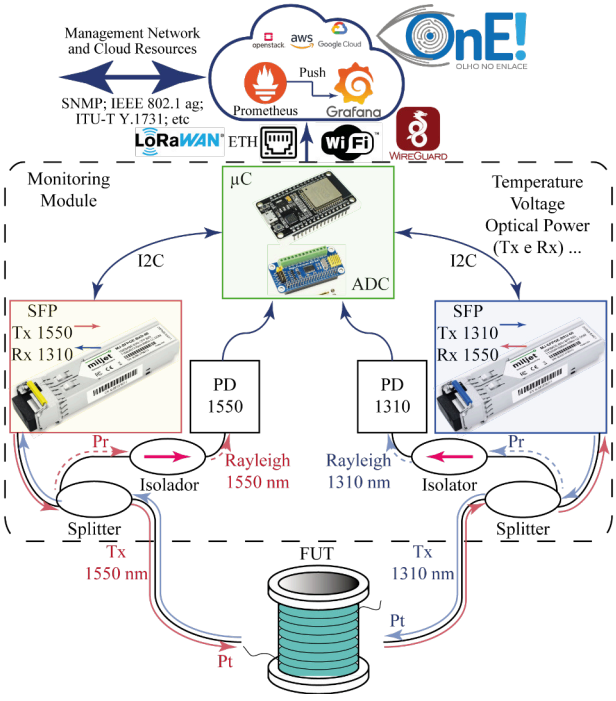
ABSTRACT

There is a growing centrality of communication systems, particularly the Internet, in people's daily activities. Nowadays, the physical communication infrastructure becomes even more critical with the migration of software, services, platforms, and functions outside institutions due to the widespread adoption of cloud computing. Consequently, there is a technical need for uninterrupted monitoring of the health of optical cables. Unlike other elements of the communication system, cables are assets exposed on poles (and/or ducts) bordering highways, railways, and streets, being vulnerable to adverse weather conditions, accidents, construction sites, among others [1].

An eventual break in an optical cable has a huge operational cost in terms of team travel, long locating, and repair times, leading to a reduction in service availability and customer satisfaction indicators. This can represent a loss much greater than the repair cost itself. Therefore, the identification and location of faults is essential. The gold standard for monitoring optical cables during their installation/repair is the Optical Time Domain Reflectometer (OTDR) [2]. OTDR has been integrated into continuous monitoring systems, allowing constant monitoring of optical cables during regular operation. However, those systems are expensive and surfer for vendor lock-in.



In this context, this work presents a monitoring system to provide continuous supervision of metropolitan optical plants to guarantee high levels of availability. Fig. 1 presents the proposal using commodity optical elements (splitters, isolators, SFPs, photodetectors) to extract data from the plant's physical layer, processed in the cloud for event detection and location. The main goal is to identify imperceptible events in the upper monitoring layers by performing measurements directly at the physical layer (fiber under test - FUT). In order to estimate attenuations in the FUT, the Transmission-Reflection Analysis technique has been adopted (TRA) [3]. This technique associates the normalized transmission and backscattered optical powers to identify where the attenuations are induced. Characterization of SFPs, simulations in Matlab, and experimental validation were performed with 1550 nm wavelength during this research. The SFPs showed up to 0.73 dBm of optical power, visibility up to 50 dB, and long-term stability. Faults/attenuations at fiber beginning (0 m), 3.29 km, 25.31 km, and fiber end (28.38 km) were simulated and experimentally validated, achieving a relative error of ~6% (200 m for 3.3 km). This error can be reduced by improving the electro-optical interface (enhancing its sensitivity) and measuring with both wavelengths 1510 nm and 1310 nm.

References:

[1] Šlapák et al., Monitoring of Fibre Optic Links With a Machine Learning-Assisted Low-Cost Polarimeter, in IEEE Access, vol. 8, pp. 183965-183971, 2020

[2] P. Healey, Review of long wavelength single-mode optical fiber reflectometry techniques. Journal of Lightwave Technology, vol. 3.4, pp. 876-886, 1985.

[3] Rodríguez et al. Interrogation of optical fiber based on the fusion of OFDR and TRA techniques. Opt Quant Electron 48, 230 (2016). https://doi.org/10.1007/s11082-016-0501-6

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Exploring the Localized Surface Plasmon Resonance Phenomenon in Au-Ag Nanoparticles Embedded in an Oxide Thin Film

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ABSTRACT

Gold (Au) and silver (Ag) nanoparticles show remarkable optical responses, because they support Localized Surface Plasmon Resonances (LSPRs). If the wavelength of incident light is much higher than the size of the nanoparticles, collective oscillations of conduction band electrons occur, enabling strong extinction bands and electromagnetic-field enhancements. For Au and Ag nanoparticles the resonance condition is met in the visible range, giving important colour effects since ancient times. Plasmonic nanoparticles have received considerable attention in many scientific fields. However, there are critical issues to be considered, since LSPR response are dependent on the size, shape, interparticle distance, and surrounding dielectric material. Manipulating such morphological features, opens a wide range of possible applications, taking advantage of far-field and near-field phenomena. In the past few years, different LSPR thin film systems have been explored, namely those composed by Au and/or Ag nanoparticles, dispersed in dielectric hosts as TiO_2, CuO, ZnO, and Al_2O_3. The thin films are prepared with variable compositions, by reactive magnetron sputtering, followed by heat-treatment at different temperatures. The LSPR band is monitored in transmittance mode using high-resolution (HR) LSPR spectroscopy systems (Figure 1), to evaluate the performance of the thin films as chemo-, and bio- sensors.

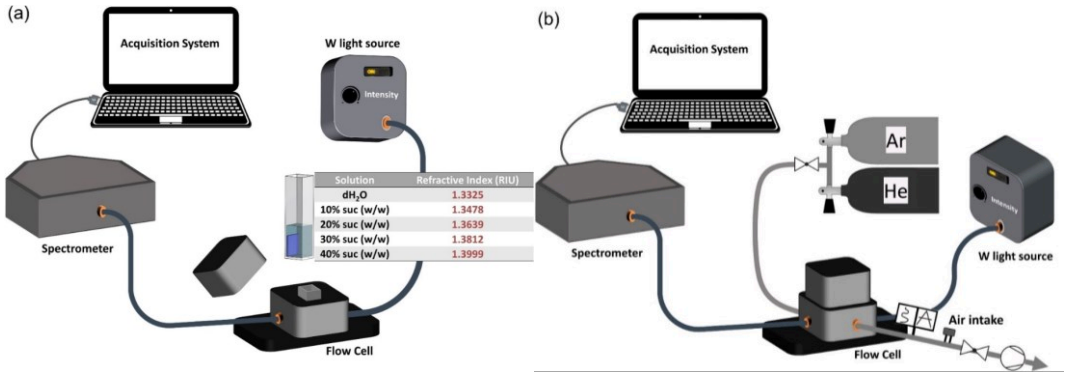

Figure 1. Schematic representation of experimental setup for HR-LSPR sensing, for liquid (a) and gas (b) sensing tests.

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Low Noise White Light Interferometry with Broad Cavity Interrogation Band and Fast Sampling

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ABSTRACT

White light interferometry (WLI), also known as Low Coherence Interferometry (LCI), is a technique that combines intensity measurement with phase measurement to provide an absolute measurement [1,2]. In general, this technique is implemented using two interferometers in a tandem configuration, with one acting as an interrogator and the other as a sensor. In this work, a complete WLI system is present (Fig. 1). This system is based on a Mach-Zehnder interferometer (MZI) as an interrogator, due to the lower attenuation and an easy broad cavity band implementation by increasing the number of turns around the actuator, and a Fabry-Perrot interferometer (FPI) as a sensor, due to its versatility, is characterized. Furthermore, an algorithm analysis is presented that allows noise reduction, fast sampling and phase linearisation. Noise reduction is achieved by correlation and convolution calculations that allow the signal reconstruction at a higher frequency sample. This can be done by matrix multiplication or using the Fourier transform. In addition, phase linearisation allows a sinusoidal signal to be applied to the actuator, resulting in smooth motion and less noise. The interrogator achieves an interrogation band of 200 µm at 750 Hz. The algorithm achieves a noise suppression of at least 30 dB and a time process of less than 1 ms for samples with 50000 points, allowing an actuator signal frequency of 1 kHz.

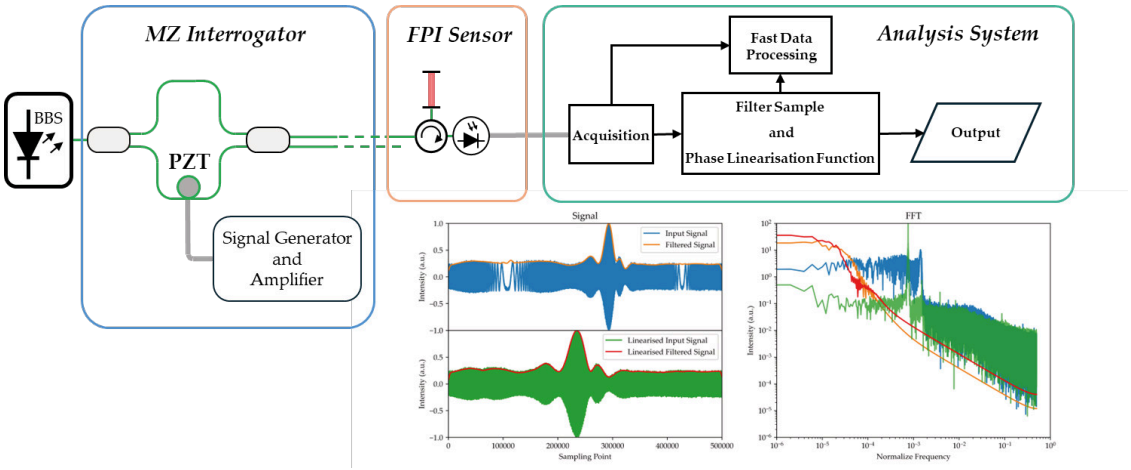

Figure 1. System scheme and the signal before and after processing.

Keywords: Optical Fiber Sensor, White Light Interferometry, Low Coherence Interferometry

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References:

[1] Q. Liu, W. Peng, " Fast interrogation of dynamic low-finesse Fabry-Perot interferometers: A review," Microw Opt Technol Lett. Jun. 2021; 63: 2279–2291, doi: 10.1002/mop.32922.
[2] P. Robalinho, A. Rodrigues, S. Novais, A. B. L. Ribeiro, S. Silva and O. Frazão, " White Light Interferometry: Absolute and High Precision Measurement for Long-Cavity Fibre Fabry-Perot Sensors," in Proceedings of the Conference EPJ Web Conf., France, Sep 2023, vol. 287, 09039, doi: 10.1051/epjconf/202328709039.

Comparative Analysis of Ethanol Gas Sensors based on Bloch Surface Wave and Surface Plasmon Resonance

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ABSTRACT

Electromagnetic surface wave (ESW) sensors leverage the high sensitivity achieved through enhanced electric field interactions with matter. Two prominent types of ESW used in optical sensors are Surface Plasmon Resonances (SPR) and Bloch Surface Waves (BSW). SPR sensors rely on the enhancement of fields at a metal-dielectric interface, whereas BSW sensors are excited in symmetry-breaking photonic crystals [1].
Ethanol plays a crucial role in modern industrial processes and consumer products, making the measurement of its concentration highly important. Sensitivity to ethanol vapours is achieved by the inclusion of ethanol-adsorptive zinc oxide (ZnO) layers [2]. The changes in optical properties result in a modulation of resonant conditions of ESW, enabling tracking of ethanol concentration in the atmosphere by VIS-NIR spectroscopy.
A comprehensive comparative study of sensor performance is carried out between SPR and BSW based sensors. Sensitivity and figures of merit are simulated by transfer matrix method towards optimized configurations. The adsorption of ethanol in ZnO is simulated as a perturbation in layer permittivity. The plasmonic structure consists of a thin film of Au topped with a ZnO cap layer. For the BSW-bearing structure, alternating layers of TiO2 and ZnO with a TiO2 cap layer are considered.

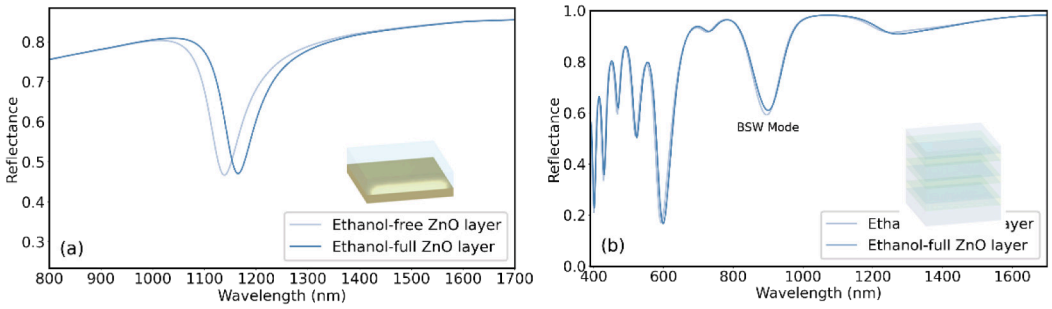

Fig. 1. (a) SPR and (b) BSW spectra for ethanol vapour sensing. The ethanol adsorption in ZnO layers can be simulated as a perturbation in layer permittivity.

Both structures are expected to exhibit high sensitivity to ethanol vapour concentration. The SPR-based structure shows higher spectral sensitivity and easier fabrication. The BSW-based structure, however, shows enhanced band definition and benefits from a more stable all-dielectric composition. These structures can be readily fabricated by RF magnetron sputtering and characterized in a controlled atmosphere for validation of simulation work.

Acknowledgements: This work is co-financed by Component 5 - Capitalization and Business Innovation, integrated in the Resilience Dimension of the Recovery and Resilience Plan within the scope of the Recovery and Resilience Mechanism (MRR) of the European Union (EU), framed in the Next Generation EU, for the period 2021 – 2026, within project ATE, with reference 56; and by National Funds through the Portuguese funding agency, FCT – Fundação para a Ciência e a Tecnologia, within project UIDP/50014/2020.

References:
[1] M. Gryga, et al., “Bloch Surface Wave Resonance Based Sensors as an Alternative to Surface Plasmon Resonance Sensors”, Sensors 2020, *20*(18), 5119
[2] Luís C. C. Coelho, et al., "Characterization of zinc oxide coated optical fiber long period gratings with improved refractive index sensing properties", Sensors and Actuators B: Chemical 223 (2016) 45–51

POF Sensor for Dynamic Physiological Evaluation in a Dog-Assisted ASD Therapy: A Case Study

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ABSTRACT

Optical fiber sensors have been validated for physiological measurement as a potential device for smart textiles and wearable sensors [1]. Also, developing sensors with Polymeric Optical Fiber (POF) shows promising applications in dynamic and real scenarios, as low-cost alternatives and non-direct measurement of pulse and respiration [2]. Furthermore, the functioning of POF sensors can be used in no-skin contact applications, such as in highly skin-sensitive children with autism spectrum disorder (ASD) during therapies. On the other hand, dog-assisted therapy (DAT) is a stress-reducing method for several populations [3] and has been analyzed to identify the real impact of animal-child interactions on improving therapies and stress-related events [4]. DATs are real dynamic settings to validate POF sensors in monitoring children with ASD. This work presents a case study in three weekly DAT sessions focused on speech therapy in a subject with ASD. A validated low-cost POF sensor [5] was used in this first dynamic physiological measurement scenario, as shown in Figure 1. A pre-post-test evaluation with the Phonological Awareness Test (PECFO) was conducted and the analysis of five Heart Rate Variability (HRV) variables was made to compare the participant's physiological status before and during the DAT. Figure 1 shows the obtained pulse signal, showing the dynamic movements affecting the signal but being able to obtain the pulse peaks. The physiological comparison showed a difference in the mean peak-to-peak time interval when the child was interacting with the dog than previous to the interaction in session 1 and session 2 (p-value<0.05). Also, with the DAT and the relation with the physiological analysis, an improvement in the PECFO assessment in the phonological consciousness was obtained, increasing by eight points after the three weeks therapy.

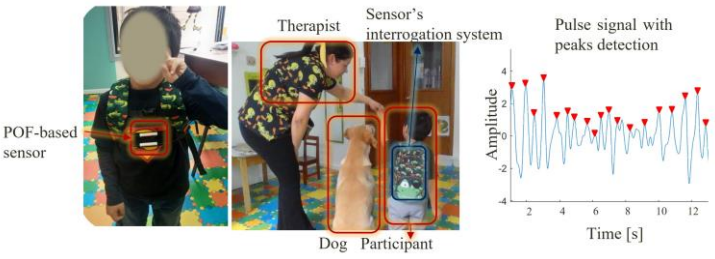

Figure 1. The POF-based sensor in a dynamic DAT session.

This case study showed the potential use of optical fiber sensors in dynamic environments such as DATs as a no-skin contact device, and for wearable or smart textiles, mainly in children with ASD. In addition, it is a potential tool to identify the real impact and benefits of dog-child interactions in therapies. Future work will improve the POF-sensor's response in terms of sensitivity and performance in dynamic settings and it will be applied in other ASD therapies, to promote stress awareness and control strategies by analyzing HRV variables.

Keywords: Polymeric Optical Fiber sensor, Dog-assisted therapy, dynamic physiological measurement.

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References:

[1] K. Chethana, et al. "Fiber Bragg grating sensor-based device for simultaneous measurement of respiratory and cardiac activities". Journal of Biophotonics, 10(2), 278-285, 2017.
[2] A. Arifin, et al. "Polymer optical fiber-based respiratory sensors: Various designs and implementations". Journal of Sensors, 1-6, 2019.
[3] C. Wijker, et al. "Effects of dog assisted therapy for adults with autism spectrum disorder: An exploratory randomized controlled trial". Journal of autism and developmental disorders, 50(6), 2153-2163, 2020.
[4] R. E. Griffioen, et al. "Group Changes in Cortisol and Heart Rate Variability of Children with Down Syndrome and Children with Autism Spectrum Disorder during Dog-Assisted Therapy". Children, 10(7), 1200, 2023.
[5] M.Gaitán-Padilla et al. "Development of a Polymeric Optical Fiber Sensor for Stress Estimation: A Comparative Analysis between Physiological Sensors". (Under submission) IEEE Sensors.

Thermal Blood Flowmeter Based on Cascaded Fabry-Pérot Interferometers Improved by Enhanced Harmonic Vernier Effect

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ABSTRACT

Accurate blood flow measurement is crucial in various clinical scenarios for diagnosing and treating vascular conditions. While non-invasive methods such as MRI and Doppler ultrasound are commonly used but have drawbacks such as high cost and lengthy procedure times for MRI and accuracy challenges for Doppler ultrasound. These limitations often require invasive methods, and thermal anemometry is favoured for its cost-effectiveness, real-time measurement, and ability to make precise diagnoses.
This research presents an innovative thermal blood flowmeter that utilizes cascaded Fabry-Pérot Interferometers (CFPI) and multimode fibre (MMF). The MMF is linked to a green LED for modulating blood temperature, and the resulting temperature change is inversely proportional to the flow volume. The CFPI consists of a polymer cavity created by NOA65 and an air cavity. Using NOA65 in the CFPI enhances its temperature sensitivity due to the exceptional thermo-expansion ability of NOA65 compared to silica glass fibre. The lengths of the cavities are precisely controlled to create an enhanced harmonic vernier effect. Unlike the typical separate FPI system with a vernier effect that only contains one sensing cavity while the reference cavity length remains constant, the CFPI is more compact and further enhances the sensor's sensitivity because the lengths of the two cavities change in opposite directions. By combining these two methods, the CFPI's temperature sensitivity is significantly improved, enabling the detection of minor temperature changes with different flow volumes.
In conclusion, this study successfully designed and tested a CFPI blood flowmeter based on the enhanced harmonic vernier effect. The lengths of the NOA65 and air cavities are 285.1 μm and 408.4 μm, respectively. The sensor's temperature sensitivity can reach 26.67 nm/℃ and successfully measure blood flow in a phantom system ranging from 14 ml/min to 500 ml/min.

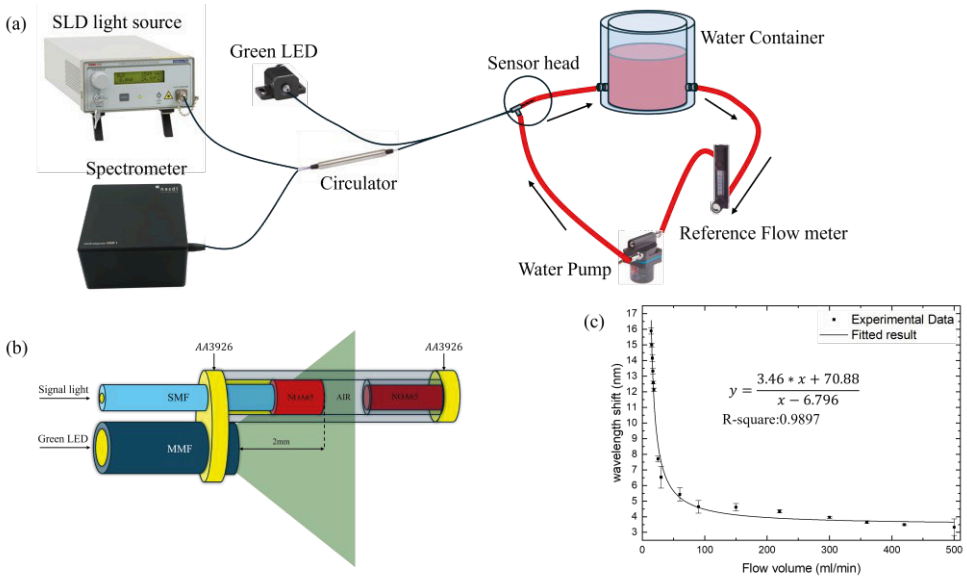

Figure 1. (a) System setup (b) Sensor structure (c) Blood flow measurement result

Continuous Variables Quantum Cryptographic Systems – Development, Deployment and Accreditation

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ABSTRACT

Continuous Variables Quantum Key Distribution (CV-QKD) tackles the problem of the generation and distribution of symmetric cryptographic keys without assuming any computational limitations on a supposed adversary [1], doing so while employing standard telecom equipment [2]. In recent years, quantum cryptography has attracted more and more investment, and presently systems have started to reach the market. However, research in the field is still very active, with efforts being made to both increase the system's performance, reduce costs and close security loopholes.
We present our novel, pilot-aided, CV-QKD system, employing a polarization diverse heterodyne receiver with a locally generated Local Oscillator, a diagram of which is presented in Figure 1. The performance of this system under a high polarization drift scenario. We then proceed to explore methods for improving the performance of our previously proposed system by increasing the cardinality of the constellation. The impact of device imperfections on the performance and security of CV-QKD is also explored at length.

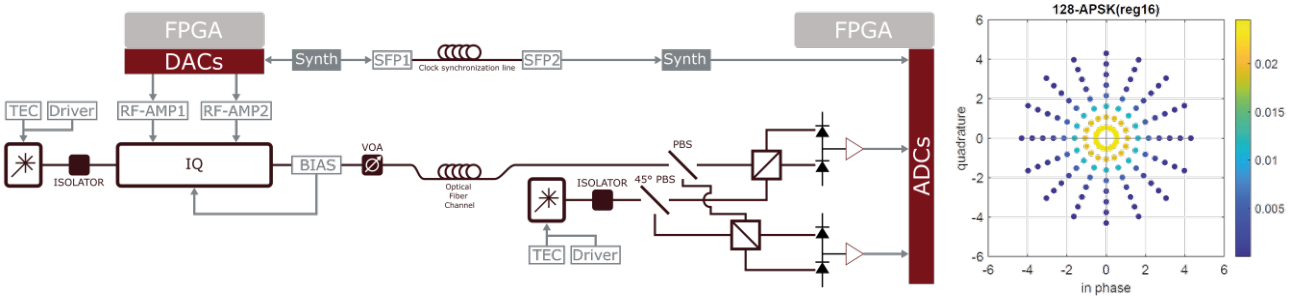

Figure *1* Block diagram of the experimental CV-QKD system (left). Scatter diagram of the 16-state, regular 128-APSK constellation with binomial distribution of the amplitudes. Individual state probability identified by color (right).

Following from the study of device imperfections, this presentation concludes with a with a foray into current and past efforts for deploying an accreditation test-lab for commercial QKD systems, currently being undertaken in the Nostradamus project. For an example, we present current work being done to implement the class of coherent detector control saturation attacks [3].

Keywords: Continuous Variables Quantum Key Distribution, Polarization Diverse, Side-Channel Attacks, Device Imperfections

Acknowledgements: Nitin Jain, for writing the description of the coherent detector control attack under the Nostradamus project that will inform the second half of this presentation.

References:

[1] A. V. Sergienko, *Quantum Communications and Cryptography*. CRC Press, 2018.
[2] F. Grosshans and P. Grangier, 'Continuous Variable Quantum Cryptography Using Coherent States', *Phys. Rev. Lett.*, vol. 88, no. 5, p. 057902, Jan. 2002, doi: 10.1103/PhysRevLett.88.057902.
[3] H. Qin, R. Kumar, and R. Alléaume, 'Quantum hacking: saturation attack on practical continuous-variable quantum key distribution', *Phys. Rev. A*, vol. 94, no. 1, p. 012325, Jul. 2016, doi: 10.1103/PhysRevA.94.012325.

An FPGA-based Physical Layer for a CV-QKD System

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ABSTRACT

Continuous-variable quantum key distribution (CV-QKD) offers a practical and efficient solution to assure the secrecy of confidential information [1], being of special interest for military and governmental applications. By allowing the use of off-the-shelf lasers and detection setups, CV-QKD systems have low implementation cost and can be integrated with deployed telecommunication infrastructures [1]. Despite the apparent simplicity of the experimental implementation, the digital signal processing (DSP) and post-processing procedures for CV-QKD are highly complex and computationally demanding. As such, state-of-the-art experimental implementations of CV-QKD systems do not account for the post-processing of the raw keys and implement the DSP in offline using the central processing unit (CPU) [2]. Additionally, waveform generators and oscilloscopes are usually considered to generate and sample the signal, respectively [2]. Offline implementations of a CV-QKD system have already been reported in the literature using general purpose processor (GPPs) for the heavy DSP, integrated with standard digital-to-analog converter (DAC) and analog-to-digital converter (ADC) devices, to semi-automatize the communication between PCs at the transmitter (Tx) and at the receiver (Rx), and the CV-QKD equipment [3]. Moreover in [4], we present the Tx's field programable gate array (FPGA) architecture regarding resource occupation analysis, configuration parameters and timing issues. In this work, we further improve the experimental implementation of the CV-QKD system by taking the Tx's and Rx's architecture from GPPs to a real-time platform, i.e. the FPGAs (Fig. 1). Moreover, we validate all implemented FPGAs' subblocks for both the Tx and the Rx. We consider a back-to-back implementation to test the signal generated by the Tx's FPGA, and the synchronization between both the Tx's and Rx's FPGA modules. Secondly, we integrate the FPGAs with the quantum front-end implemented in the laboratory (Fig. 1) and test the Rx's FPGA architecture, validating the results with the Rx's DSP.

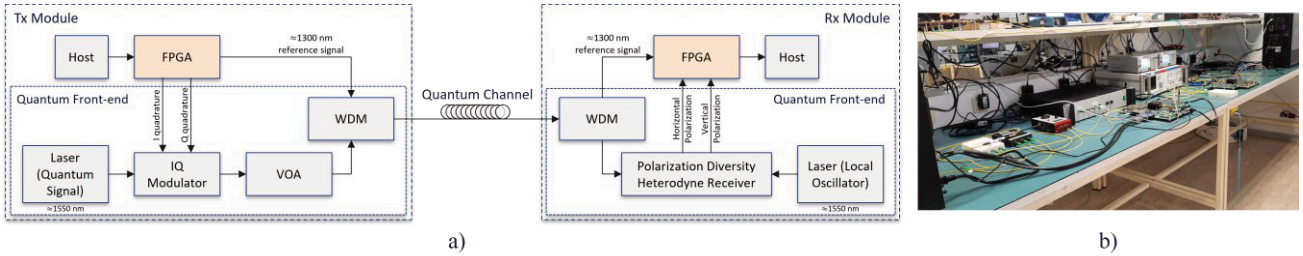

Figure 1 – a) Schematic representation of the physical layer of the CV-QKD system using FPGAs. b) Experimental implementation of the physical layer of the CV-QKD system.

Keywords: Quantum Communications, Quantum Key Distribution, Continuous Variables, Physical Layer, FPGA.

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References:

[1] S. Pirandola et al., "Advances in Quantum Cryptography," Advances in Optics and Photonics, vol. 12, no. 4, p. 1012, Dec. 2020.
[2] F. Roumestan et al., "Shaped Constellation Continuous Variable Quantum Key Distribution: Concepts, Methods and Experimental Validation," Journal of Lightwave Technology, pp. 1–8, 2024.
[3] D. Pereira, A. N. Pinto, and N. A. Silva, "Polarization Diverse True Heterodyne Receiver Architecture for Continuous Variable Quantum Key Distribution," Journal of Lightwave Technology, vol. 41, no. 2, pp. 432–439, Jan. 2023.
[4] G. Anjos et al., "An FPGA-Based Physical Layer Approach for a CV-QKD Transmitter," 2023 23rd International Conference on Transparent Optical Networks (ICTON), Jul. 2023.

High-Performing Synchronization Techniques for Quantum Key Distribution Systems

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ABSTRACT

Quantum key distribution (QKD) consists in a promising solution to achieve secure communications by generating an identical key at the transmitter and receiver [1]. Although these systems can be considered a mature technology, there is still a need to optimize several of its subsystems, making the overall system more efficient and cost-effective. Indeed, the synchronization system represents one of such subsystems. Currently, the main commercial systems use a synchronization method composed of dedicated hardware [2] [3], represented in Figure 1 as dashed lines and blocks, with the tendency to evolve towards a more a simpler configuration. Taking this into account, this work investigates an effective synchronization technique with low computational complexity for QKD systems, capable to offer a good balance between efficiency and simplicity/cost. This technique consists of removing the reference signal preparation, which operates in gated mode, as described in Figure 1.

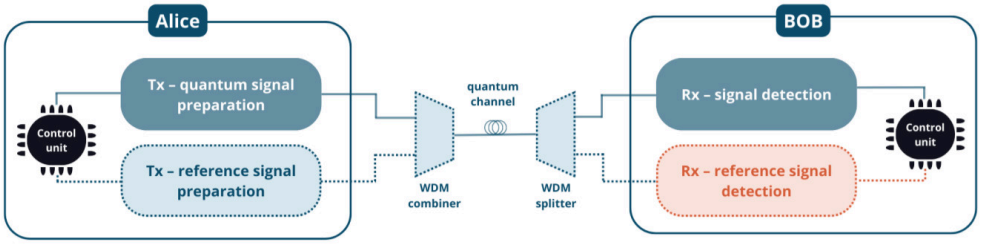

Figure 1. Representation of the two approaches to synchronize QKD systems: the standard one, with dedicated hardware for synchronization, which includes an optical reference signal; the simplified one (followed in this work), where the hardware (represented by the dotted lines and blocks) is removed, and synchronization is performed using only the quantum signal.

The clock synchronization is essential for the proper functioning of the QKD system, enabling a correct detection of the time window in which the optical pulse is contained [4]. After the measurement of the quantum states, a correspondence between the sent qubit and the detection events needs to be achieved. The approach followed in this work employs the utilization of qubits similar to the exchanged during the QKD protocol, without the necessity of incorporating additional hardware. Consequently, it is only necessary to prepare and measure the quantum states, i.e., the qubits. The method consists of implementing an algorithm that recovers the period and the time offset, which are mandatory for Bob to determine the expected arrival time of the qubits sent by Alice.

Acknowledgements: This work was supported by the EU DIGITAL-2021-QCI-01 Programme, through the project PTQCI (GA 101091730), and by FEDER, through the COMPETE 2020, under the project QuantumPrime, (ref. PTDC/EEI-TEL/8017/2020).

References:

[1] N. Gisin, G. Ribordy, W.Tittel, and H. Zbinden, "Quantum cryptography", Reviews of modern physics, vol. 74, no. 1, pp. 145-195, 2002.
[2] M. F. Ramos, N.A.Silva, N.J.Muga, and A.N.Pinto, "Reference Clock Signal Distribution for Quantum Key Distribution", SBRC Workshop de Comunicação e Computação Quântica WQuantum, 2021
[3] S.T.Mantey, M.F.Ramos, N.A.Silva, N.J.Muga, and A.N.Pinto, "Frame Synchronization for Quantum Key Distribution Systems", 2022 IEEE Globecom: Quantum Communications and Information Processing, 2022
[4] L.Calderaro, A.Stanco, C.Agnesi, et al, "Fast and Simple Qubit-Based Synchronization for Quantum Key Distribution", Physical Review Applied, vol. 13, no. 5, 2020

Quantum Technology Pathways for Paraxial Fluids of Light

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ABSTRACT

Quantum Fluids of Light form a family of experimental platforms that are now set to enable a new generation of quantum technologies through their unique versatility. In this presentation, we put in perspective our experimental work on the topic of Paraxial Fluids of Light with photorefractive crystals by discussing our ongoing research efforts for paving technology pathways for these systems, from quantum simulators to quantum computing. In a broad perspective, Paraxial Fluids of Light explore the interplay of wave and particle-like dynamics experienced by a laser beam as it propagates inside a nonlinear optical media. As the mathematical model that describes these dynamics is isomorphic to that of a 2D quantum fluid, the physical system may act as an very capable analogue quantum simulator. Indeed, by leveraging on the enhanced versatility of these systems, we will demonstrate how we are able to explore and observe unprecedented phenomena from quantum turbulence[1,2] to topological matter[3] with non-trivial advantages. Besides, and looking from the information transport perspective, we will also explore how such systems may enclose unique properties to the contexts of optical computing and quantum information processing. Indeed, we will show how these setups can be an interesting playground to explore the role of nonlinearity in reservoir computing and extreme learning architectures[4,5] thus paving for edge computing devices with all-optical processing capabilities.

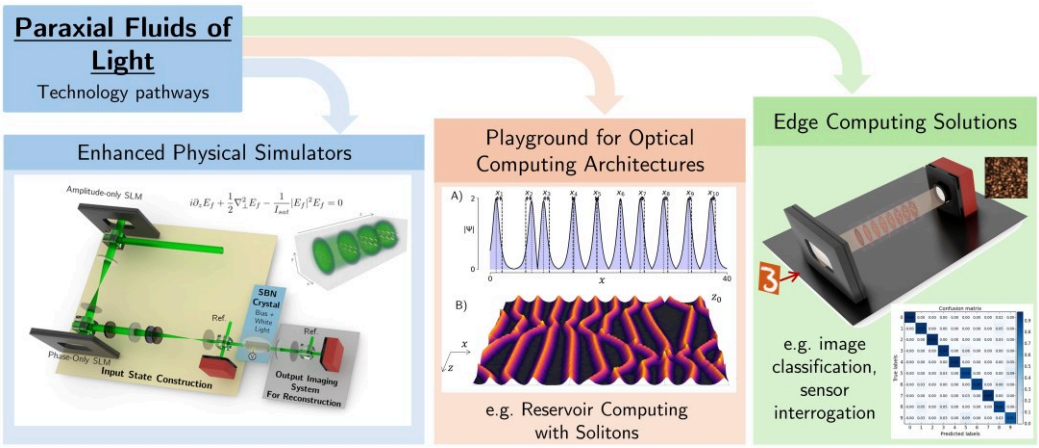

Figure 1. Overview of some technology pathways for paraxial fluids of light.

Keywords: Quantum Simulation, Nonlinear Optics, Photorefractive Crystals

Acknowledgements: This work is financed by National Funds through the Portuguese funding agency, FCT - Fundação para a Ciência e a Tecnologia, within project UIDB/50014/2020.

References:

[1] Ferreira, Tiago D., et al. "Towards the experimental observation of turbulent regimes and the associated energy cascades with paraxial fluids of light." New Journal of Physics 24.11 (2022): 113050.
[2] Ferreira, Tiago D., Jakub Garwoła, and Nuno A. Silva. "Exploring the dynamics of the Kelvin-Helmholtz instability in paraxial fluids of light." Physical Review A 109.4 (2024): 043704.
[3] Xia, Shiqi, et al. "Topological phenomena demonstrated in photorefractive photonic lattices." Optical Materials Express 11.4 (2021):1292-1312.
[4] Silva, Nuno Azevedo, Tiago D. Ferreira, and Ariel Guerreiro. "Reservoir computing with solitons." New Journal of Physics 23.2 (2021): 023013.
[5] Silva, Nuno A., Vicente Rocha, and Tiago D. Ferreira. "Optical Extreme Learning Machines with Atomic Vapors." Atoms 12.2 (2024): 10.

Intracellular Nanothermometers. From Fluorescent Proteins to Quantum Sensing Probes

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ABSTRACT

In this keynote talk, we present luminescence-based methods for measuring temperature within biological cells, underscoring the importance of subcellular temperature monitoring in biological and medical contexts. Temperature regulation is crucial for optimal cellular function, and precise temperature control can enhance medical therapies. Notably, magnetic hyperthermia and photothermal hyperthermia are emerging cancer treatments that aim to selectively raise temperatures to target tumours while preserving healthy tissue.
For spatially resolved temperature measurement, various luminescence properties of molecular or nanoscale probes are utilized. We critically examine the benefits and limitations of these approaches. Our discussion includes the use of diverse fluorescent sources, such as proteins and quantum sensors like fluorescent nanodiamonds, to track intracellular temperature changes. Quantum sensors typically measure physical parameters by probing spin dynamics through optically detected magnetic resonance (ODMR) experiments, with ODMR traces analysed to extract information on magnetic fields [1] and temperature.
Both protein-based and nanodiamond-based technologies enable detailed observation of temperature variations at subcellular levels within biologically relevant temperature ranges. For specific biological questions or medical therapies, tailored functionalized variants are necessary. We highlight the use of GFP as an effective sensor for detecting temperature changes induced by metabolic activity [2] and other GFP variants for measuring the effects of magnetic hyperthermal treatments [3], such as those employed in cancer therapies. Additionally, we present recent advancements in photothermal therapy efficacy mapping using fluorescence molecules and nanodiamond quantum sensors, which are highly photostable and robust across wider temperature ranges relevant to hyperthermia applications.

Keywords: Nanothermometry, bioimaging, functional imaging, in vitro research, FLIM

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References:
[1] F. Camarneiro et al., "Magnetic Field Mapping Around Individual Magnetic Nanoparticle Agglomerates Using Nitrogen-Vacancy Centers in Diamond," Particle and Particle Systems Characterization, vol. 38, no. 8, (2021).
[2] OA Savchuk, O.F. Silvestre, R.M.R. Adão, J.B. Nieder, "GFP fluorescence peak fraction analysis based nanothermometer for the assessment of exothermal mitochondria activity in live cells", Scientific reports 9 (1), 7535 (2019).
[3] PL Silva, OA Savchuk, J Gallo, L García-Hevia, M Bañobre-López, J.B. Nieder, "Mapping intracellular thermal response of cancer cells to magnetic hyperthermia treatment" Nanoscale 12 (42), 21647-21656 (2020).

Muscle Activity Detection Using Photoplethysmography and Machine Learning Algorithms

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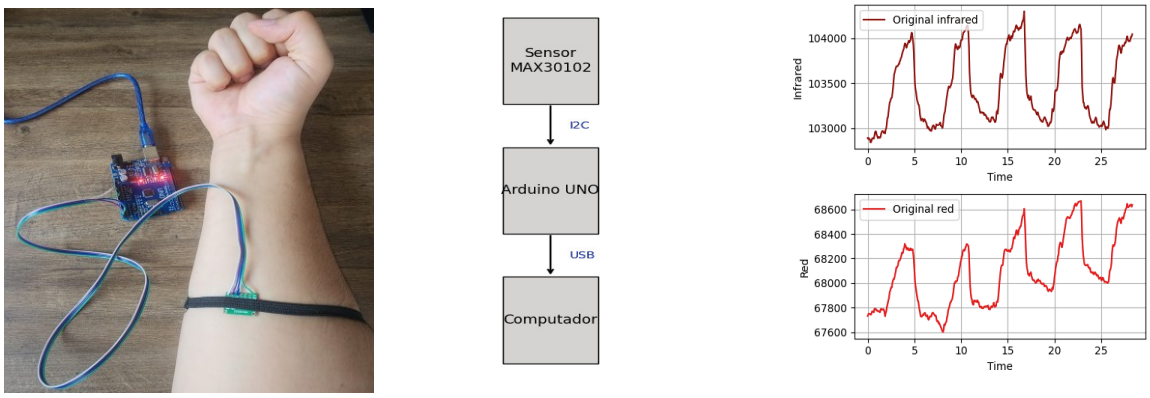
ABSTRACT

This study presents an optical sensor for detecting and characterizing muscle activity using Photoplethysmography (PPG). The sensor uses infrared and red LEDs to penetrate the skin, with photodiodes measuring reflected light from blood vessels. The analog signals are converted to digital data for analysis. Measurements were taken on upper limbs, and future work will include testing with amputees. Unlike surface Electromyography (sEMG), optical methods are resistant to electromagnetic interference and do not require conductive gel or adhesive tape [1]. Proper wavelength selection is crucial for deep tissue penetration [2]. This study expands on [3] by training a machine learning algorithm to recognize hand movements, achieving up to 90% accuracy with a Support Vector Machine (SVM). This approach is beneficial for controlling prosthetic devices post-injury or amputation.



a) b) c)

Figure 1: a) Experimentalsetup; b) Data acquisition schematic; and c) Raw data.

Keywords: photoplethysmography; machine learning; muscle activity

References:

[1] T. Hamaoka and K. K. McCully, “Review of early development of near-infrared spec- troscopy and recent advancement of studies on muscle oxygenation and oxidative metabolism,” The Journal of Physiological Sciences, vol. 69, pp. 799-811, 2019. [Online]. Available: https://doi.org/10.1007/s12576-019-00697-2.

[2] A. V. Mo¸co, S. Stuijk, and G. de Haan, “New insights into the origin of remote PPG signals in visible light and infrared,” Scientific Reports, vol. 8, no. 8501, pp. 1-10, 2018. [Online]. Available: https://doi.org/10.1038/s41598-018-26068-2.

[3] M. Sikora and S. Paszkiel, “Muscle activity measurement using visible light and in- frared,” IFAC-PapersOnLine, vol. 52, no. 27, pp. 329-334, 2019. [Online]. Available: https://doi.org/10.1016/j.ifacol.2019.12.682.

Optical fibre sensors for the evaluation of vital signs in a smart seat

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ABSTRACT

Despite all the medical advances in late decades, cardiovascular diseases continue to be the main cause of death worldwide. Solely in 2019, 18.6 million people died due to cardiovascular diseases, namely stroke, hypertension, and coronary heart disease [1]. Strikingly, 84% of cardiopulmonary arrests in hospitals, could have been avoided, if the patients had been regularly monitored [2]. A new approach to disease prevention focuses on non-intrusive monitoring, which means individuals do not need to perform any specific actions or wear devices to enable the tracking of health parameters. This can be achieved by embedding smart sensors into everyday objects and environments.

This work focuses on developing fiber Bragg gratings (FBG) sensors to be applied in a smart seat, aiming to measure vital signs such as heart and respiratory frequencies in a non-intrusive way. FBGs are great candidates for this application due to their ease of production, capability for multiplexing, immunity to electromagnetic interference and ease of integration on different structures due to its micrometric diameter [3].

In this work, FBGs are explored to monitor the vibrations of the body due to the heart cycle, based on a method called ballistocardiography (BCG). Four FBG-based sensors were developed, being each sensor composed by a fiber embedded in flexible polymeric materials and custom-made 3D parts which are moveable and are incorporated directly into the seat. Below the movable piece is the polymeric membrane with an embedded FBG. The working fundamentals of the system consists of when a person seats, the membrane with the FBG is strained with the BCG pattern. In this prototype, different parameters were analysed, namely: two different polymeric materials (*Ecoflex* and *Dragon Skin*); two shapes of the interfaces/moveable pieces to test the impact of shape in deformation of the membranes and fibres; and 4 sensing positions on the seat.

To preliminarily evaluate the system performance, tests were conducted on four volunteers, two males and two females. Besides gender, different ages were also considered, with one female and one male in the age group of 20-25, and the other two in the 35-40 range. Tests were conducted twice for all individuals, with acquisitions of two minutes each, at the same time the subject had wearable reference devices for respiratory waveform and electrocardiogram monitoring. The collected data was synchronized, and the FBGs data was processed to remove high frequency noise and to extract the respiratory and heart signals. The accuracy of the prototype was evaluated by comparing the heart and respiratory rates from both devices in the different time windows. This work paves the way for advances in terms of invisible/non-intrusive monitoring, ensuring a continuous a reoccurring health monitoring for wellbeing evaluation and cardiovascular prevention.

Keywords: non-intrusive monitoring, fibre Bragg gratings, ballistocardiography, polymers.

Acknowledgements: The present study was developed in the scope of the Project "Agenda ILLIANCE" [C644919832-00000035 | Project nº 46] – WP4 OLI Health, financed by PRR – Plano de Recuperação e Resiliência under the Next Generation EU from the European Union; partially supported by project i3N (UIDB/50025/2020,UIDP/50025/2020 and LA/P/0037/2020) funded by national funds through the FCT and MEC of Portugal. Cátia Leitão thanks the CEEC contract (2020.00154.CEECIND/CP1589/CT0019, https://doi.org/10.54499/2020.00154.CEECIND/CP1589/CT0019), funded by national funds through the FCT.

References:

[1] A. Rifat, "The State of Cardiovascular Disease in G20+ Countries," HPHR Journal, vol. HSIL, no. 2022, May 2022.
[2] W. Q. Mok, W. Wang, and S. Y. Liaw, "Vital signs monitoring to detect patient deterioration: An integrative literature review," Int J Nurs Pract, vol. 21, no. S2, pp. 91–98, May 2015.
[3] A. Almeida, S. Brás, and C. Leitão, "Non-intrusive monitoring of heart rate by an office chair instrumentated with optical fiber sensors," in 2023 IEEE 7th Portuguese Meeting on Bioengineering (ENBENG), IEEE, Jun. 2023, pp. 17–20.

Development of all-polymer interferometric biosensors for label-free detection

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ABSTRACT

Polymer-based integrated optics provide advantages in terms of large-scale and low-cost fabrication of multifunctional biosensors when compared to semiconductor materials. Although they are not yet competitive with the latter ones in terms of sensitivity, they have good biocompatibility and suitable designs may provide sufficient sensitivity for label-free biosensing. A new design for integrated Mach-Zehnder interferometers based on asymmetric arms has been proposed and experimentally demonstrated, avoiding the need for additional fabrication steps for an interaction window [1] where biosamples are placed. This difference in the dimensions of the interferometer arms causes an asymmetric change in the effective refractive index, which ultimately leads to a phase variation in the output signal. In this work, we present results for the development of two integrated asymmetric interferometers. We first present the optical principles and the optimization methods used based on mode-solver simulations that return the optimal fabrication dimensions of the interferometer. The designed operation wavelength was set to 650 nm and the polymers chosen were EpoClad and EpoCore [2]. We then discuss the fabrication of these interferometers using e-beam lithography and present characterization results.

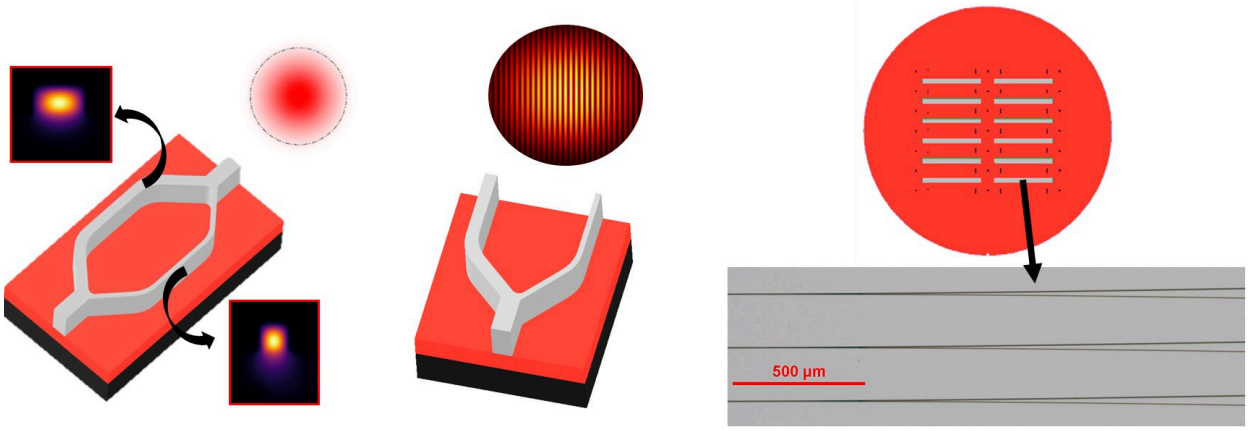

Figure 1. Left and Center: Interferometers with asymmetric arms based on strip waveguides (not to scale). Left: Mach-Zehnder interferometer. The rectangular boxes with arrows correspond to the first-order modes (mode-solver simulations). Center: Young interferometer with two asymmetric arms. The main difference between this design and the Mach-Zehnder one is the detection mode: in the latter case, a single intensity point is measured, while in the former case, a full interference pattern is available. Right: Illustration of a wafer (on top) with several chips containing several interferometers. The rectangle at the bottom corresponds to an optical microscope image of one of these chips.

Keywords: Waveguides, Polymer waveguides, Integrated optical devices, Interferometry, biosensors.

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References:

[1] M. Hofmann et al., "Asymmetric Mach–Zehnder interferometers without an interaction window in polymer foils for refractive index sensing," Appl. Opt., vol. 55, no. 5, pp. 1124-1131, February 2016.
[2] F. J. Gordo, J. Tátá, et al. "Design and manufacture of an all-polymeric integrated multimode interferometer for visible photonics." Opt. Express, vol. 30, no. 17 pp. 31147-31156, August 2022.

Poster Session

Wednesday

July 17 | 16:00–17:30

An affordable optical detection scheme for LSPR sensors

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ABSTRACT

Biosensing technologies are essential to advancing human healthcare since they enable rapid point-of-care (POC) testing and diagnosis, potentially saving time and lives. Biosensors utilizing molecular markers have promise in early disease detection. Such as Local Surface Plasmon Resonance (LSPR) sensors with gold nanoparticles (AuNPs), they are promising due to their simple structure and high sensitivity. However, commercialization is hindered by production costs and the need for precise optoelectronic systems. This article proposes an affordable optical detection scheme for LSPR sensors named BioColor. The BioColor system incorporates a color CMOS camera to capture images of light passing through LSPR sensor elements represented by AuNP-composed plasmonic papers. The differences in the refractive index in the surrounding medium cause shifts in the spectrum of the transmitted light, hence changing its color. This color difference can be detected using image processing algorithms. The detection results are visually represented on the BioColor mobile app, allowing instant automated access to sensing results.

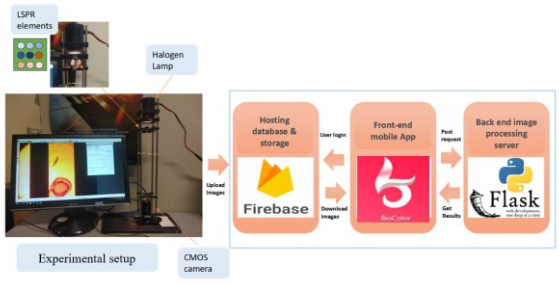

Figure 1. BioColor system architecture.

This study examines the sensitivity of the AuNP-based substrates in different solutions with increasing refractive index: (1) dry substrate, (2) substrate immersed in water, (3) substrate immersed in a mixture of glycerol and ethanol, and (4) substrate immersed in glycerol. The image processing algorithm described in our conference paper is employed to process the captured color images of substrates. Then the processed images are compared using the color distance metric CIEDE2000. In calculating color differences, each substrate is characterized by its mean and dominant color to assess their accuracy. In addition, two types of incident light are applied: halogen lamp and led light to test their effect on enhancing the color variations, hence the sensor's sensitivity. This innovative approach contributes a valuable progress in developing affordable biosensors for point-of-care diagnostics. Particularly, when the LSPR substrate is functionalized with antibodies targeting a specific pathogen to be detected with high sensitivity.

Acknowledgments: This research was supported by Portuguese national funds provided by FCT – Fundação para a Ciência e Tecnologia, through the Portuguese FCT program, Center of Technology and Systems (CTS) UIDB/00066/2020 / UIDP/00066/2020, and by project IPL/IDI&CA2023/LUMINA_ISEL

Design And Development Of A Color Picker System To Integrate In Poc Device Systems.

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ABSTRACT

Nowadays is increasing the demand for miniaturized, user-friendly, automated, and portable sensing systems able to provide a fast and reliable response. In this context, colorimetric detection has emerged for its intrinsic advantages, such as simplicity and rapidity, but also for the outstanding development of novel materials, such a plasmonic nanoparticles, and new technologies. Herein, the Color Picker system, a system reproducing in the backlight of a RGB Display the color revealed by the TCS34725 Color sensor, has been developed and tested in the evaluation of the color differences of plasmonic paper (common paper including plasmonic metal nanoparticles into its structure) coming up from the different refractive index (RI) of the medium surrounding the particles. The results showed that the system is responsive to the changes in the dielectric environment embedding the plasmonic paper, thus providing a tool for a colorimetric detection that can be successively integrated into next generation diagnostic devices for real world applications such as the detection of acute kidney disease (AKI) or the surface spike protein of SARS-CoV-2 to be used in home environment, externally from clinical practice and hospitals.

Fig. 6. Color Picker system showing the color of the plasmonic paper on the display.

Keywords: plasmonic paper, PoC devices, Color sensor, personalized medicine.

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Low cost vector mode direct write lithography for optical waveguide fabrication

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ABSTRACT

Photolithography is a critical process in traditional semiconductor manufacturing and most recently in photonic integrated circuits fabrication, enabling the creation of intricate patterns on various surfaces. Apart from being very expensive, traditional photolithography systems use a set of prefabricated contact masks, with the device designs; this technique suffers from limitations in resolution, flexibility (a new set of masks is needed for each design) and high cost. To overcome some of this constraints, direct write lithography techniques where developed by different manufacturers. In these techniques a beam of light [1] or electrons [2] is used to expose the photoresist by moving a focused spot, in raster mode, over the surface while modulating the beam intensity. This way, the maskless lithography processes will reduce the cost and time needed for the fabrication of microelectronic and photonic device. Despite the advantages, the cost of commercially available systems is still considerably high, thus limiting its use in small labs and teaching environments. In order to develop photonic structures in the micro meter range we engineered and fabricated a low cost (<20k€) tool adapted to the creation of optical waveguides and other modules. A rendering of the system is showed in figure 1.

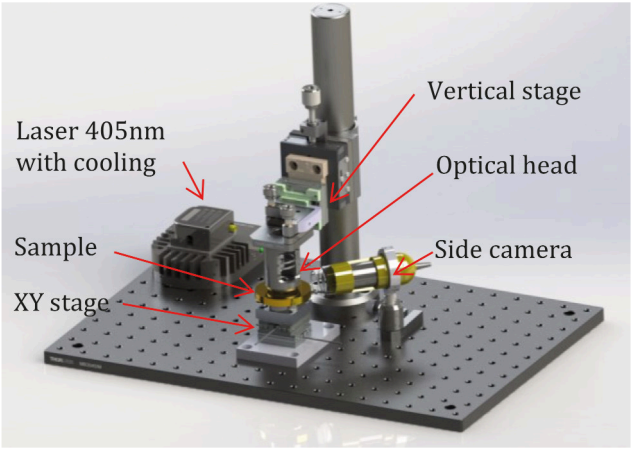

Figure 1. Rendering of the direct laser write system.

The system uses a 405nm 10 mW laser and can structure many negative photoresists designed for direct write, like the micro resist technology mr-DWL series. The focusing of the beam on the surface is controlled by a vertical positioning stage Xeryon XLS-3-40-1250 that moves the optical head. The sample is fixed on a vacuum chuck with the XY position controlled by two closed loop piezo stages with 78nm resolution Xeryon XLS-1-40-78. The software for controlling the system was developed in house and accepts GDSII and Gerber file formats. Optical wave guides were fabricated and characterized to test the system, with promising results.

Acknowledgements: This research was supported by Portuguese national funds provided by FCT – Fundação para a Ciência e a Tecnologia, through Center of Technology and Systems (CTS) UIDB/00066/2020 / UIDP/00066/2020, by FCT project ASER-META 2022.07694.PTDC

References:

[1] H. Ulrich, R.W. Wijnaendts-van-Resandt , C. Rensch, W. Ehrensperger " Direct writing laser lithography for production of microstructures", Microelectronic Engineering, Volume 6, Issues 1–4, December 1987, Pages 77-84
[2] F. Laulagnet, J. Dallery, L. Pain, M. May, B. Hémard, F. Garlet, I. Servin, C. Sabbione, "E-beam direct write lithography: the versatile ally of optical lithography," Proc. SPIE 12497, Novel Patterning Technologies 2023, 1249706 (30 April 2023);

Chitosan-coated optical fiber sensor for the detection of bisphenol A

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ABSTRACT

In food safety, bisphenol A (BPA) is a well-known food contact material contaminant. Its presence in food products is mainly due to migration from polycarbonate plastics and epoxy resins in food packaging but can also originate at the early stages of food production since it is also an environmental contaminant [1, 2]. However, BPA has been shown to be an endocrine disruptor that poses a serious risk to human health [3]. Bisphenol A is traditionally detected in foodstuffs by chromatographic methods, that are laborious, expensive, and time-consuming. Optical fiber sensors are seen as a promising alternative for the detection of chemical compounds, however, to be selective to the target compound the surface of the sensor needs to be modified so it can adsorb only the desired molecule. Chitosan is an abundant polysaccharide derived from chitin. Due to its many hydroxyl and amino functional groups, it has high biosorbent ability and, as such, has been proposed as an effective adsorbent for several chemical contaminants, including BPA [4, 5].
In this work, we propose an optical fiber sensor comprised of a section of a microstructured fiber spliced between two sections of single-mode fiber for the measurement of refractive index. To increase the sensor selectivity towards BPA, the sensor was coated with three layers of a chitosan film. The sensor was characterized in regard to its response to concentration variations, before and after functionalization, using BPA solutions in the concentration range between 0.1 and 1 mg/mL. A maximum sensitivity of 2.04 pm/(mg/mL) was obtained for the chitosan coated sensor, which is over three-times higher compared to the sensitivity of the sensor before coating.

Keywords: Microstructured fiber, optical fiber sensor, refractive index sensing, chitosan, bisphenol A.

Acknowledgements: This work was financially supported by national funds (OE) UIDB/50025/2020 & UIDP/50025/2020, and LA/P/0037/2020 through FCT/MCTES. The work of Ana I. Freitas was supported by the research fellowships SFRH/BD/145262/2019 and BI/UI96/7903/2024. The work was also funded by the German Federal Ministry of Education and Research (BMBF): "RUBIN – QUANTIFISENS - TP11: Specialty fibers and fiber-based components for omnifunctional fiber sensor systems" (FKZ: 03RU1U071J).

References:

[1] F. Vilarinho, R. Sendón, A. van der Kellen, M. F. Vaz, A. S. Silva, "Bisphenol A in food as a result of its migration from food packaging," Trends in Food Science & Technology, vol. 91, pp. 33-65, September 2019.
[2] A. Ballesteros-Gómez, S. Rubio, D. Pérez-Bendito, "Analytical methods for the determination of bisphenol A in food," Journal of chromatography A, vol. 1216, no. 3, pp. 449-469, January 2009.
[3] V. Mustieles, S. C. D'Cruz, S. Couderq, A. Rodríguez-Carrillo, J.-B. Fini, T. Hofer, I.-L. Steffensen, H. Dirven, R. Barouki, N. Olea, M. F. Fernández, A. David, "Bisphenol A and its analogues: A comprehensive review to identify and prioritize effect biomarkers for human biomonitoring," Environment International, vol. 144, November 2020.
[4] A. Zhou, W. Chen, L. Liao, P. Xie, T. C. Zhang, X. Wu, X. Feng, "Comparative adsorption of emerging contaminants in water by functional designed magnetic poly(N-isopropylacrylamide)/chitosan hydrogels," Science of The Total Environment, vol. 671, pp. 377-387, June 2019.
[5] E. B. Simsek, D. Saloglu, N. Ozcan, I. Novak, D. Berek, "Carbon fiber embedded chitosan/PVA composites for decontamination of endocrine disruptor bisphenol-A from water," Journal of the Taiwan Institute of Chemical Engineers, vol. 70, pp. 291-301, January 2017.

Optical Study of Gallium Oxide Thin Films deposited by RF-Sputtering

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ABSTRACT

Gallium Oxide is a wide-bandgap semiconductor which has been steadily growing in popularity due to its ultra-wide bandgap, excellent thermal and chemical stability, availability of bulk substrates and distinctive opto-electrical properties. In addition to these properties, Ga_2O_3 is distinguished by its electrical properties, such as a high breakdown electric field of 8 MV/cm and a high n-type conductivity when doped with different elements such as Si, Ge or Sn, among others. The combination of these optical and electrical properties makes this semiconductor an excellent candidate for the development of various applications such as deep-UV photodetectors [1], low-loss optical waveguides [2], or even solar cells [3]. RF-Sputtering stands out among other possible epitaxial deposition techniques due to its ability to produce Ga_2O_3 thin films with high uniformity, homogeneity, excellent adhesion and at a low-cost.

In this work, an exhaustive study is presented on the influence of different parameters, such as deposition pressure and power, and annealing temperature and time, on the optical and electrical properties of Ga_2O_3 thin films deposited by RF-Sputtering on c-plane sapphire and silicon substrates. These thin films are then fully characterized according to their opto-electrical properties, morphology, and composition. Optical studies include transmission spectra measurements, to ascertain their bandgap, as well as ellipsometry measurements, in the DUV-NIR, from 55° to 75°, and an analysis of the photoconductivity response. Techniques such as X-Ray Diffraction, Rutherford Backscattering Spectrometry (RBS), Raman Spectroscopy and Atomic Force Microscopy are then employed to complement these results, allowing us to discuss how the structural properties, composition, stoichiometry, and surface roughness of the thin films affect the optical properties.

Annealing the thin films grown on sapphire causes two separate processes: at relatively low temperatures, they crystallize into β-Ga_2O_3 with a (-201) orientation; at high enough temperatures, interdiffusion between the Ga_2O_3 and the Al_2O_3 occurs at the film-substrate interface. This leads to the formation of a β-$Al_xGa_{2-x}O_3$ alloy, which has very interesting, and tunable, optical properties, such as bandgap and breakdown field [4]. Preliminary results show that, for the optimized growth pressure, annealing at 500°C and 750°C does not change the bandgap significantly, while annealing at 1000°C leads to an increase from 4.81 to 5.21 eV. In the case of the samples annealed at 1000°C, aluminum interdiffusion was confirmed by RBS, from which it was possible to estimate an interdiffused aluminum fraction of x=0.24. This method shows great potential, in terms of both economic and technical advantages.

Keywords: Ga_2O_3, thin films, sputtering, diffusion, β-$(AlGa)_2O_3$

References:

[1] Y. Peng, Y. Zhang, Z. Chen, D. Guo, X. Zhang, P. Li, Z. Wu, W. Tang, "Arrays of Solar-Blind Ultraviolet Photodetector Based on β-Ga_2O_3 Epitaxial Thin Films", IEEE Photonics Technology Letters, vol. 30, no. 11, pp. 993-996, June 2018

[2] J. Zhou, H. Chen, H. Fu, K. Fu, X. Deng, X. Huang, T. Yang, J. Montes, C. Yang, X. Qi, B. Zhang, X. Zhang, Y. Zhao, "Demonstration of low loss β-Ga_2O_3 optical waveguides in the UV-NIR spectra", Appl. Phys. Lett., vol. 155, pp. 251108, 2019

[3] A. Saikumar, S. Nehate, K. Sundaram, "Review – RF Sputtered Films of Ga_2O_3", ECS Journal of Solid State Science and Technology, vol. 8, no. 7, pp. Q3064-Q3078, 2019

[4] C. Liao, K. Li, C. Torres-Castanedo, G. Zhang, X. Li, "Wide range tunable bandgap and composition β-phase $(AlGa)_2O_3$ thin film by thermal annealing", Appl. Phys. Lett., vol. 118, pp. 032103, 2021

Accommodative and Binocular Predictors for Ocular Symptoms

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ABSTRACT

Visual efficiency and comfort are essential for optimal visual performance and can be compromised by demanding near-vision tasks. This study investigates which parameters of visual efficiency determine ocular symptoms in university students.
The sample of this cross-sectional study was recruited from undergraduate and master's students at the University of Minho. Participants completed a questionnaire distributed through the university network and volunteered for a complete visual examination. The study received institutional ethical approval. The questionnaire, implemented via Google Forms, consisted of three parts: (1) sociodemographic and clinical information, (2) the 15-item Convergence Insufficiency Symptom Survey (CISS) with a cutoff score of 21 points for symptomatic (scores range from 0 to 60 points, with lower scores indicating fewer symptoms), and (3) an invitation to continue participating in the study.
The visual examination assessed refractive state, accommodation (amplitude of accommodation [AA], positive and negative relative accommodation [PRA and NRA], lag of accommodation by Monocular Estimate Method [MEM], and monocular accommodative facility [AF]), and binocular vision (von Graefe horizontal phorias and positive and negative fusional vergence [PFV and NFV] at near and distance). Exclusion criteria included age over 37 years, refraction over ±6.00D, incomplete questionnaires, ocular pathology history, and systemic diseases or medications affecting vision. A multilinear regression was conducted to investigate whether the refraction, accommodative and binocular parameters were predictors of the dependent variable CISS score.
Seventy-one students initially participated, with 20 excluded based on the criteria, resulting in a final sample of 51 subjects. The mean age (±SD) was 24.8±5.6 years, ranging from 17 to 37 years. The sample comprised 20 females (39%; mean age 22.7±4.5 years) and 31 males (61%; mean age 26.1±5.9 years). Multiple linear regression identified AA (β=-1.38; p=0.08) and NRA (β=-9.73; p=0.03) as significant predictors of the CISS score. The final model was CISS_Score = 45.02 - 1.38AA - 9.73NRA, explaining approximately 20% of the variability in the CISS score (p<0.0001, R^2 adjusted=0.172).
The model indicated that accommodative parameters, specifically AA and NRA, are significant predictors of the CISS score. An increase of 1D in AA and NRA decreases the CISS score by approximately 1 and 10 points, respectively. This suggests that the amount of available accommodation and the ability to relax accommodation significantly influence visual comfort for subjects with demanding near-vision tasks.

Acknowledgements: This work was supported by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding UIDB/04650/2020.

References:
[1] M. W. Rouse, E. J. Borsting, G. Lynn Mitchell, M. Scheiman, S. A. Cotter, J. Cooper, M. T. Kulp, R. London, J. Wensveen & Group, C. I. T. T. (2004). "Validity and reliability of the revised convergence insufficiency symptom survey in adults". Ophthalmic and Physiological Optics,
24(5), 384–390.

Influence of anterior keratometry and axial length repeatability in intraocular lens power calculation – A bibliographic and simulation study

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ABSTRACT

Accurate calculation of intraocular lens (IOL) power in cataract surgery is heavily dependent on preoperative biometric measurements. Current biometers allow for precise and reproducible measurements of various ocular components. However, each measured ocular element introduces a measurement error, which can cumulatively increase the error in the IOL power calculation. This study aims to determine the contribution of measurement error (repeatability) in the calculation of IOL power by different biometers.
A literature review was conducted using the PubMed database to identify articles that studied the repeatability of different biometers in cataract patients. The repeatability coefficients for mean anterior keratometry and axial length associated with each instrument were used to generate normal distributions representative of measurement error. The IOL power calculation was performed for a combination of eyes with different anterior keratometries (40 to 46 D) and axial lengths (20 to 30 mm). The influence of measurement error on the IOL power calculation (matrix based-method) was determined through Monte Carlo simulations.[1]
The repeatability of mean keratometry across different biometers is approximately ±0.20 D, and that of axial length is ±20 micrometers. The variability in IOL power calculation associated with keratometry error ranges from ±0.15 to ±0.20 D, depending on the central keratometry value, while the variability in IOL power associated with axial length ranges from ±0.06 to ±0.12 D. The combination of keratometric and axial length measurement errors produces a variability in IOL power calculation between ±0.15 D and ±0.25 D.
Biometers with different optical operating principles provide measurements with low measurement error for ocular components critical in calculating intraocular power. Measurement error associated with keratometry has the greatest influence, accounting for approximately 80 to 90% of the variability in IOL power calculation when considering mean keratometry and axial length. Eyes with higher mean keratometry and shorter axial lengths are most affected by measurement error in the IOL power calculation.

References:

[1] A. Langenbucher; S. Reese; T. Sauer; B. Seitz, “Matrix-based calculation scheme for toric intraocular lenses”. Ophthalmic Physiol. Opt. 2004, 24, 511–519.

pH Sensors Based on PAni-coated Specialty Optical Fibers

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ABSTRACT

This paper reports on study of two optical fiber pH sensors based on polyaniline (PAni) coatings. The first sensor uses a trenched core-free fiber (TCFF), as depicted in Fig. 1a, while the second is based in a side-polished D-shape fiber. PAni was synthesized over the fibers via oxidative polymerization to make them sensitive to pH changes [1].
The TCFF-based sensor showed an optimal linear response range from pH 4.2 to 8.1 with a sensitivity of 1.06 mW/pH, as seen in the sigmoidal fit curve in Fig. 1b. The D-shape fiber sensor had a linear range from pH 2.75 to 6.8 with a sensitivity of 0.95 mW/pH.

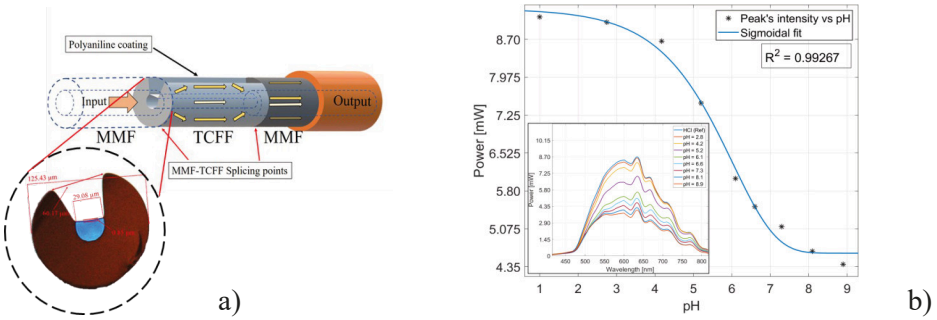

Figure 1. a) TCFF-based pH optical fiber sensor. b) Sensitivity of TCFF-based sensor to pH variation. *Inset:* spectral evolution.

The sensors were also tested for temperature cross-sensitivity. The TCFF sensor showed some variations below 25°C while the D-shape sensor was highly stable across temperatures. The TCFF configuration provided an enhanced pH sensing response compared to the D-shape fiber, with higher sensitivity in the linear range, better repeatability, and minimal temperature cross-sensitivity above 25°C. The combination of both sensors could provide a full pH measurement range from 2.75 to 8.1. These results are in good agreement with the work developed by [2], [3], where other PAni-coated fiber-optic structures for pH sensing were used.

Keywords: Trenched core-free fiber, pH sensor, polyaniline, side-polished fiber.
Acknowledgements: This work was supported in part by project PID2022-137269OB-C21 funded by MCIN/AEI/ 10.13039/501100011033 and FEDER "A way to make Europe", and TED2021-130378B-C22 funded by MCIN/AEI/ 10.13039/501100011033 and European Union "Next generation EU"/PRTR.

References:

[1] Y. Chen, "A review of polyaniline based materials as anodes for lithiumion batteries," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 677, no. 2, p. 022115, Dec. 2019, doi: 10.1088/1757-899X/677/2/022115.
[2] A. Lopez Aldaba, Á. González-Vila, M. Debliquy, M. Lopez-Amo, C. Caucheteur, and D. Lahem, "Polyaniline-coated tilted fiber Bragg gratings for pH sensing," *Sensors and Actuators B: Chemical*, vol. 254, pp. 1087–1093, Jan. 2018, doi: 10.1016/j.snb.2017.07.167.
[3] G. Lopes *et al.*, "Innovative optical pH sensors for the aquaculture sector: Comprehensive characterization of a cost-effective solution," *Optics & Laser Technology*, vol. 171, p. 110355, Apr. 2024, doi: 10.1016/j.optlastec.2023.110355.

Photoinduced birefringence in azopolymers measured at 1550 nm

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ABSTRACT

Azobenzenes are a class of compounds containing two phenyl rings separated by two nitrogen atoms. Their remarkable photo sensitive properties have made them excellent candidates for photonics applications, in fields such as optical data storage, optical switching, micro-patterning, among others [1]. One of their most interesting properties is the ability to orient the azo chromophores, via incident linearly polarized light, along a particular direction. This reorientation gives the azobenzene compound a strong birefringence in a well-defined axis, which can then be erased through circularly polarized light or an increase in temperature.
Several studies have been conducted on the writing/erasing cycles of azopolymers, for the visible spectrum [2]. In this work we propose the study of photoinduced birefringence in azopolymers measured at the telecom band of 1550 nm.
The results present the measured birefringence of a thin film of the azopolymer PAZO, read at 1550,12 nm wavelength. The birefringence is induced by the impinging of linearly polarized light at 450 nm during the first 750 seconds. The recording laser is then turned off for 500 s and the relaxation and stabilization of the birefringence is monitored. For the final 250 s the recording laser is turned on again, but this time circularly polarized, thus erasing the recorded birefringence.
The birefringence reaches a maximum of 4.65×10^{-2} during the recording phase and stabilizes at 4.24×10^{-2} during the relaxation phase.

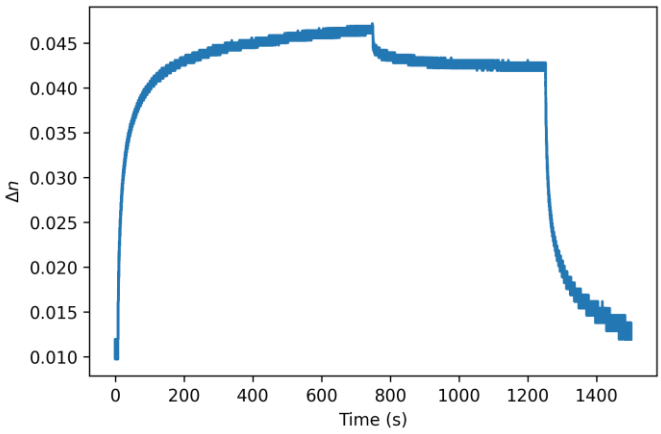

Figure 1. Recording (0 to 750 s), relaxation (750 to 1250 s) and erasure (1250 to 1500 s) of birefringence in azopolymer thin film measured at 1550,12 nm.

Keywords: Azobenzene, Polarization

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References:

[1] A. Natansohn, P. Rochon, "Photoinduced motions in azo-containing polymers", Chemical Reviews, vol. 102, no. 11, pp. 4139-4175, October 2002.
[2] L. Nedelchev, D. Ivanov, B. Blagoeva, D. Nazarova, "Optical anisotropy induced at five different wavelengths in azopolymer thin films: Kinetics and spectral dependence", Journal of Photochemistry and Photobiology A: Chemistry, vol. 376, pp. 1-6, December 2018.

Distributed Acoustic Sensing on SAGRES Submarine Cable

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ABSTRACT

Distributed acoustic sensing (DAS) is a technique that allows continuous and simultaneous data acquisition of strain rate and temperature with high spatial resolution over distances up to hundreds of kilometres. The widespread availability of optical fiber cables makes DAS an appealing technology for various applications, including geophysical sensing [1], infrastructure monitoring [2], and the detection of sea life and ships [3]. This approach enables cost-effective data collection with extensive spatial coverage by capitalizing on existing infrastructure.
In this study, the data were acquired utilizing an OPTODAS system from Alcatel Submarine Networks (ASN). The OPTODAS system was deployed on the Sagres cable, a submarine fiber cable with a total length of 302 km, that connects Sesimbra to Burgau in Portugal. The signal of the cable was acquired with a gauge length of 4.1 meters, for an extension of 22 km, with an acquisition frequency of 1250 Hz. Different events can be detected, namely, waves ripple, as it is possible to verify in Figure 1, seismic activity or perturbations caused by ocean traffic.

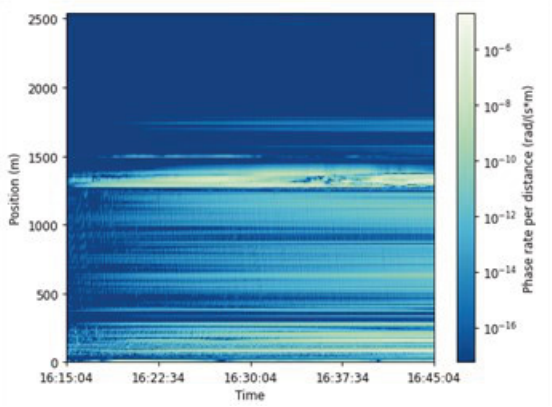

Figure 1. 2D graph of strain recordings over time and length.

Keywords: distributed acoustic sensing, events detection, submarine cables

Acknowledgements: This paper builds on work done within the "SUBMarine cablEs for ReSearch and Exploration | SUBMERSE" - EU funded project (HORIZON-INFRA-2022-TECH-01 Grant agreement 101095055), and we acknowledge the support provided by the SUBMERSE partners.

References:
[1] E. F. Williams, M. R. Fernández-Ruiz, R. Magalhaes, R. Vanthillo, Z. Zhan, M. González-Herráez, H. F. Martins, "Distributed sensing of microseisms and teleseisms with submarine dark fibers", Nature Communications, no.10, p.5778, December 2019.
[2 H. Liu, J. Ma, W. Yan, W. Liu, X. Zhang, C. Li, "Traffic flow detection using distributed fiber optic acoustic sensing", IEEE Access, no. 6, pp. 68968-68968, September 2018.
[3] L. Bouffaut, K. Taweesintananon, H. J. Kriesell, R. A. Rørstadbotnen, J. R. Potter, M. Landrø, S. E. Johansen, J. K. Brenne, A. Haukanes, O. Schjelderup, F. Storvik, Front. Mar., "Eavesdropping at the speed of light: Distributed acoustic sensing of baleen whales in the Arctic", Frontiers in Marine Science, no. 9, p. 901348, July 2022.

Use of laser technology for the postural classification of bedridden people

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ABSTRACT

This work presents an innovative method for the automated classification of postures of bedridden people [1, 2] using laser technology [5]. With the aim of improving the quality of medical care and facilitating the continuous monitoring of patients in clinical and home environments, a system is proposed that uses laser sensors to capture the three-dimensional geometry of body postures. Through advanced computer vision processing techniques [3, 4], a robust classification algorithm is developed capable of identifying and categorizing lateral decubitus postures, also known as lateral safety position, which are commonly used to lay down patients who are permanently bedridden. Experimental results, performed so far, show sufficient accuracy in posture classification, suggesting the potential of this technology to improve the monitoring and care of bedridden patients, while providing periodic warnings to medical staff when a patient has exceeded the recommended time in the same posture, to avoid the appearance of skin ulcers.

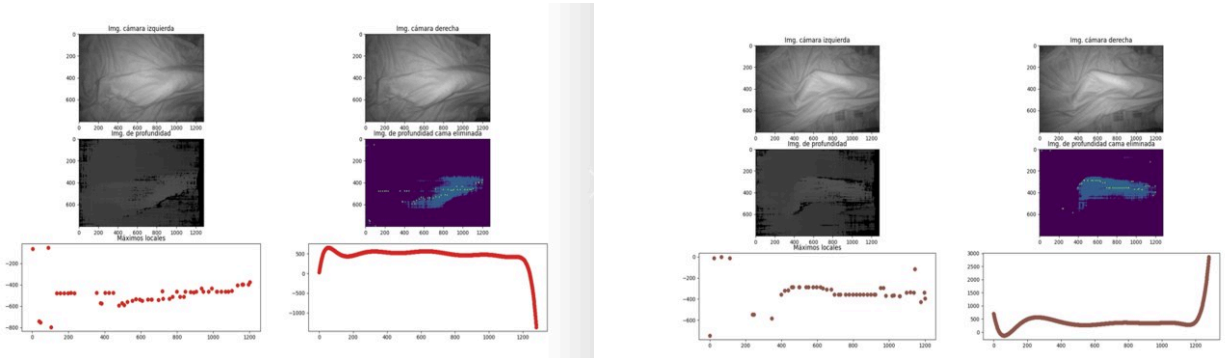

Figure 1. Screenshots of the proof of concept of the proposed algorithm using a commercial stereo camera.

Keywords: Laser, posture classification, bedridden care

Acknowledgements: This work is being carried out thanks to the Industrial Doctorate Grants at the Ferrol Industrial Campus and the collaboration with Anta Norte S.L

References:

[1] Tam, Andy and So, Bryan and Chan, Tim and Cheung, Alyssa and Wong, Duo Wai-Chi and Cheung, Chung-Wai, " A Blanket Accommodative Sleep Posture Classification System Using an Infrared Depth Camera: A Deep Learning Approach with Synthetic Augmentation of Blanket Conditions", Sensors, vol. 21, pp.553, August 2021.
[2] Cao, Ting and Armin, Mohammad Ali and Denman, Simon and Petersson, Lars and Ahmedt-Aristizabal, David, " In-Bed Human Pose Estimation from Unseen and Privacy-Preserving Image Domains" in IEEE 19th International Symposium on Biomedical Imaging (ISBI), Kolkata (India), March 2022, pp. 1 - 5.
[3] Salvi, Joaquim and Pages, Jordi and Batlle, Joan, " Pattern codification strategies in structure light systems", Pattern Recognition, vol. 37, pp. 827-849, April 2004.
[4] Salvi, Joaquim and Fernandez, Sergio and Pribanic, Tomislav and Llado, Xavier, " A state of the art in structured light patterns for surface profilometry", Pattern Recognition, vol. 43, pp. 2666-2680, August 2008.
[5] Jezeršek, Matija and Flezar, Matjaz and Mozina, Janez, "Laser multiple line triangulation system for real-time 3-D monitoring of chest wall during breathing ", Strojniski Vestnik, vol. 54, pp. 503-506, August 2008.

Reflection Fiber Loop Mirrors for the Measurement of Strain and Temperature

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ABSTRACT

Sensors using fiber loop mirrors (FLMs) are widely used in the measurement of strain and temperature with high sensitivity. They have been used by integrating a wide range of highly-birefringent (Hi-Bi) optical fibers. The single FLM configuration (with one section of Hi-Bi fiber) does not allow for the discrimination of the two parameters. Typically, this can be achieved in a transmission configuration by combining two FLMs in series [1] or two cascaded Hi-Bi fibers in a single FLM [2].
In this work, two different configurations based in a reflection scheme are explored. The first configuration contemplates the use of two cascaded PANDA-type Hi-Bi polarization maintaining fibers (coil and straight) with different lengths. Besides, one polarization controller is used between the coupler and the straight PANDA fiber section (see Figure 1). In the second configuration, the two PANDA fiber sections are intercalated by a second polarization controller (represented in dash lines in Figure 1). The spectral response is measured in reflection, via an optical circulator. In the first configuration, simultaneous measurement of strain and temperature are proposed, whereas in the second configuration independent measurement of strain and temperature is achieved.

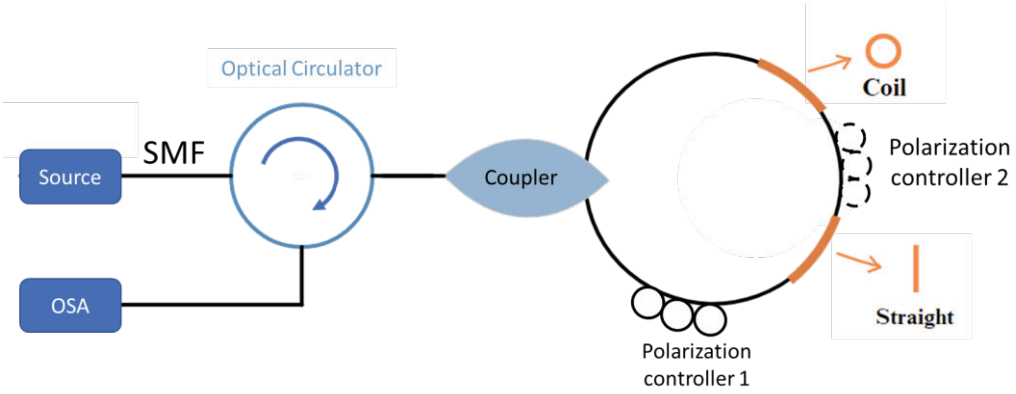

Figure 1 – Scheme of the experimental setup with the two sensors in series.

Keywords: fiber loop mirror, panda fiber, strain, temperature.

Acknowledgements: This work was supported also by project i3N, UIDB/50025/2020, UIDP/50025/2020 and LA/P/0037/2020 which was financed by national funds through the FCT and the MEC of Portugal.

References:
[1] Z. Ding, Z. Tan, S. Xiao, and H. Gao, "Sensitivity amplification of high birefringence fiber loop mirror temperature sensor with Vernier effect," *Appl Phys B*, vol. 127, no. 5, pp. 1–10, 2021, doi: 10.1007/s00340-021-07612-x.
[2] Z. C. Ding, Z. W. Tan, Y. S. Gao, Y. Wu, and B. Yin, "Strain and temperature discrimination using a fiber Bragg grating concatenated with PANDA polarization-maintaining fiber in a fiber loop mirror," *Optik (Stuttg)*, vol. 221, no. June, p. 165352, 2020, doi: 10.1016/j.ijleo.2020.165352.

Ion-implanted β-Ga_2O_3 microtubes & nanomembranes for photonic applications

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ABSTRACT

The modification of wide bandgap semiconductors by ion implantation is one of the key enabling technologies for photonic applications. On the one hand, it allows for the controlled introduction of foreign ions into the lattice, with the goal of exploiting their intraionic transitions in the optical spectral range. On the other hand, defects induced during the implantation process often have interesting optical properties themselves (e.g., the well-known nitrogen-vacancy colour centre in diamond) and can be used to modify the samples' optical properties (e.g., changing the refractive index to create a waveguide).
Monoclinic β-Ga_2O_3, with its ultrawide bandgap of ~4.8 eV at room temperature, has been gaining increased interest as one of the most promising semiconductors for photonic applications, due to its potential as an excellent host matrix for different optical centres. Some of these applications include solar-blind ultraviolet (UV) photodetectors, integrated waveguides or ionising radiation sensors, such as iono- or thermoluminescent dosimeters [1]. Moreover, thanks to the (100) easy-cleavage plane, this material lends itself to the production of thin flakes produced by conventional mechanical exfoliation techniques (e.g., the scotch tape method), which have been exploited for their luminescence properties [2].
In this work, we report a novel process to fabricate β-Ga_2O_3 microtubes and nanomembranes by ion implantation into (100)-oriented single-crystals [3]. Under specific implantation conditions, the induced strain field promotes the rolling-up of the surface layer, forming a microtube. These strains can then be relaxed under thermal annealing, which triggers the unrolling of the microtubes and the formation of nanomembranes with bulk-like crystalline quality. This process enables the fabrication of nanomembranes which can be customised to the desired application, by offering improved reproducibility and control of parameters such as the membrane thickness or its optical, magnetic or electrical properties.
With the goal of understanding the physical processes underlying this newly-reported implantation-induced exfoliation phenomenon, this work consists on a detailed study of β-Ga_2O_3 samples implanted with Cr under different conditions, combining X-Ray Diffraction, Rutherford Backscattering Spectrometry in the Channelling Mode and Molecular Dynamics simulations. In particular, the agreement between experiment and simulation concerning defect profiles and subsequent strain and stress fields created by the implantation allows the comprehension of the physical phenomena leading to exfoliation. Furthermore, the recovery of the implantation damage at moderate temperatures, which leads to nanomembranes with excellent crystalline quality, allows their exploitation as UV photodetectors with promising properties.

References:

[1] M. Peres, K. Lorenz et al., "Micro-Opto-Electro-Mechanical Device Based on Flexible β-Ga_2O_3 Micro-Lamellas", ECS J. Solid State Sci. Technol., vol. 8, no. 7, p. Q3235–3241, June 2019.
[2] D. M. Esteves, K. Lorenz, M. Peres et al., "Probing the Cr^{3+} luminescence sensitization in β-Ga_2O_3 with ion-beam-induced luminescence and thermoluminescence", Sci. Rep., vol. 13, no. 4882, March 2023.
[3] Patent "Process for Producing Rolls and Membranes of Submicrometric thickness of Ga_2O_3 by Ion Implantation": PT 117063; EU PCT/PT/2022/050006; USA R6157.0189/189US

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Electric power generation from solar irradiation by using multiplexed holographic lenses and a hybrid photovoltaic thermal system

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ABSTRACT

Nowadays, photovoltaic (PV) and Peltier cells, and solar collectors can be used in order to generate electrical power from solar irradiation. The combination of PV and Peltier cells builds a hybrid photovoltaic thermal (PVT) system. Usually, the solar collectors focus the solar irradiation onto a PV cell, the multiplexed holographic lenses (MHLs) is an example of a transmissive solar collector that heat the surface of a PV. In this work, MHLs are designed for wavelengths in the visible spectrum in order to focus solar irradiation of these wavelengths onto a PV cell array. The remaining wavelengths of solar irradiation transmitted by the MHLs are redirected onto a Peltier cell array. The proposed design is intended to take advantage of solar energy in its different wavelengths to generate electricity more efficiently and to safeguard the useful life of the PV cells by not irradiating them with solar energy in infrared wavelengths. Finally, a relationship between the solar energy incoming into the MHLs with the generated electric potential differential by the Peltier cells is presented and this result is compared with the obtained from a PV cell.

Keywords: Multiplexed holographic lenses, photovoltaic and Peltier cells, solar energy, energy conversion.

Low-Cost Prototype for Real-Time Analysis of Liquid Crystal-based Optical Sensors

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ABSTRACT

In the food production industry, controlling potential risks to human consumption must be done promptly and accurately. This is crucial to prevent the spread of life-threatening pathogens, which could be achieved by in situ detection of said pathogens, such as E. coli, a bacteria capable of resisting harsh conditions, and which is prevalent in bivalve harvesting [1, 2]. In general, in the aquaculture industry, the quality control of production tanks through non-invasive methods is the most desirable, promoting less stressful environments for healthy fish reproduction. In several studies, fish stress levels have also been proven to relate to water pollution, i.e. the release of cortisol stress hormones is associated with the pollution of the production environment. The real-time monitoring of this hormone could lead to reduced mortality rates and better growth performance [3]. Based on the liquid crystal-based optical sensors developed by Soares et al [4], we designed a low-cost prototype, using a Raspberry Pi microcontroller and a digital High-Quality camera, based on the working principles of the Polarized Optical Microscope (POM). This prototype can estimate in real time the concentration of the analyte present in the biosensor, which could be constructed for both E. coli and cortisol detection. The setup estimates the concertation from the percentage of coloured pixels observed from light's distortion by the biosensor, sitting between two crossed polarizers. It focuses on improving not only on the time required for the analysis of these sensors, removing the dependency on the POM but also leaving room for improved portability. The design of the prototype allows for the flexibility of light source choice, while also allowing it to be tuned for the utilization of sunlight as a source for bacteria detection. This concept is a step in contributing to a cost-efficient and timely detection of analytes addressing the present problem in the aquaculture industry.

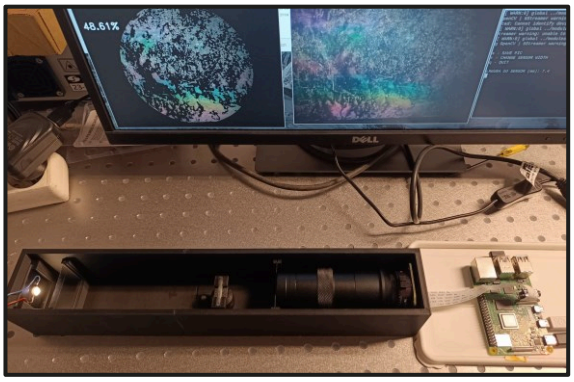

Figure 1. Working prototype, connected to a monitor and using an LED as a light source.

References:

[1] D. K. Bagenda, S. Nishikawa, H. Kita, et al., «Impact of feeding on oyster depuration efficacy under conditions of high salinity and low temperature», Aquaculture, vol. 500, 135–140, Feb. 2019.

[2] Centers fo Disease Control and Prevention (CDC), Foodborne diseases active surveillance network (foodnet) - pathogen surveillance, https://wwwn.cdc.gov/foodnetfast/, [Accessed 09-04-2024], 2022

[3] D. Aguiar, C. Marques, and A. C. Pereira, «The importance of monitoring cortisol in the agri-food sector—a systematic review», Metabolites, vol. 13, no. 6, p. 692, May 2023.

[4] M. S. Soares, R. G. Sobral, N. Santos, C. Marques, and P. Almeida, «Liquid crystal-based immunosensor for the optical detection of escherichia coli at low concentration levels», IEEE Sensors Journal, 2023.

High photoinduced birefringence in thermally treated layers of the azopolymer PAZO with significantly changed absorbance spectrum

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ABSTRACT

In this experimental work we present the effect of thermal treatment of azopolymer thin films on their absorbance spectra and how that influences the photoinduced birefringence of the azopolymer. The azopolymer we use – PAZO (poly[1-[4-(3-carboxy-4-hydroxyphenylazo)benzene sulfonamido]-1,2-ethanediyl, sodium salt]) is commonly investigated material for polarization holography [1-3] because it is easily accessible and has well pronounced photoanisotropic properties. In a recent study it was discovered that its absorbance spectrum gradually changes upon heating to 250-300°C and as a result the absorbance in the range 400-600 nm is increased [4]. That raises the question is it possible to increase the photoinduced birefringence for wavelengths that are far away from the peak of absorbance located approximately at 360 nm. For example, there are powerful lasers at 532 nm, which could be used for optical recording instead of traditionally used lasers in the blue and UV range.
To answer this question we investigated thin film samples of PAZO deposited on quartz substrate and measured continually their spectra of absorbance while heating the samples from room temperature to 250°C with thermal system "Linksys 32" and also, we measured the photoinduced birefringence using pump laser at 532 nm before and after the thermal procedure. Thus, we report significant increase of the birefringence at 532 nm after the thermal treatment and discuss future applications.

Keywords: azopolymer PAZO, photoinduced birefringence, thermal treatment, polarization holography.

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References:

[1] L. Nikolova and P. S. Ramanujam, Polarization Holography, Cambridge, UK: Cambridge University Press, 2009.
[2] A. Emoto, E. Uchida, and T. Fukuda, "Optical and physical applications of photocontrollable materials: Azobenzene-containing and liquid crystalline polymers," Polymers, vol. 4, pp. 150-186, 2012.
[3] X. Wang, Azo Polymers: Synthesis, Functions and Applications, Berlin, Germany: Springer-Verlag, 2017.
[4] G. Mateev, L. Nedelchev, A. Georgiev, and D. Nazarova, "Improvement of the photoinduced birefringence in azopolymer PAZO doped with TiO_2 nanoparticles via thermal treatment", Open Material Sciences, vol. 5, pp. 19-23, 2019.

Mobile system to detect plastic particles in critical scenarios: potential approach for attachment in UAVs

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ABSTRACT

Microplastics are present in almost every place we could imagine from the oceans to the atmosphere even in the human body. Nowadays, most techniques used for the detection in the atmosphere are based on collection and posterior analysis on the ground. With a certain degree of accuracy, the prospect of this system is to determine in a more practical and rapid way the presence of those particles.
Seeing this increase in concern, the fast and accurate detection of plastic particles is even more needed than it was years ago. Currently, most of the detection involves complex, expensive, hard-to-operate systems and equipment. This paper focuses on verifying if and how a system of commercial LEDs and detectors that might be a photodiode or a phototransistor can be used for this purpose.
Our system will have a set of LEDs aligned with some detectors. Using a commercial microcontroller, we plan to identify changes in the detection that might indicate the presence or passage of particles.
This work will not only study the capacity of this system to detect particles but also, if we can make an algorithm capable of with some sort of accuracy to determine the particles automatically without any need for human intervention.
Figure 1 shows a schematic example of the scheme used for testing.

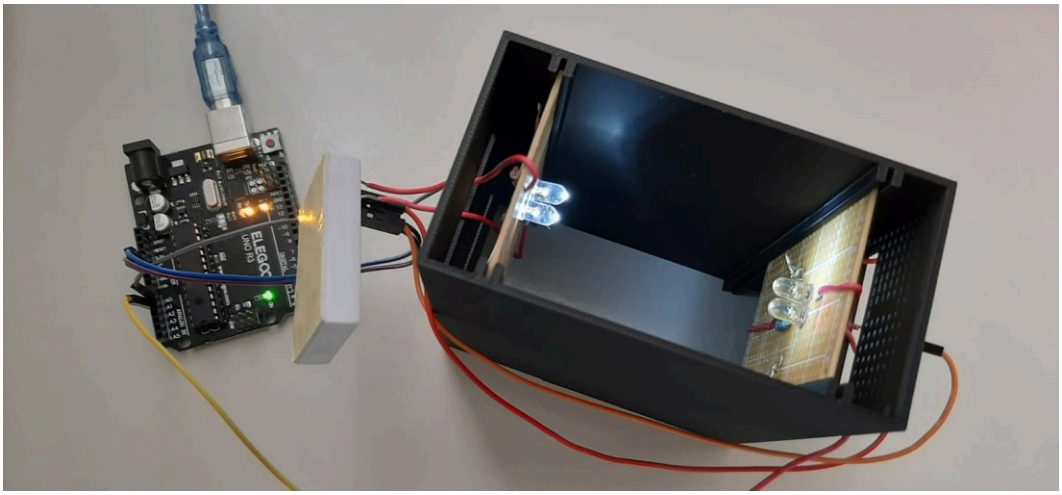

Figure 1. Experimental setup used to acquire some of the data.

Keywords: Plastic Particles; LEDs; Photodetector; Microcontroller

Independent Dynamic Bandwidth Allocation algorithms' co-existing in Virtual Passive Optical Networks and their Progression to Coherent PON

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ABSTRACT

With the rise in internet traffic, 5G applications, and high bandwidth services, network operators are more inclined to come up with innovative solutions for the provision of services and network access. In our research we have implemented the merging engine which exhibits the co-existence of the virtual Dynamic Bandwidth Allocation (DBA) algorithm at Optical Line Terminal (OLT), sharing the Passive Optical Network (PON) upstream capacity [1]. Virtualization is achieved by permitting the network operators full control over capacity assignment algorithms. This work has been evaluated with extensive simulations on NS-3 XGPON module**.** Our work presented maximization of the Bandwidth utilization by sharing the upstream frame between multiple operators. This sharing increases economic sustainability by allowing several operators to operate over the same deployed fiber and generate a customized frame-level allocation, giving them complete control over their upstream traffic scheduling.
Coherent PON (CPON) is another solution to improve the optimal performance and bandwidth management in the access networks. We have proposed a PON tomography model that uses Digital Signal Processing (DSP) techniques to collect the real time data from the OLT and Optical Network Units (ONUs). This data is used to analyze the chromatic dispersion and other nonlinearities in both physical and logical layers. This data is then trained to provide an automatic bandwidth allocation. As an outcome to this framework of CPON and Virtual PON, network performance, scalability, efficiency and bandwidth utilization of the existing network has improved and it can pave the way for future next-generation

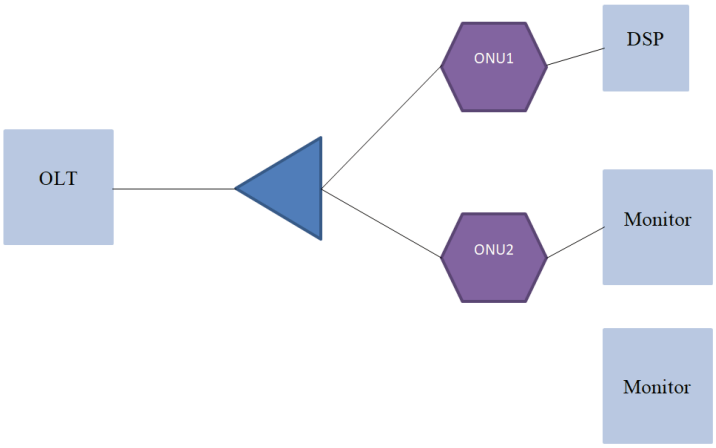

Figure 1. PON tomography model

Keywords: Passive Optical Networks, Coherent PON, Dynamic Bandwidth Allocation (DBA), Optical Line Terminal (OLT), Optical Network Unit (ONU)

References:
[1] Gulmina Malik, Akhlaque Ahmad and Arsalan Ahmad, *Merging Engine Implementation with Co-Existence of Independent Dynamic Bandwidth Allocation Algorithms in Virtual Passive Optical Networks*, in OSA Asia Communications and Photonics Conference (ACP), 2021

FBG-Based Torque and RPM Sensor Embedded in a 3D-Printed structure for Aerospace Applications

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ABSTRACT

In pursuit of a lightweight and compact sensor for monitoring the driving torque and the rotations per minute (RPM) produced by a motor, this paper advocates for the use of fiber Bragg gratings (FBGs) embedded into an additively manufactured supporting structure (figure 1). The proposed methodology involves measuring the strain in the motor's support by using two to six FBGs, depending on the desired resolution and on the budget constraints. Notably, the effects of the torque ripple [1] could be observed as a periodic wavelength variation, the frequency of the wave presented a linear correlation to the motor's RPM, which made possible to measure RPM. Additionally, a Kalman filter was implemented in an attempt of reducing the estimation error of torque and RPM. Furthermore, despite PETG being used for the supporting structure as it is less sensitive to creep when compared to other FDM filaments, it was necessary to test the evolution of estimated torque with respect to time to ensure the reliability of the developed sensor and the repeatability of its measurements. Fatigue and thermal tests were conducted to ensure it can withstand cyclic loads and to analyse how temperature fluctuations affect measurements, respectively.

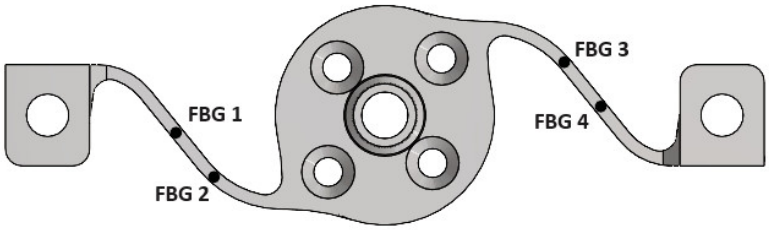

Figure 1. Torque and RPM Sensor with FBGs Embedded into Support Structure

References:
[1] S. Salon, K. Sivasubramaniam and L. Ergene, "The effect of asymmetry on torque in permanent magnet motors," *in Proceedings of the IEMDC 2001. IEEE International Electric Machines and Drives Conference (Cat. No.01EX485), Massachusetts, United States of America, 2001, pp. 208-217.*

Advanced Algorithms for Optimization of QKD Encoding Subsystems

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ABSTRACT

As advancements in quantum computing threaten classical encryption methods, quantum-resistant security solutions are crucial. Quantum Key Distribution (QKD) uses quantum mechanics to enable theoretically secure communication, detecting any eavesdropping attempts due to the properties of quantum states. Various degrees of freedom in photons, such as polarization, phase, and time-bin, can be used to encode information. Polarization-based QKD is one of the most widely implemented methods due to its simplicity and robustness. It often utilizes setups involving phase modulators or polarization controllers to manipulate photon states. Our research focuses on optimizing a polarization-based QKD encoder using Lithium Niobate electro-optic polarization controller. Each stage of these controllers acts like a customizable waveplate through the application of an electric field, and the devices we selected have 6-8 stages. They were chosen for their straightforward implementation and ability to achieve the desired output States of Polarization (SOP) without requiring any specific polarization at the input. Additionally, they feature a low response time of under 100 ns. Due to the nature of the device, multiple voltage combinations, which become more complex with the number of modulator stages, can produce the same output SOP. We present optimization methodologies for QKD protocols like BB84 that minimize voltage requirements and jumps while maintaining a well-defined SOP.

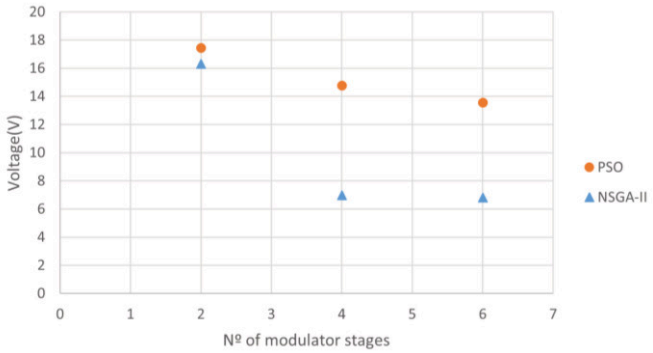

Figure 1. Optimized voltage ranges applied to each stage, for a BB84 implementation.

Figure 1 shows how the number of active stages affects the minimum voltage range required for the two orthogonal bases in BB84. We compare Particle Swarm Optimization (PSO) with scalarization [1] and the Non-dominated Sorting Genetic Algorithm II (NSGA-II) [2], which uses the Pareto front. PSO struggles with balancing weights for a single optimization function, unlike NSGA-II. NSGA-II, with an iterative constraint methodology, can improve results by over 50%, very relevant for the development of the correct electronic drivers. We also discuss results from other algorithms such as Multiple Objective PSO (MOPSO) and provide comparations on the convergence speed, population size, and other metrics that can affect the lab setup.

Acknowledgements: This work was supported by the EU QuantERA program (GA 101017733), through the project QuantaGenomics, with national funding from FCT (QuantERA/0001/2021), by the EU DIGITAL-2021-QCI-01 Programme, through the project PTQCI (GA 101091730), and by FEDER, through the COMPETE 2020, under the project QuantumPrime, (ref. PTDC/EEI-TEL/8017/2020). Hugo Costa's work was supported by FCT under Ph.D. Grant 2023.01100.BD.

References:

[1] Costa, H., Muga, N. J., Silva, N. A., & Pinto, A. N. (2022). Optimization of a Polarization-Encoding System for Practical Quantum Key Distribution. SBRC Workshop de Comunicação e Computação Quântica WQuantum.
[2] Gunantara, Nyoman. (2018). A review of multi-objective optimization: Methods and its applications. Cogent Engineering.

Development of an experimental system for nonlinear material study and characterization

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ABSTRACT

The nonlinear process of radiation emission in media is highly dependent on the structure of the material under study, in particular on the local symmetries of the crystalline structure. When the process is done in transmission, there is usually a contribution from the bulk and the surface. By studying the process on reflection, it is possible to isolate the contribution from surfaces and interfaces [1, 2]. The goal of this experiment is to characterize the structure, the symmetries, and the response to ultrafast laser light of materials. Our experiment uses a 1030 nm, 100 kHz, femtosecond, Yb:YAG laser. The beam is directed to a sample at a 45º incident angle, and the output is collected by a photomultiplier tube coupled to a monochromator. The pulse energy, pulse duration, polarization and spot size of the incident beam, and the azimuth angle of the sample can be controlled. The P and S components of the polarization of the output beam are separated and measured.

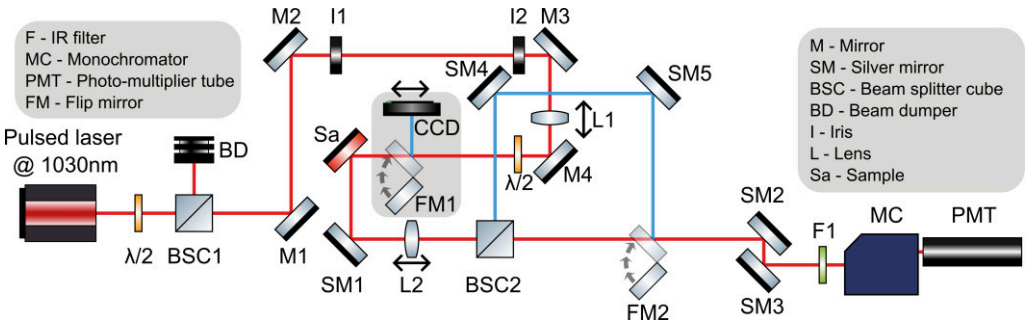

Figure 1. Diagram of the experimental setup

We present the design and implementation of the experimental system and the process of calibration of its multiple constituent parts. Furthermore, preliminary data will also be shown that been collected using a single-crystal Si (111) sample as a benchmark. An emission peak has been observed at a wavelength of about 350 nm.

Keywords: ultrafast optics, nonlinear optics, material characterization, semiconductor, lasers

Acknowledgements: IPFN activities were supported by FCT - Fundação para a Ciência e Tecnologia, I.P. by project reference UIDB/50010/2020 and DOI identifier 10.54499/UIDB/50010/2020 (https://doi.org/10.54499/UIDB/50010/2020), by project reference UIDP/50010/2020 and DOI identifier DOI 10.54499/UIDP/50010/2020 (https://doi.org/10.54499/UIDP/50010/2020) and by project reference LA/P/0061/202 and DOI 10.54499/LA/P/0061/2020 (https://doi.org/10.54499/LA/P/0061/2020).

References:

[1] A. Prylepa et al, "Material characterisation with methods of nonlinear optics", Journal of Physics D: Applied Physics, vol. 51, no. 4, pp. 043001, January 2018.
[2] Y. R. Shen, The principles of nonlinear optics. Hoboken, USA: John Wiley & Sons, 2002.

OPCPA Optimization for Ultrafast Near-Infrared Lasers

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ABSTRACT

In the past decades, there has been a rising interest in high power laser sources. Optical Parametric Chirped Pulse Amplification (OPCPA) has been employed in developing state-of-the-art sources in both the near and mid-infrared [1]. This technique uses nonlinear materials to transfer energy from a high energy pulse (pump) to an ultrabroadband pulse (signal) that can then be compressed back into high power short pulses. This circumvents the limited availability of efficient laser gain materials (for a given wavelength), allowing better pulse tunability [2]. As such, studying ways to optimise this process is of utmost importance to advance ultrashort laser pulse technology.
This project consists of studying the three main processes involved in the OPCPA setup in Laboratory of Intense Lasers (L2I)[1]: Second Harmonic Generation (SHG), Supercontinuum Generation (SCG) and the OPCPA itself. This system uses as a driver a Multipass Cell system that self-compresses 1030 nm wavelength, 100 kHz pulses to 100 fs with up to 66 W. When compared to previous efforts [2], the higher repetition rate and shorter pulses are predicted to result in better outputs, mainly better beam stability and shorter pulses. The setup consists of a SHG stage using a BBO crystal (pump), a SCG stage using sapphire (signal), converging into the final OPCPA stage that uses a YCOB crystal.

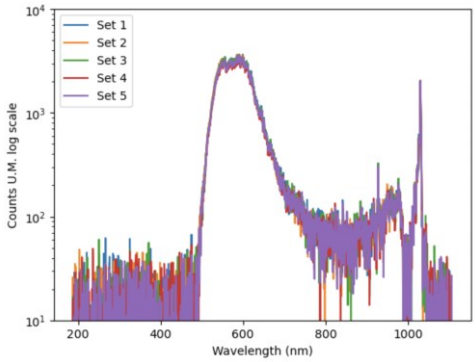

Figure 1. Supercontinuum Spectrum (5 data sets for short term stability)

At the moment, both the SCG and SHG setup are in place. The SHG has achieved conversion efficiencies above 30% and can still be optimised further. For SCG, preliminary results have also been obtained and are shown in Fig 1, where multiple spectrums were taken to show short term stability. First data on OPCPA will follow.

Keywords: nonlinear process; ultrashort pulses; parametric amplification; high power laser

Acknowledgements: IPFN activities were supported by FCT - Fundação para a Ciência e Tecnologia, I.P. by project reference UIDB/50010/2020 and DOI identifier 10.54499/UIDB/50010/2020 (https://doi.org/10.54499/UIDB/50010/2020), by project reference UIDP/50010/2020 and DOI identifier DOI 10.54499/UIDP/50010/2020 (https://doi.org/10.54499/UIDP/50010/2020) and by project reference LA/P/0061/202 and DOI 10.54499/LA/P/0061/2020 (https://doi.org/10.54499/LA/P/0061/2020).

References:
[1] Rothhardt, J. et al, “High average power near-infrared few-cycle lasers.” Laser Photonics Rev. 2017, 11, 1–25.
[2] Pires H. et al, "Ultrabroadband OPA in YCOB with a sub-ps Pump Source" Photonics 2023, 1, 0

Ultrafast Lasers Towards TRIR Spectroscopy

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ABSTRACT

Time-resolved infrared spectroscopy (TRIR) is an advanced tool for studying ultrafast molecular dynamics. As a time-resolved transient absorption spectroscopy technique, TRIR utilizes an infrared laser to excite materials under study, enabling the unravelling of complex DNA structures [1] and shedding light on chemical processes critical for drug manufacturing. Additionally, TRIR can be used to investigate material properties [2], providing insights into various scientific and industrial applications.

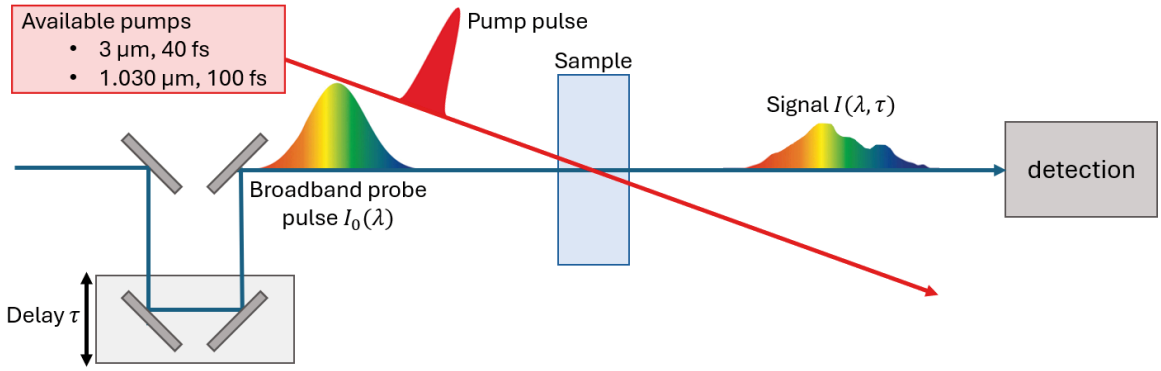

Figure 1. Schematic representation of TRIR spectroscopy.

This work establishes and benchmarks a TRIR spectroscopy workstation at the Laboratory of Intense Laser (L2I), managed by the Group of Lasers and Plasmas (GoLP) at the Instituto de Fusão Nuclear (IPFN). By leveraging the ultrafast lasers available at our institute, we can capture sub-picosecond transient states of molecules. Our laboratory is equipped with a high-energy 3 µm laser system, featuring an average power of 6.5 W, a repetition rate of 100 kHz, and pulse characteristics of 40 fs duration and 65 µJ. Additionally, we have a 1.030 µm, 100 kHz laser system that, when coupled with a multi-pass cell, achieves pulse durations of 100 fs. As a proof of principle, some initial testing has been done using rhodamine 6G, with the 1.030 µm laser as the pump and 515 nm as the probe. These unique resources position our laboratory to make contributions to the field of ultrafast TRIR spectroscopy, providing detailed insights into molecular dynamics and material properties.

Keywords: Time-resolved transient absorption, ultrafast lasers, molecular dynamics.

Acknowledgements: IPFN activities were supported by FCT - Fundação para a Ciência e Tecnologia, I.P. by project reference UIDB/50010/2020 and DOI identifier 10.54499/UIDB/50010/2020 (https://doi.org/10.54499/UIDB/50010/2020), by project reference UIDP/50010/2020 and DOI identifier DOI 10.54499/UIDP/50010/2020 (https://doi.org/10.54499/UIDP/50010/2020) and by project reference LA/P/0061/202 and DOI 10.54499/LA/P/0061/2020 (https://doi.org/10.54499/LA/P/0061/2020).

References:

[1] Michael Towrie et al. “ps-TRIR covers all the bases – recent advances in the use of transient IR for the detection of short-lived species in nucleic acids”. In: Analyst (2009).
[2] Augusto Marcelli et al. “Time Resolved IR and X-ray Simultaneous Spectroscopy: New Opportunities for the Analysis of Fast Chemical-Physical Phenomena in Materials Science”. In: Acta Physica Polonica A (2009).

Optical properties of N-doped Graphene and Carbon Nitride Quantum Dots

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ABSTRACT

The potential application of graphene quantum dots (GQDs) includes including optical detection probes, bio-imaging probes, electrochemical capacitors, solar cells, Li-ion batteries, visible-light-derived photocatalysts etc. In this study, the N-doped graphene quantum dots (NGQDs) and carbon nitride quantum dots (CNQD) samples was prepared by microwave process [1]. Citric acid, urea and distilled water was mixed in various ratio and subsequently heating at 280 ºC and was microwave on 6000 W power with a rotational speed of 60 rpm. Then the sample was heat in air. Three samples (ca. 100 g) with different ratios of citric acid to urea (1/2, 1/1, and 2/1 in w/w; labeled as NCD-1, NCD-2, and NCD-3 respectively).
The optical images of different quantum dots in distilled water under UV (365 nm) are shown in Fig. 1. The analysis reveals that Under the UV light, the quantum dots are capable of illuminating yellow-green (NCD-1), green (NCD-2), and deep blue (NCD-3) in water. The fluorescence spectrum of the synthesized quantum dots conformed to the UV-vis absorption characteristics. Fig. 2 depicts PL emission spectra of different quantum dots in distilled water. The PL response also shows a single typical band at ca. 450 nm under 340 and 360 nm, ascribed to the presence of g-C_3N_4 in the NCD-1 sample. For the NCD-3 sample, a distinct peak within the entire wavelength (320–480 nm) can be observed.

Figure 1. Optical images of different samples in distilled water under 365 nm UV light.

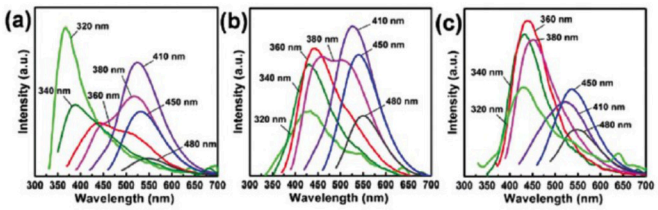

Figure 2 PL emission spectra of different samples in distilled water: (a) NCD-1, (b) NCD-2, and (c) NCD-3

Keywords: graphene, graphitic carbon nitride, quantum dots, photoluminescence, white-like light

References:
[1] S. Gu, C. T. Hsieh, Y. A. Gandomi, J. Li, X. X. Yue and J. K. Chang, "Tailoring fluorescence emissions, quantum yields, and white light emitting from nitrogen-dopedgraphene and carbon nitride quantum dots," Nanoscale, 11, pp. 16553-16561, 2019.

Ultrafast laser-assisted production of nano-and micro-plastics and their interaction with cells

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ABSTRACT

Micro- and nano-plastics (PNs) are produced in the environment from plastic waste due to environmental factors, such as light and temperature [1]. They can end up in humans via the food chain, but the impact of PNs on cellular processes has yet to be fully elucidated.
We focus on PNs fabrication by mimicking the natural degradation processes i.e., laser ablation of waste PET with an ultrafast laser (Ti: Sapphire laser modelocked, MANTIS (Coherent)). Starting conditions were found in the literature [2].

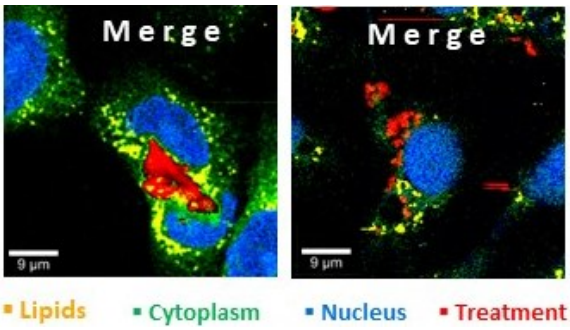

Figure 1. Images and spectra of different components of A549 cells exposed to PNs (left) and PNs TiO_2 (right) over 24 hours. The colour-coded images (merge) represent the overlapping of lipids (yellow), cytoplasm (green), nuclei (blue), and PNs/PNs TiO_2 (red).

Separately, we have illuminated PET pieces immersed into the solution of TiO_2 colloids, which should bind to PNs and enable easier visualization after cellular internalization. Square pieces of PET bottles, 1x1 cm^2, were immersed in milli-Q water and subjected to repeated ablation for 10 or 20 minutes.
PNs were characterized by dynamic light scattering, which shows PNs with a diameter between 20-50 nm. Although the PNs were ingested by the cells (Fig. 1), they did not significantly affect the cell viability.
Microscopic images were acquired with confocal Raman microscopy. Images confirm that the PNs are ingested and localized in the cytoplasm near the nucleus. Their potential interference with signalling pathways remains to be further elucidated.

References:

[1] S. Sangkham, O. Faikhaw, N. Munkong, et al. "A review on microplastics and nanoplastics in the environment: Their occurrence, exposure routes, toxic studies, and potential effects on human health", Marine Pollution Bulletin, 181 (2022) 113832.
[2] D. Zhang, Z. Li, K. Sugioka, "Laser ablation in liquids for nanomaterial synthesis: diversities of targets and liquids", J. Phys. Photonics 3 (2021) 042002.

Non-destructive gratings recorded in Bi_2TeO_5 photorrefractive crystals

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Non-destructive volume holograms or gratings are interesting for different applications and particularly useful as narrow band light filters [1]. Photorefractive Bismuth Tellurium Oxide Bi_2TeO_5 (BTeO) crystals have already been reported before, presenting interesting properties for different applications [2,3,4]. We report features of the non-destructive gratings recorded in undoped BTeO photorefractive crystals. A two-wave mixing experiment was carried out with nonexpanded 532 nm wavelength laser beams with total beam power P_T (0)=240 mW symmetrically directed onto the (100) crystal input plane of the a 2.2 mm thick nominally undoped photorefractive BTeO crystal produced with use of the double-crucible Czochralski method [5]. The gratins were recorded at room temperature for with different recording times and different spatial frequency. After that, with one of the recording beams, the sample was illuminated during 6 hours in order to erasure the photosensitivity gratings. Since then the diffraction efficiency was measured and the results are shown in Fig.1 (a) and (b). Before every recording process the sample was heating at 300 °C by 40 minutes in order to erasure any kind of gratings.

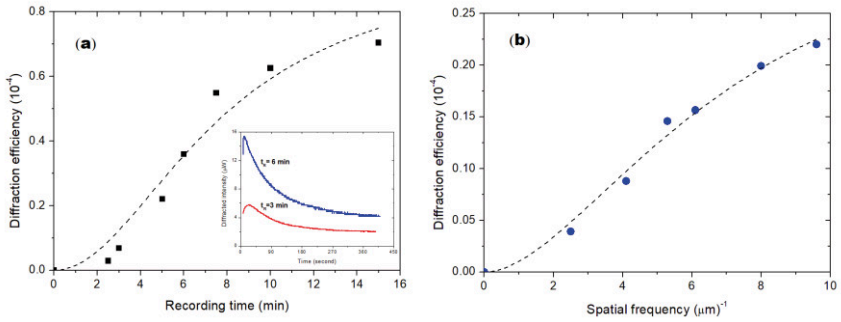

Figure 1. Diffraction efficiency as a function of recording time (■) and of the spatial frequency (•), figures (a) and (b) respectively with the dashed line being a reference guide for the eyes. The inset shows the diffraction efficiency during the erasure of the photosensitivity gratings after recording for different times and keeping constant the light intensities and the spatial frequency.

We have shown that it is possible to fixed non-destructive volume gratings in undoped BTeO photorefractive crystal at room temperature. The diffraction efficiency of the fixed gratings depends on the recording time and of the spatial frequency.

Acknowledgements: Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior (CAPES), Fundo de Apoio ao Ensino, Pesquisa e Extensão da Universidade Estadual de Campinas (FAEPEX) and Fundação de Apoio à Pesquisa do Estado de Goiás (FAPEG) all from Brazil.

Keywords: Photorefractive crystals, Diffraction gratings, Holography, Nonlinear optical materials.

References:
[1] P. Günter and J.P. Huignard, Photorefractive Materials and Their Applications I, Topics in Applied Physics, Vol. 61, Springer-Verlag, Berlin, Heidelberg, 1988.
[2] I. Földvári, C. Denz, A. Péter, J. Petter, and F. Visinka, Bismuth tellurite a new material for holographic memory, Opt. Commun. 177, 105–109 (2000).
[3] Han, M., Wang, C., Niu, K. *et al.* Continuously tunable ferroelectric domain width down to the single-atomic limit in bismuth tellurite. Nat Commun 13, 5903 (2022).
[4] I. de Oliveira and D. Capovilla, Volatile and permanent optical gratings recorded in Bi_2TeO_5 photorefractive crystal under high cw intensity, Appl. Opt. 59, 2248-2253 (2020).
[5] J.F. Carvalho, Z.V. Fabris, I. de Oliveira, J. Frejlich, Crystal growth of Bi_2TeO_5 by a double crucible Czochralski method, Journal of Crystal Growth, Vol. 401, 795-797, (2014).

The link between ocular high-order aberrations and accommodative disorders

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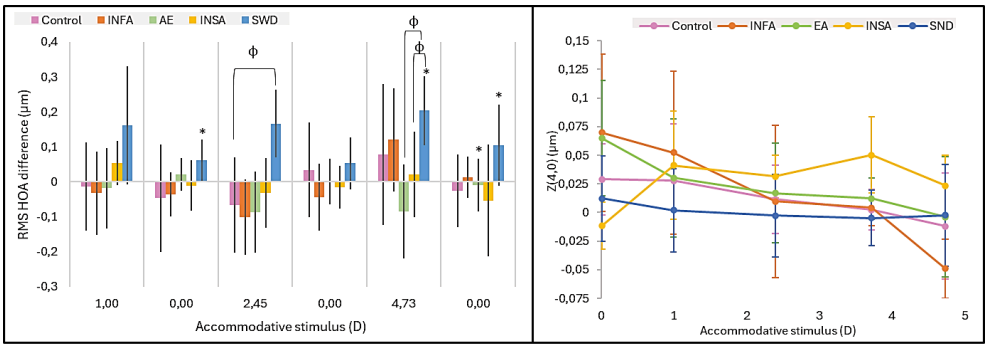
ABSTRACT

The human eye adjusts its focus through a process called accommodation, where the crystalline lens changes shape to ensure a clear image on the retina. Some young subjects have this ability reduced, with slower, higher or lower responses than normal, leading to a range of symptoms, more relevant for near-vision activities.[1]
High-order ocular aberrations and accommodation are closely related. [2] Because they affect the accuracy of the accommodative response, they may also be related to these accommodative disorders. Understanding their relationship is essential for developing more effective diagnostics and optical therapeutic approaches for these subjects. This study aimed to explore the role of high-order aberrations and their changes during accommodation in the development of accommodative disorders.
An adaptive optical system with a Hartmann-Shack aberrometer assessed real-time ocular aberrations in the right eye while inducing accommodation with negative lenses, leading to a sequence of accommodative and disaccommodative stimuli: 0.00D, 1.00D, 0.00D, 2.45D, 0.00D, 4.73D and 0.00D.
The measurements were taken in 63 subjects divided into five groups: control, three groups of three different types of accommodative disorders: INFA, EA and INSA, and a group of subjects with symptoms related to near vision activities but without any accommodative disorder previously diagnosed (SWD).
Root-mean-square (RMS) of high-order aberrations (HOA) was calculated for all stimuli. The difference between the value for each stimulus and the initial value and the changes in spherical aberration (4th order) with accommodation (Figure 1) were obtained.



*statistically significant compared to the initial value; ϕstatistically significant between groups

Figure 1. RMS HOA differences between the stimulus and the initial value (on the left) and changes of spherical aberration (4th order) with accommodation in the different groups.

Some groups with accommodative disorders revealed particular changes in wavefront aberrations during accommodation, different from those without any disorder or symptom. These findings provide a better understanding of accommodative disorders and suggest the importance of considering the analysis of high-order aberrations in subjects with these conditions. The use of wavefront aberrometry may be used as a tool to improve the effectiveness of their diagnosis and follow-up.

Keywords: High-order aberrations, Shack-Hartmann, Accommodation

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References:

[1] Gomes J, Sapkota K, Franco S. "Central and Peripheral Ocular High-Order Aberrations and Their Relationship with Accommodation and Refractive Error: A Review," Vision (Basel). 7;7(1):19, 2023
[2] Cheng H, Barnett JK, Vilupuru AS, Marsack JD, Kasthurirangan S, Applegate RA, Roorda A. "A population study on changes in wave aberrations with accommodation," J Vis. 16:4(4):272-80, 2004

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Optimization of an Acousto-Optic Modulation System for Laser Power Stabilization

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ABSTRACT

The intensity of a laser that operates continuously does not remain constant over time, presenting periodic or random fluctuations in the short and long term due to various reasons, such as poorly filtered sources, mechanical vibrations, competition of modes within the cavity laser, variations in the supply current, among others [1]. These intensity fluctuations reduce the signal-to-noise (S/N) ratio, which represents a significant problem for precision spectroscopic applications [1]. In the case of laser diodes, the frequency varies with the current, so it is not feasible to use this to correct the intensity, requiring external active stabilization methods [1,2].

This work presents an optimized acousto-optic modulation (AOM) system for precise laser beam power stabilization. The AOM electronically controls the output intensity, blocking the zero order and using the diffracted first order. A beam splitter allows a small portion of the output signal to be monitored by a photodiode equipped with a transimpedance amplifier, which then processes the signal through a PID ontroller. A precision reference voltage (V_{REF}) pprovides the set point for the PID, determining the desired intensity level at the output. The PID output signal controls a voltage-controlled variable RF attenuator circuit, continuously adjusting the output signal to maintain stable power.

The results of the output power behavior of the laser with extended cavity with the PID off and on. The data were captured with an oscilloscope, adjusting the Offset voltage of the transimpedance amplifier so that the output voltage was zero at the desired power, thus observing the variation of the output power as a function of time. Without the control, the power variation was approximately 3%, reducing to 0.4% with the control system activated.

This research underscores the critical role of optimizing acousto-optic modulation systems in laser power stabilization, essential for enhancing precision and reliability in applications reliant on laser stability.

Keywords: Acousto-Optic Modulation, Acousto-Optic Modulator optimization, Laser power modulation, Laser stabilization

References:

[1] Ennio Arimondo, M Inguscio y P Violino. “Experimental determinations of the hyperfine structure in the alkali atoms”. En: Reviews of Modern Physics 49.1 (1977), pa´g. 31.

[2] Matthew Aldous et al. “Carrier frequency modulation of an acousto-optic modulator for laser stabilization”. En: Optics Express 25.11 (2017), pa´gs. 12830-12838.

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Raman-Based DTS for Forest Fire Detection Using Existing Telecommunications Fiber Networks

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ABSTRACT

Distributed fiber sensors (DFSs) allow continuous, real-time measurements along several kilometers of optical fiber with a single interrogator. Raman-based distributed temperature sensors (DTSs) are the most used for temperature applications due to their low complexity and insensitivity to other parameters. The absolute fiber temperature is determined by analyzing the backscattered Raman bands ratio (anti-Stokes and Stokes) [1]. Recently, DFSs signals and data transmission coexistence in fiber networks was demonstrated, however, the use of C band channels for sensing has reduced the network's transmission capacity [2].
In this work, we propose an optimized Raman-based DTS that uses the existing telecommunications fiber infrastructure for forest fire detection. To maintain the network's transmission capacity, we use a pump source outside the standard telecommunications windows.
The proposed DTS uses a 1064 nm wavelength pump source with 6.7 W peak power pulses, 50 ns pulse width and 10 kHz repetition rate, and standard single-mode fiber as sensing element. The Raman bands are detected by avalanche photodiodes and processed by an oscilloscope [3], with temperature and spatial resolutions of 17 °C and 47 m, respectively.
The proposed DTS detects temperature variations compatible with the ones expected for aerial fibers in the case of wildfires.

Keywords: Distributed Temperature Sensor; Optical Fiber Sensor; Raman backscatter; Forest Wildfire

Acknowledgements: This work is funded by FCT/MCTES through national funds and when applicable co-funded EU funds under the project FireTec, UIDB/50008/2020-UIDP/50008/2020 and UIDB/50025/2020-2023, and by FCT through Joana Vieira's grant 2023.03578.BD.

References:

[1] J. Li and M. Zhang, "Physics and applications of Raman distributed optical fiber sensing," *Light Sci. Appl.*, vol. 11, no. 128, 2022.
[2] G. A. Wellbrock *et al.*, "Field Trial of Distributed Fiber Sensor Network Using Operational Telecom Fiber Cables as Sensing Media," 2020.
[3] J. Vieira, R. N. Nogueira, and A. M. Rocha, "Experimental characterization of a Raman based distributed temperature sensor using a 1064 nm pump," *EPJ Web Conf.*, vol. 287, no. 1, p. 09032, 2023, doi: 10.1051/epjconf/202328709032.

Volatile Organic Compounds Sensor Based on Chitosan-Coated Multimode Interferometer

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ABSTRACT

Volatile organic compounds (VOCs) are byproducts of cellular metabolism within the human body and can be detected in the gaseous phase of clinical samples such as breath, saliva, sweat, feces, and urine. These low molecular weight compounds constitute the "metabolic signature" and can be influenced by various pathological conditions, making some VOCs potential biomarkers for specific diseases. Variations in their concentrations may reflect changes in metabolic pathways, including disruptions in protein and enzyme activities, gene activation or repression and other metabolic processes. These alterations can be identified in biological samples using different techniques such as optical fiber sensors (OFSs) [1].
The early detection of diseases is essential for effective treatment outcomes, with VOC profiles presenting significant potential for the development of rapid, non-invasive, and cost-efficient disease screening tools. Ethanol and 2-propanol, as volatile alcohols, exhibit differential associations with a variety of diseases across multiple organic samples, including different types of cancers. Monitoring these compounds in biological samples could contribute to the development of new innovative integrated health systems [1,2].
In this study, we propose a sensor that integrates a multimode interference optical fiber structure with chitosan functionalization. The multimode sensor was fabricated by fusion splicing a coreless fiber (CSF) to a single-mode fiber (SMF) and the chitosan coating in the coreless fiber was obtained by the dip coating technique. Our findings demonstrate that the sensor exhibits a sensitivity of 3.8 nm/(mol/mol of 2-propanol) and 3.0 nm/ (mol/mol of ethanol) in hydroalcoholic solutions. The sensor also shows stability, highlighting the potential of our sensor design for detecting 2-propanol and ethanol in gas phase analyses.

Keywords: Volatile Organic Compounds, Multimode Interferometer, Chitosan, Optical Fiber Sensor

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References:
[1] M. Ding, and G. Brambilla, Biophotonics for Medical Applications: "3-Optical fibres and sensors for biomedical applications" Woodhead Publishing Series in Biomaterials, 53–78, (2015).
[2] X. Sun et al., "Detection of volatile organic compounds (VOCs) from exhaled breath as noninvasive methods for cancer diagnosis", Analytical and Bioanalytical Chemistry, 408, 2759–2780, (2015).

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Development and Characterization of Fiber Optic Sensors for Radiation Detection

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ABSTRACT

The use of optical fibers for sensing has significant advantages in many applications, particularly in unusual applications, such as in environments with radiation, whether as temperature sensors or dosimeters [1,2]. In this context, the present work aims to contribute to the knowledge of the impact of proton radiation on optical-fiber-based sensors. It was investigated the impact of proton radiation on the transmission of multimode silica fibers doped with Germanium (GIF625 from Thorlabs) in the visible spectral range.
Using a new configuration at Campus Tecnológico e Nuclear's Tandem Accelerator in Lisbon, that allowed for external beam irradiation of the samples, the multimode fibers were irradiated with a beam of 3 MeV energy protons, at different distances from the accelerator window, varying particle penetration. This study focused on how the optical transmission of the silica fibers responded to changes in the irradiation parameters (particle energy and fluence) and on how their recuperation may be achieved using optical or thermal annealing.
Multiple fibers were studied at the same time, further structuring the obtained results. The Radiation Induced Attenuation (RIA) was found to be higher for lower wavelengths of the transmission spectra. Separate studies were also conducted on the recuperation of transmission capacity based on temperature and visible light incidence.
The potential for developing a real-time dosimeter based on the ratio between the RIA levels on UV/blue and red/NIR spectral bands will be evaluated.

Keywords: Proton Radiation, Radiation-Induced Attenuation, Silica Optical Fiber, Multimode Optical Fiber, Optical Recuperation, Temperature Annealing, Optical Annealing.

References:

[1] J. Zhang *et al*., " Recent Advances in Optical Fiber Enabled Radiation Sensors", Sensors, vol. 22, no. 3, pp. 1126, 2022.
[2] F. Fricano et al., "Very High Dose Rate Proton Dosimetry with Radioluminescent Silica-based Optical Fibers", IEEE Trans Nucl Sci, pp. 1, 2024.

Design and characterization of a compact extended cavity laser diode with applications in high-resolution spectroscopy and absorption-based laser sensors.

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ABSTRACT

Owing to their small size, compact design, and low power consumption, laser diodes (LDs) are widely used in various applications, including Metrology, Interferometry [1], High-Resolution Optical Spectroscopy [2] , and Atomic Cooling [3]. Nevertheless, a laser diode operating in free-running mode typically exhibits a spectral width on the order of tens of MHz, limiting its utility in these applications. Therefore, reducing this spectral width is essential to enhance its performance. One effective approach to achieve this is by extending its cavity and applying optical feedback using a diffraction grating or a partially reflective mirror. The use of diffraction gratings is a widely adopted method because, in addition to reducing the spectral width, it allows for precise tuning of the laser wavelength within a few nanometers.

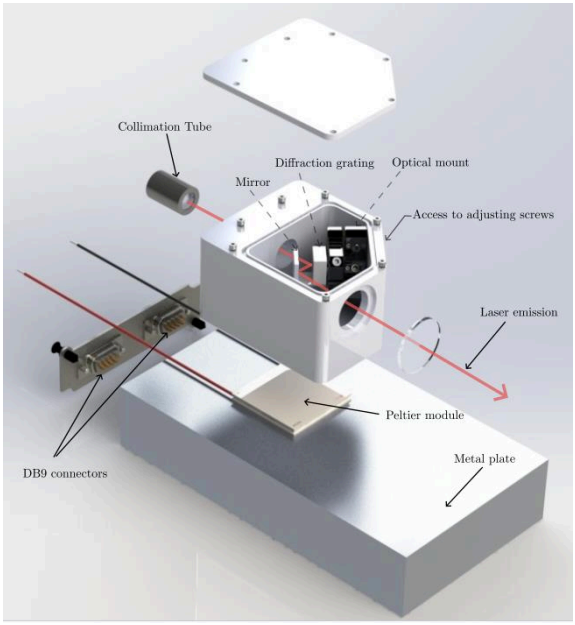

Figure 1. Exploded diagram showing details of the designed optical cavity.

In this study, we present the design and characterization of an extended cavity for a laser diode in Littrow configuration. The designed cavity was initially tested with a 780 nm laser diode but can be easily implemented at other wavelengths. The proposed design was employed to acquire the hyperfine structure spectrum of Rubidium and was stabilized to one of its hyperfine transitions using phase detection techniques, achieving a stability of 0.47 MHz. The spectral width of the designed laser was 340 kHz, determined using the self-heterodyne technique. Figure 1 shows the designed optical cavity.

Keywords: (External Cavity, Diode Laser, Littrow, Hyperfine Structure)

References:

[1] A. Abou-Zeid, "Diode lasers for interferometry," *Precis. Eng.*, vol. 11, no. 3, pp. 139–144, 1989, doi: 10.1016/0141-6359(89)90068-8.
[2] D. Das and V. Natarajan, "High-precision measurement of hyperfine structure in the D lines of alkali atoms," *J. Phys. B At. Mol. Opt. Phys.*, vol. 41, no. 3, 2008, doi: 10.1088/0953-4075/41/3/035001.
[3] J. R. Anglin and W. Ketterle, "Bose-Einstein condensation of atomic gases," *Nature*, vol. 416, no. 6877, pp. 211–218, 2002, doi: 10.1038/416211a.

Low-cost Laser Frequency Stabilization Using Analog Multiplier Integrated Circuit and Piezo-Modulation Mirror.

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ABSTRACT

External-cavity diodes laser (ECDL) operating in free-running mode exhibit frequency shifts due to various factors, such as temperature variation, mechanical vibrations, fluctuations in the power supply current, etc. This makes it difficult for them to be used in applications such as metrology, atomic cooling, interferometry, etc., where laser frequency stabilization is required.
Precision frequency stabilization techniques require modulation of the laser beam. This modulation can be done directly by modulating the diode current, or indirectly, which takes place once the laser exits the cavity. The latter is achieved using devices such as acousto-optic modulators (AOM) [1] or electro-optic modulators (EOM) [2], or by coupling a mirror to a piezoelectric actuator [3]. Although indirect modulation is easy to implement, it introduces residual amplitude and decreases the signal-to-noise ratio (S/N) of the laser. On the other hand, modulation using AOM or EOM is costly and impractical for portable applications, as well as being less accessible for laboratories with limited budgets.
In this work, a laser stabilization system is presented, which utilizes a mirror coupled to a low-cost piezoelectric actuator as a frequency modulator, and an analog four-quadrant multiplier integrated circuit as a phase detector. The dispersion signal obtained was used as an error signal in a PID controller, allowing the stabilization of an extended cavity laser to one of the hyperfine structures of rubidium.

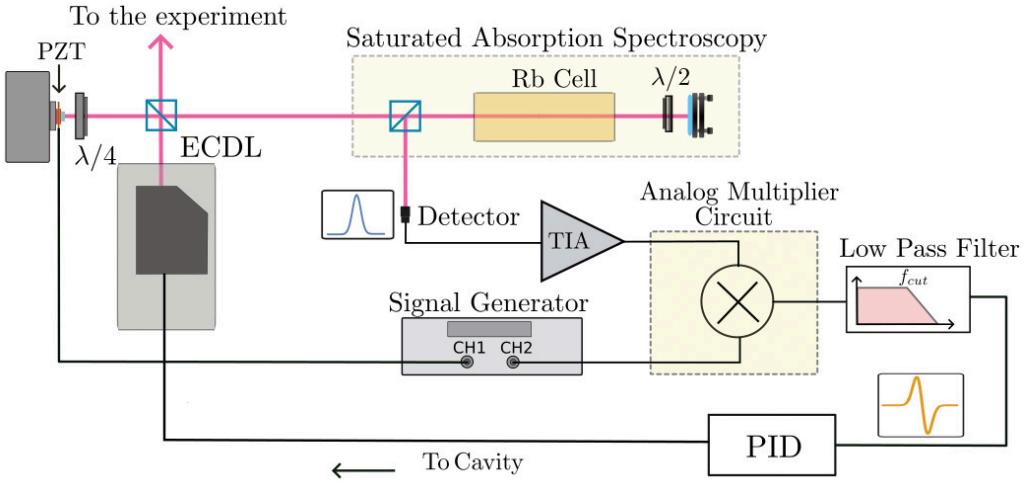

Figure 1. Experimental setup. The laser is modulated using a piezoelectric actuator (PZT) and passed through the Rubidium cell. The absorption signal is sent to a transimpedance amplifier (TIA), multiplied by a reference signal, and then passed through a low-pass filter. The resulting dispersion signal is used to stabilize the laser at the atomic transition.

Keywords: (ECDL, Analog multiplier, Laser Stabilization, EOM, AOM)

References:

[1] A. G. Truscott, N. R. Heckenberg, and H. Rubinsztein-Dunlop, "Frequency stabilized grating feedback laser diode for atom cooling applications," *Opt. Quantum Electron.*, vol. 31, no. 5, pp. 417–430, 1999, doi: 10.1023/a:1006962911229.
[2] C. Mok, M. Weel, E. Rotberg, and A. Kumarakrishnan, "Design and construction of an efficient electro-optic modulator for laser spectroscopy," *Can. J. Phys.*, vol. 84, no. 9, pp. 775–786, 2006, doi: 10.1139/P06-074.
[3] T. Mitsui, K. Yamashita, and K. Sakurai, "Diode laser-frequency stabilization by use of frequency modulation by a vibrating mirror," 1997.

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Colour image encryption system based on a nonlinear joint transform Correlator in the fractional Fourier domain

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We propose a new encryption and decryption system for colour images using a nonlinear fractional joint transform correlator (JTC) architecture. The colour images are defined in the RGB colour space and each colour channel is processed as a grayscale image in this work. Therefore, we use three original grayscale images to encrypt and these images, which are all of the same MxN pixel size, are encoded in phase at the input plane of the JTC without overlapping. We design the encryption system using the double random phase encoding (DRPE) technique and a nonlinear JTC in the fractional Fourier domain (FrFD) along with six random phase masks (RPMs) and three original grayscale images. The joint fractional power spectrum (JFPS), which is the intensity of the fractional Fourier transform (FrFT) of the input plane of the JTC, is modified nonlinearly in order to obtain a real-valued encrypted image with enhanced security. The security keys of the proposed encryption system are given by the six RPMs and the fractional order of the FrFT. The decryption system is based on two successive FrFT. The information required by the decryption system corresponds to the encrypted image, the six RPMs and the fractional order of the FrFT. The nonlinear modifications of the JTC allow to improve the security of the encrypted image and the quality of the decrypted images. Finally, we present computational simulations that show the feasibility and performance of the proposed colour image encryption and decryption system based on a nonlinear JTC in the FrFD.

Keywords: Colour image, Encryption-decryption system, Joint transform correlator (JTC), Fractional Fourier transform, nonlinear operations.

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Simultaneous authentication of three users or images using an image encryption system based on a nonlinear joint transform correlator in the Fourier domain

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ABSTRACT

In this work, a new encryption-decryption system based on a nonlinear joint transform correlator (JTC) is proposed for the simultaneous authentication of three users or images. The three images to be authenticated can be independent signals from three users or they can be related to each other, with the three images belonging to a single user. The encryption system uses a nonlinear JTC in the Fourier domain with a single image to be encrypted along with a random phase mask (RPM) and three phase-only distributions represented by three RPMs and the three images to be authenticated. The resulting single encrypted image is a real-valued distribution. The decryption and authentication processes are performed jointly, in order to simultaneously authenticate the three users or images by analyzing and verifying the decrypted image obtained. The encryption-decryption system has seven keys, which along with the JTC nonlinearities allow the proposed security system to be protected against brute force and plaintext attacks. The feasibility and validity of this proposal is verified through computational simulations of the encryption system and the joint decryption and authentication system.

Keywords: Simultaneous authentication of multiple images, Image encryption systems, Joint transform correlator, Fourier domain.

Comparative Analysis of Physiological Vergence Angle Calculations from Objective Measurements of Vergence

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ABSTRACT

The video-based eccentric photorefractometry device PowerRef 3 (PlusOptix) is widely used for non-invasive, dynamic, and objective eye accommodation measurements. It simultaneously integrates Purkinje image eye tracking for gaze position measurements, using a population-averaged Hirschberg ratio (HR) of 11.82° [personal communication], along with pupillometry. Previous research has emphasized that using the population-average HR (a calibration factor used to convert the distance between the Purkinje image and the center of the entrance pupil obtained in millimeter into angular units of gaze position) is prone to inaccuracies as the intersubject variability of HR can vary roughly between 7 and 16°/mm [1, 2]. Even after applying the individual HR, vergence data obtained from Purkinje image eye tracking show an offset between the visual axis and the pupillary axis, corresponding to the kappa angle, which varies significantly between individuals. Previous studies have mentioned this as a limiting factor for data interpretation [3, 4] since the reported vergence angle estimates are divergent relative to the target even in binocular-aligned conditions and near distances where a convergent eye position would be expected. To date, the calibration of an individual kappa angle for obtaining a physiological vergence angle has not been described, but there has been a suggestion to use an automated algorithm with a promising but rather complex algorithm verification procedure that assumes a theoretical kappa angle of 5° [5], as well as a method where an 11.2° offset to the visual vergence angle is used [4].Since there is no consensus on the optimal method for calculating physiological vergence angles from Purkinje image-based eye gaze trackers, we investigated and compared three approaches using data obtained from the PowerRef 3.
Twenty-three participants aged 25 ± 4 years were enrolled in this study. Participants were instructed to maintain their gaze on a fixed stimulus (a Maltese cross) at five different distances: 25 cm, 30 cm, 50 cm, 70 cm, and 6 m. Vergence data were recorded at a 50 Hz frequency for 10 seconds at each distance with the PowerRef 3 device. For each participant, the individual kappa angle was measured using a WAM 700+ multifunctional wavefront aberrometer device (employing the Scheimpflug technique).
The results demonstrated that the corrected physiological vergence angle measurements closely matched the expected values at corresponding distances for all three methods: (1) correcting for the individual kappa angle, (2) using values obtained at a 6-meter distance adjusted for individual pupil distance, and (3) applying a fixed offset value modified for a 6-meter distance. Our proposed methodology offers accurate visible vergence angle correction, enabling the use of Purkinje image-based eye gaze trackers without their own calibration technique to measure physiological vergence angles.

Keywords: vergence angle, Hirshberg ratio, kappa angle, calibration, PowerRef 3

Acknowledgements: The research was supported by the Latvian Council of Science, project No. lzp-2021/1-0399.

References:

[1] K.K. Jagini, H. Vaidyanath, S.R. Bharadwaj, "Utility of Theoretical Hirschberg Ratio for Gaze Position Calibration," Optom Vis Sci. 91, 778-785, 2014.
[2] M. Ntodie, S.R. Bharadwaj, S. Balaji, K.J. Saunders, J.A. Little, "Comparison of Three Gaze-position Calibration Techniques in First Purkinje Image-based Eye Trackers," Optom Vis Sci 96, 587-598, 2019.
[3] C. Mestre, S. Neupane, V. Manh, K. Tarczy-Hornoch, T.R. Candy, "Vergence and accommodation responses in the control of intermittent exotropia," Ophthalmic Physiol Opt 43, 598-614, 2023.
[4] L. Kooijman, D. Dodou, S.T. Jansen, T.S. Themans, J.N.M. Russell, S.M. Petermeijer, J.R.C. Doorman, J.H. Hablé, D.S. Neubert, M.J.C. Vos, J.C.F. de Winter, "Is accommodation a confounder in pupillometry research?" Biol. Psychol. 160, 108046, 2021.
[5] J. Liu, J. Chi, H. Sun, "An Automatic Calibration Method for Kappa Angle Based on a Binocular Gaze Constraint," Sensors 23, 3929, 2023.

Non-intrusive and Low Visual Impact Relative-Displacement Sensors Based on Fiber Bragg Gratings for Structural Health Monitoring Applications

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ABSTRACT

In this work, it is reported the development and production of displacement sensing devices with minimal intrusion and very low visual impact for medium and long-term monitoring of crack and joint movements. These sensors, based on fiber Bragg gratings (FBGs), are relatively easy to fabricate and replicate, presenting simple design and principle of operation, which contributes to a straightforward installation and operation. Furthermore, they display great versatility, as the alternative pre-strain mechanism of these devices allows to easily adjust the distance between the optical fiber holders, using a steel rod that is removed after installation (see Figure 1a).

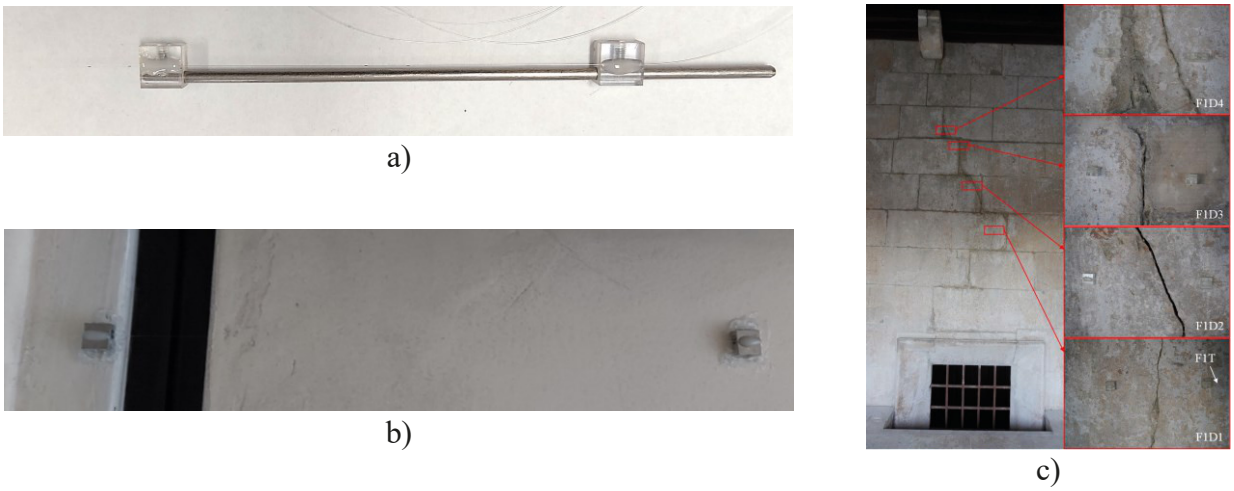

Figure 1. a) FBG-based relative displacement sensor composed by transparent polycarbonate holders with the removable steel rod, b) sensor installed at the Physics Department of the University of Aveiro and c) sensors installed at the Monastery of Batalha.

After their production and characterization, these sensors were installed in key locations in the Monastery of Batalha (Batalha, Portugal) and in the Physics Department of the University of Aveiro (Aveiro, Portugal), and the monitoring results during the following months are presented and discussed. The characteristics and performance of these displacement sensors highlight their potential for Structural Health Monitoring (SHM) applications, enabling the study of various building types and long-term monitoring of strategic, faulty and/or damaged structural features. On the other hand, the obtained data can in the future be used to support the decisions in possible interventions and calibrate numerical models.

Keywords: Fiber Bragg Gratings, Optical Fiber Sensors, Structural Health Monitoring

Synergistic effect of near infrared light and Ag-based metal-organic frameworks, loaded with sulphur or nitrogen carbon dots, on wound healing

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ABSTRACT

Infrared light has a beneficial effect on wound healing [1], which requires special treatment. Since carbon dots (CDs) demonstrated an anti-microbial effect [2], we compare the synergistic effect of near-infrared light (NIR) and Ag-metal organ framework (AgMOF) loaded either with S-doped CDs (S-CD@AgMOF) or N-doped CDs (N-CDs@AgMOF), synthesized as described in the literature [3]. We tested the influence of (S, N-)CDs@AgMOFs on MRC-5 (fibroblast cell line) and wound closure potential by a migration/scratch assay. Cells were grown in the medium and treated with S, N-CDs@AgMOF in the dark or upon 10-minute-long illumination from an optically pumped semiconductor laser (Mantis, Coherent, USA).

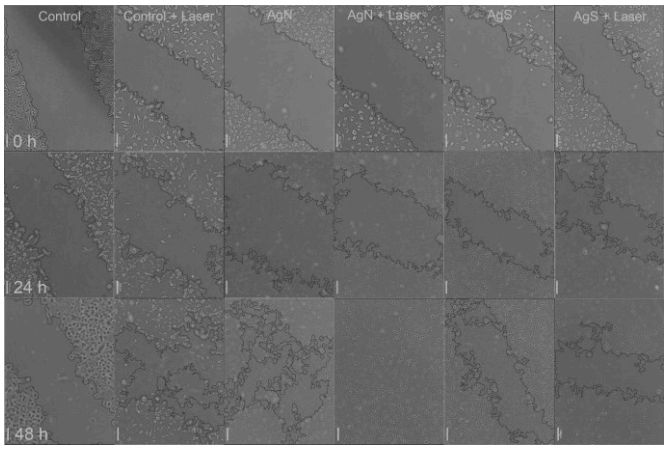

Figure 1. Migration of MRC-5 fibroblast cells after the treatment of light combined with S, N-CDs@AgMOF as indicated in the Figure. Photos of scratched areas were taken at 0 h, 24h, and 48h after the initial treatment.

Our results show a slight increase in MRC-5 cell viability after the NIR light illumination, which increases after the previous treatment with N-CDs@AgMOF (AgN). Treatment of cells with S-CDs@AgMOF (AgS) does not significantly affect cell growth either under light illumination or in the dark. Similar results are obtained in the migration assay (Fig. 1). It appears that the closure of a scratch (0h row, Fig. 1) was complete only after the NIR@N-CDs@AgMOF treatment. In conclusion, we demonstrated a dopant-specific effect on wound healing and that N-CDs@AgMOF have the potential to be further tested in light-enhanced wound healing.

References:

[1] R.F Chen et al., "Far-infrared Therapy Accelerates Diabetic Wound Healing via Recruitment of Tissue Angionesis in a Full-Thickess Wound Healing Model in Rats, Biomedicines, 9 (2021) 1922
[2] M.Z. Meziani et al., "Visible-Light-Activated Bacterial Functions of Carbon "Quantum" Dots", ACS Appl. Mater. Interfaces, 8 (2016) 10761–10766
[3] X. Zhang et al., "MOFs and MOF-Derived Materials for Antibacterial Applications, "J. Func. Biomater., 13 (2022) 215.

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Lighting preferences of Iberian sausages for Spanish observers

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ABSTRACT

The Technical Committee 1-90 of the International Commission on Illumination (CIE) "Methods for evaluating the colour-quality of white-light sources" is close to finish its works proposing several indices to choose appropriate white light sources for different applications. We have developed a visual experiment testing lighting preferences for 18 samples of Iberian sausage slices, considering the 3 CIE standard illuminants (D65, D50, A), 5 CIE Blue LED illuminants [1], and 7 white light sources from supermarkets in Japan and Spain. We measured the spectral reflectance factors of these 18 sausage samples using a 2D Topcon SR-5100 spectroradiometer and generated images with the same average luminance for each illuminant/source. These images were assessed in a calibrated EIZO ColorEdge CG2700X monitor by a panel of 20 Spanish observers with normal color vision (50% females, average age 50 years), who performed 18,000 visual assessments using the pair comparison (only 8 samples) and magnitude estimation (18 samples) psychophysical methods. Visual preferences obtained using these two methods had a high correlation. We found best correlations with visual preferences for the Gamut Area Index [2] and Correlated Color Temperature of illuminants/sources, while the CIE general color rendering index [1] and CIE color fidelity index [3] achieved very low correlations.

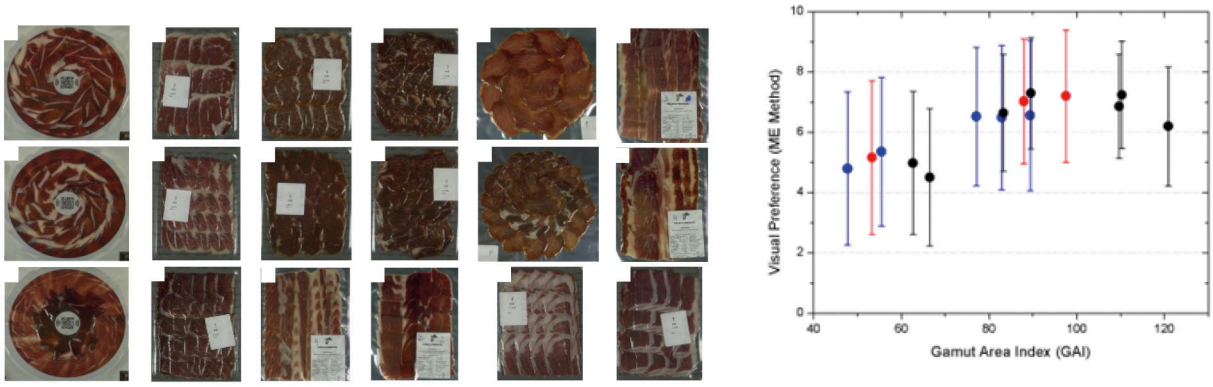

Fig. 1. Left: The 18 sausage samples used in the visual experiment (D65 illuminant). Right: Average visual preferences and standard deviations (magnitude estimation method) for 20 Spanish observers vs. values of Gamut Area Index [2] (results for 3 CIE standard illuminants, 5 CIE Blue LEDs and 7 light sources in red, blue and black colors, respectively).

Keywords: Lighting, colorimetry, food preference.

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References:

[1] CIE 015:2018. Colorimetry, 4th Edition. CIE Central Bureau, Vienna (2018).
[2] M. S. Rea, J. P. Freyssinier-Nova. Color rendering: A tale of two metrics. Color Res. Appl. 33, 192-202 (2008).
[3] CIE 224:2017. CIE 2017 Colour Fidelity Index for accurate scientific use. CIE Central Bureau, Vienna (2017).

Liquid Crystal-based Immunosensor for the Optical Detection of Cortisol

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ABSTRACT

The population increases every year and will reach a level where fish consumption will exceed the production capacity of the oceans and seas [1]. Aquaculture can respond to this growth, specifically using Recirculating Aquaculture Systems (RAS) with limited water exchange [2], [3]. RAS has been the protein production sector with the highest growth in the world [4]. Nonetheless, in these complex systems, stress can be induced, leading to reduced food intake, reduced growth performance, and mortality [5]. There is a huge gap in this industry in terms of smart sensors for in situ and real-time detection of cortisol (stress hormone), which brings a weak understanding of the wellbeing of fish.
Therefore, we developed a liquid crystal-based optical biosensor that detected cortisol in a range of 0.1 to 50 ng/mL. The inner device surfaces were treated so that the nematic liquid crystal (LC) molecules perfectly aligned along a direction normal to the surfaces. To function as biorecognition molecules, anti-cortisol antibodies were immobilized on the inner surfaces. The principle behind the detection method is related to the distortion of the mean orientation of the LC molecules in the presence of cortisol. This study is an important contribution to address this sector problem.

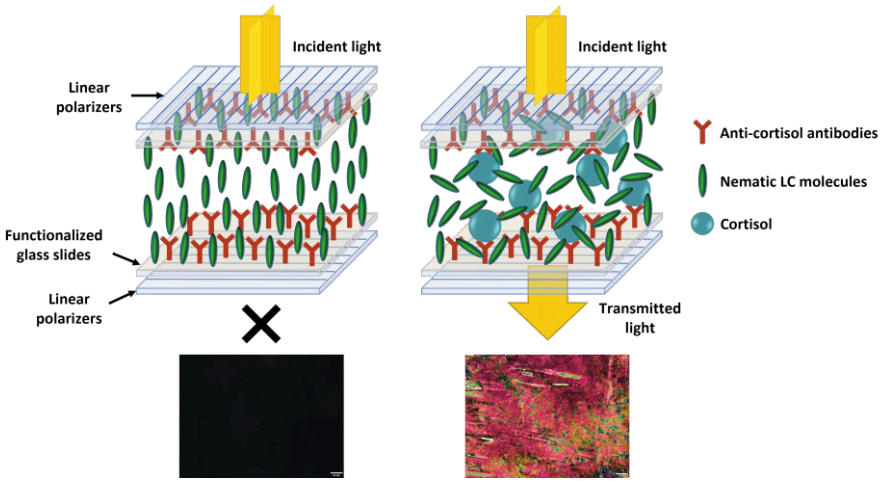

Figure 1. Sensor assembly and detection mechanism.

References:
[1] United Nations Department of Economic and Social Affairs, "World Population Prospects 2022," Summary of Results, Accessed: Aug. 03, 2022. [Online]. Available: https://population.un.org/wpp/Graphs/DemographicProfiles/Line/900
[2] J. Ranganathan, R. Waite, T. Searchinger, and C. Hanson, "How to Sustainably Feed 10 Billion People by 2050, in 21 Charts," World Resources Institute, Accessed: Oct. 06, 2023. [Online]. Available: https://www.wri.org/insights/how-sustainably-feed-10-billion-people-2050-21-charts?utm_campaign=socialmedia&utm_source=twitter.com&utm_medium=worldresources&utm_content=bloggraphic
[3] J. Bregnballe, "A Guide to Recirculation Aquaculture: An introduction to the new environmentally friendly and highly productive closed fish farming systems," Food Agric. Organ., pp. 1–100, 2015.
[4] FAO, The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, 2022.
[5] K. Ogawa, F. Ito, M. Nagae, T. Nishimura, M. Yamaguchi, and A. Ishimatsu, "Effects of acid stress on reproductive functions in immature Carp, CYPRIMUS CARPIO," Water, Air, Soil Pollut., vol. 130, pp. 887–892, 2001.

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Enhancing Cross-Correlation Techniques for Distributed Fibre Optic Sensors: A Study on Fitting Methods and Spectrum Window Analysis

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ABSTRACT

Cross-correlation methods are extensively utilized in the domain of Distributed Fibre Optic Sensors, enabling the estimation of the degree of shift by comparing two signals: the reference and the measurement [1]. In the field of Rayleigh-based distributed sensors, the frequency shift of the backscattering signals facilitates the measurement of environmental conditions such as temperature, strain, pressure, or humidity in contact with the fibre [2]. The cross-correlation method yields a spectrum with an intensity response, where the peak indicates the point of maximum similarity between the signals, representing the frequency shift.
However, distortions in the correlation peak can occur due to noise in the reference and measurement signals, which can significantly affect the accuracy and reliability of the results. Additionally, the spectrum may have few data points, making it challenging to detect the maximum with precision and leading to less reliable measurements. These distortions cause the correlation peaks to deviate from a single, well-defined shape, and instead, they may exhibit similarities to second-degree polynomials, third-degree polynomials, Lorentzian, or Gaussian curves. Such variations in peak shape complicate the analysis and interpretation of the data, requiring more advanced and robust methods to accurately determine the frequency shift.
In this paper, we explore various fitting methods while also analysing different spectrum window sizes to achieve greater accuracy in determining the frequency shift. This study is part of the development of a prototype Phase-sensitive OTDR setup for temperature and humidity measurements [3]. The goal is to reduce small fluctuations in the results and enable fast measurements in real environments. The data analysed during this study was acquired in a pilot test organized by FiberSight in partnership with Inmatica S.p.A., where almost 200 meters of optical fibres were buried in the botanical garden of the University of Lecce, Italy.

Keywords: Fibre optics sensors, Rayleigh scattering, cross-correlation, frequency shift, peak finding.

References:

[1] L. Zhang, L. D. Costa, Z. Yang, M. A. Soto, M. Gonzalez-Herráez, and L. Thévenaz,"Analysis and reduction of large errors in rayleigh-based distributed sensor", Journal of Lightwave Technology, vol. 37, no. 18, pp. 4710–4719, 2019

[2] Tiago FP Neves, Lorenzo Scherino, Rémy Bernard, Monika Bouet, Aymeric Pastre, Regina Magalhães, Sonia Martin-Lopez, Hugo F Martins, Paolo Petagna, Luc Thévenaz, "Humidity-insensitive optical fibers for distributed sensing applications", Applied optics, vol 62, 15, pp 4017-4029, 2023

[3] Tiago FP Neves, Li Zhang, Fan Yang, Kenny H Tow, Paolo Petagna, Luc Thévenaz, "A kilometre-range distributed relative humidity sensor", Seventh European Workshop on Optical Fibre Sensors, vol 11199, pp, 319-322, 201

Enzymatic Plasmonic Optical Fiber Biosensor for Uric Acid Detection

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ABSTRACT

Uric acid plays significant roles in our body, acting as an antioxidant, contributing to the elimination of metabolic toxins, and helping to combat certain infections. Changes in uric acid concentration in our body can be an important indicator for diagnosing diseases such as gout, severe inflammatory arthritis, multiple sclerosis, among others [1]. Uric acid levels are usually determined in blood and/or urine samples, resorting to traditional techniques that exhibit several disadvantages, namely need of specialized technicians and the long time between sample collection and results. Therefore, methods for faster, more efficient, stable, and highly sensitive uric acid detection are in demand [2]. Fiber optic biosensors are a promising option, allowing real-time detection, quantification, and monitoring of uric acid concentrations in blood plasma or urine.
In this work, enzymatic plasmonic optical sensors for uric acid detection were developed using silica core (400 μm diameter) multimode optical fibers. To fabricate the sensors, the coating and cladding were removed from the fiber extremities, and a gold thin film was deposited on their surface, creating uncladded gold-coated tip sensors (Au-tips) [3]. Initially, the fibers were characterized to refractive index (RI) and temperature. For the former, glucose solutions with RI between 1.3330 and 1.3692 RI units (RIU) were used, resulting in a linear trend with a sensitivity of 1420.71 ± 59.76 nm/RIU. For the thermal characterization, the temperature was varied between 15 and 27 °C in 3 °C intervals, showing a negative linear trend with a sensitivity of -0.05± 0.01 nm/°C. Subsequently, the optical fibers were functionalized with uricase enzyme to enable uric acid specific detection. An ethanolic solution of 11-mercaptoundecanoic acid (MUA) was used to create a carboxylated surface. Then, the MUA-Au-tips were immersed in a solution of 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide (EDC) and *N*-hydroxysuccinimide (NHS) to activate the carboxyl groups and allow the formation of covalent bonds with the uricase. Finally, ethanolamine was used to passivate the remaining carboxyl groups. After this biofunctionalization process, tests were conducted in the clinical range of uric acid, between 0.17 and 42.03 mg/dL. The process was carried out for different pH values, 7.4 and 8.5.
Preliminary results point out an increased sensitivity for pH 8.5, corresponding to the optimal enzyme activity. However, at this pH the gold coating seams to suffer delamination, disabling the Au-tip reutilization. Therefore, more data must be gathered to better understand the sensing mechanisms behind plasmonic enzymatic biosensors.

Keywords: Uncladded optical fiber tip, Surface Plasmon Resonance (SPR), Uricase, Biosensing

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References:

[1] S. Aafria et al., "Electrochemical biosensing of uric acid: A review," Microchem. J., vol. 182, p. 107945, Nov. 2022, doi:10.1016/J.MICROC.2022.107945.
[2] K. Amreen, S. Nisha, and A. Senthil Kumar, "Undiluted human whole blood uric acid detection using a graphitized mesoporous carbon modified electrode: a potential tool for clinical point-of-care uric acid diagnosis," Analyst, vol. 143, no. 7, pp. 1560–1567, Mar. 2018, doi: 10.1039/C8AN00306H.
[3] A. S. Assunção et al., "Detection of NT-proBNP Using Optical Fiber Back-Reflection Plasmonic Biosensors," Biosensors, vol. 14, no. 4, p. 173, Apr. 2024, doi: 10.3390/BIOS14040173/S1.

Colorimetric assay for magnesium detection envisioning heart failure management at point-of-care

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ABSTRACT

Heart failure (HF) is a cardiovascular disease with significant morbidity, mortality and healthcare expenses that is witnessing a growing prevalence [1]. Sudden cardiac death (SCD) is a possibly fatal consequence of HF that can be triggered by cardiac arrhythmias. Therefore, HF patients require regular management, which should involve monitoring electrolyte imbalances, such as magnesium (Mg^{2+}) deficiencies, that contribute to arrhythmias [2].
This work describes a colorimetric assay based on calmagite (1-(1-hydroxy-4-methyl-2-phenylazo)-2-naphthol-4-sulfonic acid), a complexometric indicator with affinity towards Mg^{2+} that becomes metallized in its presence [3]. The calmagite response could be seen by the naked eye and was quantified by UV-Vis and RGB (Red, Green, Blue) analysis. Increasing Mg^{2+} concentrations caused a decrease in the ratio between absorbance at 620 and 520 nm and an increase in the Euclidean distance. The influence of interferents was studied using Ca^{2+}, K^{+} and Na^{+}, with the latter having a significant impact on the response. Furthermore, the detection feasibility in substrate was demonstrated using polyethylene terephthalate (PET) sheets and polyacrylamide hydrogels, though further work is necessary.
The research in progress paves the way for measuring Mg^{2+} in sweat at the point-of-care aiming HF management owing to the assay's simplicity, fast response and low limit-of-detection.

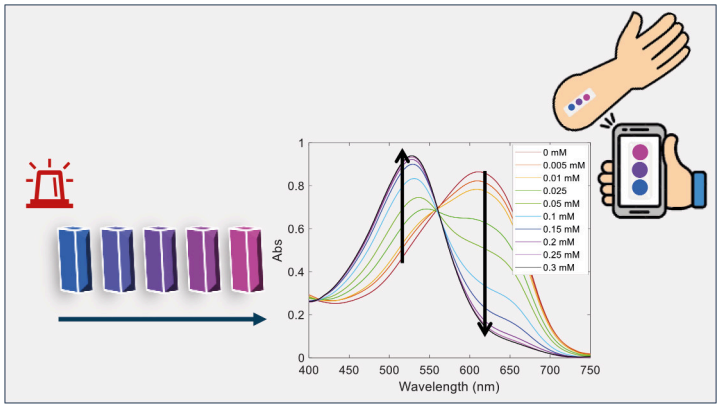

Figure 1. Schematic representation of the colorimetric detection strategy of Mg^{2+} based on calmagite, using UV-Vis spectrophotometry and a smartphone camera aiming point-of-care analysis of sweat.

Keywords: Biosensor, calmagite, colorimetry, magnesium

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References:

[1] T. A. McDonagh et al., "2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure," Eur. Heart J., vol. 42, no. 36, pp. 3599–3726, 2021
[2] C. Urso, S. Brucculeri, and G. Caimi, "Acid–base and electrolyte abnormalities in heart failure: pathophysiology and implications," Heart Fail. Rev., vol. 20, no. 4, pp. 493–503, 2015
[3] Z. Rasouli and R. Chavami, "Simultaneously detection of calcium and magnesium in various samples by calmagite and chemometrics data processing," Spectrochim. Acta Part A Mol. Biomol. Spectrosc., vol. 169, pp. 72–81, 2016

Biomolecular changes in A2780 ovarian cancer cells induced by a photoactive system based on carbon dots loaded with Ru complex

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ABSTRACT

Photosensitive carbon dots (CDs), thanks to their physicochemical properties, can be nanocarriers and photosensitizers in photodynamic therapy (PDT) [1]. Functionalization of CDs results in their increased anti-cancer efficiency caused by better entering of a nucleus [2]. We investigate the biochemical changes induced by the interaction of A2780 ovarian cancer cells with pristine and N-doped CDs loaded with Ru-complex ((N-)CDs@RuCN) in the dark and upon ultraviolet (UV) light illumination.

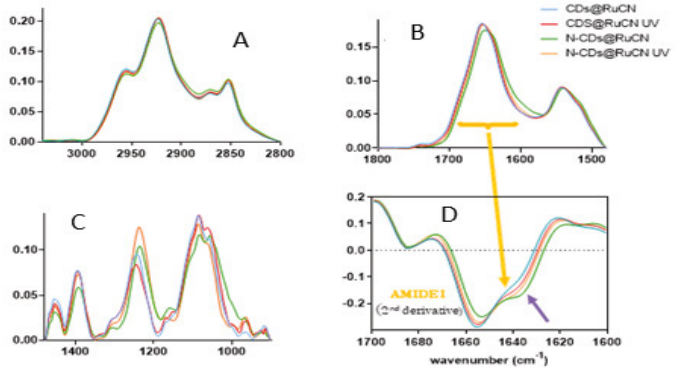

Figure 1. SR FTIR spectra of A2780 cells treated with (N-)CD@RuCN. (A) lipid region, (B) protein region, (C) nucleic acid region, and (D) second derivative of the protein region.

Computational chemistry and biology enabled identifying potential protein targets in the A2780 cells. Synchrotron Radiation Fourier Transform Infrared Spectroscopy (SR FTIR) revealed significant structural changes upon the light illumination of the cells treated with N-CD@RuCN [3]. The illumination of A2780 cells treated with N-CDs and RuCN increases the cytotoxicity of the system. Changes in lipids, proteins and nucleic acids are detected by SR FTIR spectroscopy, and they are the most significant after the treatment with N-CD@RuCN and UV light. Structural biomolecular changes are attributable to the effect of light and the production of reactive oxygen species, which is increased by illumination of the A2780 cells treated with (N-)CD@RuCN system. Finally, the most probable target proteins in A2780 cells belong to the Wnt signalling pathway and are rich in β-structure.

References:

[1] H. He et al. "Diketopyrrolopyrrole-based carbon dots for photodynamic therapy", Nanoscale 10 (2018) 10991–10998.
[2] Y. K. Jung et al., "Cell Nucleus-Targeting Zwitterionic Carbon Dots", Sci Rep. 5 (2015) 18807.
[3] M. D. Nešić et al., "Biochemical changes in cancer cells induced by photoactive nanosystem based on carbon dots loaded with Ru complex", Chemico-Biological Interactions 360 (2022) 109950.

Optical fiber sensor for voice assessment

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ABSTRACT

Voice is the most frequently exploited medium of communication. Its excessive use, driven by professional circumstances, and other external factors, such as alcohol and tobacco, can lead to vocal pathologies [1]. These issues can result in voice alterations and even problems in sentence articulation. Currently, these types of anomalies can be diagnosed using methods such as laryngoscopy exams. However, the discomfort caused by the invasiveness of these procedures has prompted research aimed at developing new, more patient-friendly, analysis techniques.

In this work, the development of an optical fibre sensor to be placed near the vocal cords for vocalization assessment is proposed. The sensor consisted of a 3D printed bendable material, called Flexible, with a fibre Bragg grating (FBG) incorporated within it (Fig. 1). For the integration of the FBG, the printing process was paused midway to place the FBG, and then resumed. The sensor was tested in two healthy volunteers (female and male), aiming to analysis its response compared with reference values, with regards to the fundamental frequency (f_0).

The test consisted of repeating a vowel four times during a period of 5 s, with a 5 s pause (P) between each vocalization (repeated for all vowels) (Fig. 1). As expected, the values obtained for the f_0 associated with the different vocalizations are within the ranges of reported reference values for healthy subjects [2,3]. Furthermore, the f_0 values in the case of the male volunteer are lower than those for the female volunteer; these results are consistent with the findings reported in the literature [2,3]. The developed sensor could be an important tool for voice analysis, however, validation in a broader population and an exhaustive comparison with a commercial system are still needed.

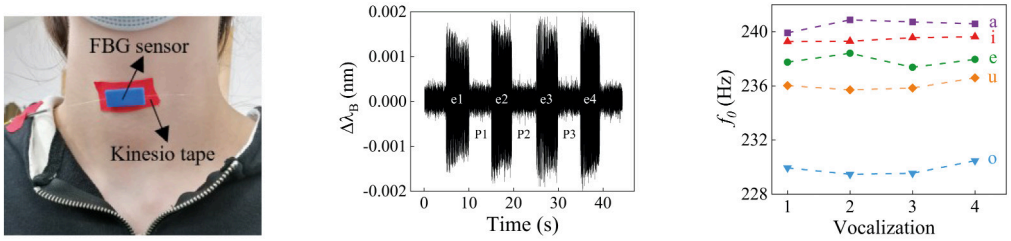

Figure 1. Left) Application of the FBG-sensor in a volunteer; Centre) Bragg wavelength variation ($\Delta\lambda_B$) with the vocalization of the vowel "e", with the identification of the pause periods (P); Right) Representation of the f_o for the five vowels, for the female volunteer.

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References:

[1] R. Islam, *et al.*, "A survey on signal processing based pathological voice detection techniques", IEEE Access, vol. 8, 66750 (28 pp.), 2020.
[2] U. Cesari, *et al.*, "Voice disorder detection via an m-health system: design and results of a clinical study to evaluate Vox4Health", BioMed Research International, vol. 2018, 8193694 (19 pp.), 2018.
[3] M. Baki, *et al.*, "Reliability of OperaVOX against multidimensional voice program (MDVP)", Clinical Otolaryngology, vol. 40, pp. 22-28, 2015.

Fiber optic sensor for arterial pulse wave analysis on the carotid artery

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ABSTRACT

Increased artery stiffness occurs naturally with aging, but can be accelerated by genetic factors, unhealthy lifestyles, and certain diseases. This condition increases the probability of cardiovascular diseases development, which account for almost a third of the total deaths in the world per year, and therefore it is essential to improve techniques for their prevention. Over the years, several studies and techniques have been developed to assess arterial stiffness. One of the most used processes for this effect is the study of the pulse wave, namely waveform related indexes, such as the stiffness index and the augmentation index [1, 2].
In this work, a fiber Bragg grating (FBG) based prototype was developed and characterized with the aim of monitoring the pulse wave in the carotid artery. For this purpose, a pen was designed and 3D-printed.
The fiber with the FBG enters the pen on one end and is glued to the other end to a movable interface that leans against the measurement site. This interface is moved by the pulsar of the carotid artery which causes deformation in the fiber with the pulse wave pattern.
Before the assembly of the prototype, the FBG was characterized to strain, and additional tests were made to assess the ideal pre-strain to be applied to the fiber in the pen to optimize its sensitivity to movements in the displacement and frequency ranges of the carotid pulse. Thus, sinusoidal waves were applied to the FBG through a piezoelectric actuator to the fiber with different pre-applied strains, analysing which pre-strain optimized the sensitivity. After the assembly of the fiber to the 3D-printed piece, the prototype was tested with synthetized pulse waves (represented in figure 1) and in 4 volunteers of different ages and gender, comparing the arterial pulse wave and stiffness indexes acquired with the FBG probe and a reference medical device

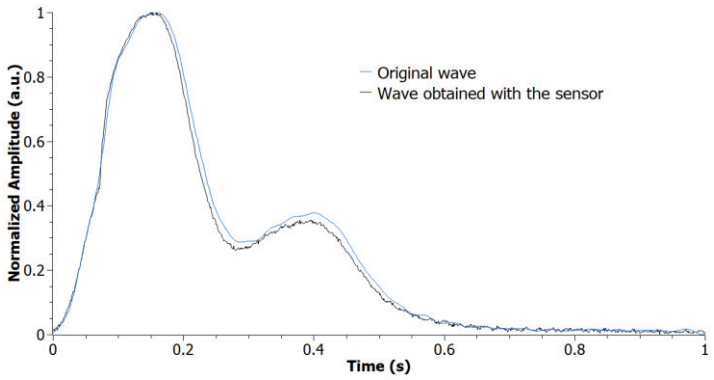

Figure 1. Comparation between the original pulse wave and the one obtained with the sensor

Keywords: artery stiffness, carotid artery, FBG, pulse wave.

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References:

[1] J. Alastruey et al., "Arterial pulse wave modeling and analysis for vascular-age studies: a review from VascAgeNet," American Journal of Physiology - Heart and Circulatory Physiology, vol. 325, no. 1. American Physiological Society, pp. H1–H29, Jul. 01, 2023. doi: 10.1152/ .00705.2022.
[2] J. H. Janner, N. S. Godtfredsen, S. Ladelund, J. Vestbo, and E. Prescott, "Aortic augmentation index: Reference values in a large unselected population by means of the sphygmocor device," Am J Hypertens, vol. 23, no. 2, pp. 180–185, Feb. 2010, doi:10.1038/ajh.2009.234.

Development of a High-Precision, Portable and Automated Mobile Laser Scanner for the Recording and Digitation of Texture and Micro-marks in Archaeological and Heritage Stone.

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ABSTRACT

The use of laser tools to digitise cultural heritage items is becoming more widespread, but is generally limited to manual systems that rely on the user's movement, or expensive automated equipment that is designed to scan large items but is not always able to accurately measure or reproduce specific details of small size [1].

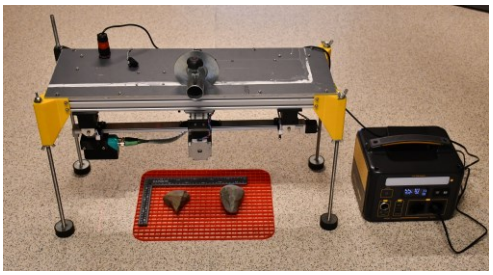
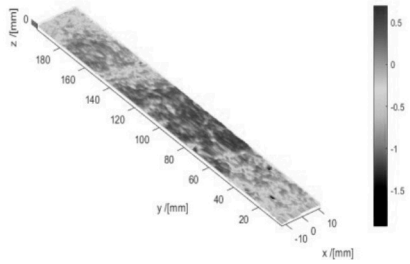
a)  b) 

Figure 1. a) Image of the PALLAS system. b) Topography of an granite ashlar (plane XY) with the heights (Z).

In this paper we present the novel high-precision system PALLAS, which allows the automatic digitisation of three-dimensional detailed surfaces. The equipment has been built using a set of motors and linear axes, control electronics and a line laser scanner that can be moved along the XY working plane. It is battery powered for ease of use in the field and uses a standard laptop to communicate via a Wi-Fi network. Custom software has been developed to automatically calculate the trajectory, control the movement and store the profiles generated by the scanner. The software can also be used to reconstruct the surface from the set of scanner profiles, allowing the XYZ coordinates of any point on the surface to be measured, and also to obtain areal roughness parameters to characterise the finish and texture of the stone surface [2]. Preliminary results obtained from masons' marks, rock engravings and petroglyphs are presented.

Acknowledgements: Work carried out under the Memorandum of Understanding between the Universidade da Coruña and the Centro Camuno di Studi Preistorici (Brescia, Italy). Work partially financed by PID2021-123948OB-100, funded by MCIN/AEI/ 10.13039 /501100011033 and by the ERDF "A way of making Europe" of the European Union.

References:

[1] Masciotta, M. G., Sanchez-Aparicio, L. J., Oliveira, D. V., & Gonzalez-Aguilera, D. (2023). Integration of Laser Scanning Technologies and 360º Photography for the Digital Documentation and Management of Cultural Heritage Buildings. International Journal of Architectural Heritage, 17(1), 56–75. https://doi.org/10.1080/15583058.2022.2069062

[2] Freire-Lista, D.M., Campos, B.B., Moreira, P., Ramil Rego, A. y Lopez Díaz, M.J. (2023): Building Granite Characterisation, Construction Phases, Mason's Marks and Glyptography of Nossa Senhora de Guadalupe Church, Mouçós e Lamares, Galicia-North Portugal Euroregion. Geoheritage, 15: 24. https://doi.org/10.1007/s12371-023-00790-4

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Azobenzene-based customized surfaces: a new approach towards the development of Orbital Angular Momentum devices

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ABSTRACT

Over the past three decades, light's orbital angular momentum (OAM) features have aroused great interest because its technological perspectives in the developing of sensor devices and communications. Particularly in the field of optical communications exploiting the OAM features of a light beam offers an additional degree of freedom for multiplexing and transmitting multiple independent data streams within a single spatial mode using the spatial division multiplexing (SDM) technology, allowing scaling up a channel capacity of communication links by a very high order of magnitude, allowing it to circumvent the reaching of optical fibers non-linear Shannon limit. The creation of OAM features to a light beam is normally attained by the use of spatial-generating devices as cylindrical lenses, spiral phase plates, phase holograms, spatial light modulators and optical fibers [1-4]. These devices are relatively complex to produce and settle with. Recently, azobenzene-based films have gained attention towards the creation creating and customization of OAM-carrying beams. Unique features of azobenzene films, namely net mass transport induced by light as a result of successive photomerization features about the N=N bound, allows the creation of customized reliefs [5]. This feature enables the fabrication of diffractive optical devices such as spiral phase plates and holograms by accurately imprinting a phase profile on an incident light beam. By adequately patterning azobenzene films surfaces with diffractive optical elements, such as spiral phase plates, one can selectively create OAM-carrying beams allowing multiple distinct channels to be encoded within a single optical beam. This can significantly increase the data transmission capacity of optical communication systems with this OAM multiplexing technique. Additionally, azobenzene films based holographic optical components can be used to build and reconstruct intricate wavefronts. In fact, one can create OAM-based holograms by imprinting holographic designs on azobenzene films, making simpler to control and shape optical beams for specific communication requirements. Finally, azobenzene-based thin films are easy for integration into optical communication mainly due to their reconfigurability, compactness, and infrastructure compatibility, which are the main features for achieving OAM-based technologies. In this work, the use of azobenzene films in the generation and modification of OAM beams for optical communications through light-induced isomerization will be discussed.

Keywords: orbital angular momentum; azobenzene; photoisomerization; optical communication
Acknowledgements: This research is supported by the Portuguese National Funding Agency (FCT-MCTES), UIDB/04559/2020 (LIBPhys), and UIDP/04559/2020 (LIBPhys).

References:

[1] Temitope M. Olaleye Paulo A. Ribeiro and Maria Raposo, "Generation of Photon Orbital Angular Momentum and Its Application in Space Division Multiplexing", Photonics, 10(6), 664, June 2023, https://doi.org/10.3390/photonics10060664
[2] Pan, J., Shen, Y., Wan, Z.; Fu, X., Zhang, H., Liu, Q., "Index-Tunable Structured-Light Beams from a Laser with an Intracavity Astigmatic Mode Converter", Phys. Rev. Appl., October 2020, 14, 044048, https://doi.org/10.1103/PhysRevApplied.14.044048
[3] Andersen, M., Alperin, S.N., Voitiv, A.A., Holtzmann, W.G., Gopinath, J.T.; Siemens, M.E., "Characterizing vortex beams from a spatial light modulator with collinear phase-shifting holography", Appl. Opt., October 2019, 58, 404, https://doi.org/10.1364/AO.58.000404
[4] Ma, M.; Lian, Y.; Wang, Y.; Lu, Z., "Generation, Transmission and Application of Orbital Angular Momentum in Optical Fiber: A Review", Front. Phys., November 2021, 9, 773505, https://doi.org/10.3389/fphy.2021.773505
[5] Temitope M. Olaleye, Maria Raposo and Paulo A. Ribeiro, "Generation of Orbital Angular Momentum Light by Patterning Azopolymer Thin Films", Photonics, 10(12), 1319, November 2023, https://doi.org/10.3390/photonics10121319

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Microdisplacement SMF-sensor based on ultrafast laser-assisted etching method

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ABSTRACT

This work presents the suitability of an SMF into which a transverse through-hole microchannel has been incorporated, to be employed as a micro-deformation sensor. Microchannel inscription was performed by the ultrafast laser-assisted etching technique [1], in which a femtosecond fiber laser irradiates an SMF segment to selectively enhance a subsequent wet-etching process [2].Once manufactured, the reflectance of the structure was characterized using the experimental setup illustrated in Figure 1 (a), where a circulator (CIR) allowed light from a broadband light source (BLS) ranging from 1450 to 1650 nm to be retrieved on an optical spectrum analyzer (OSA), once reflected in the structure (depicted by a microscope image). The obtained results are shown in Figure 1 (b) for a 600-με range of applied microstrain.
Given the periodic nature of the spectra, its sensitivity to microstrain was directly analyzed in the spatial frequency domain using the FFT algorithm. Figure 1 (c) shows the magnitude of the Fourier transform, revealing a main peak at 0.05 nm-1. Since the peak position remained constant under deformation, its phase could be reliably monitored with the strain applied. The result of this dependence can be observed in the inset of Figure 1 (c), where the fitting of experimental measurements indicates a strong linear trend, with a coefficient of determination of 0.9917. Similarly, the resulting sensitivity of -0.28 rad/mε surpasses those obtained in recent studies employing different in-line interferometers [3].
Finally, the repeatability of this phase-strain response was verified by applying successive cycles of stretching and relaxation as illustrated in Figure 1 (d), resulting in an average sensitivity of -0.31 rad/ mε and a coefficient of variation under 9%. All these results support the suitability of the structure as a micro-deformation sensor.

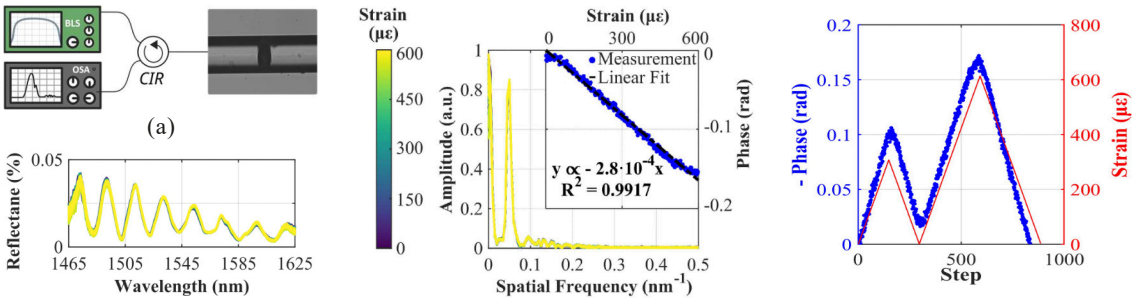

Figure 1. Set up employed in sensor characterization (a), reflectance under strain applied in spectral (b) and transformed (c) domains, and phase evolution during succesive deformation-relaxation cycles (d).

Keywords: Femtosecond laser, microdisplacement sensor, ultrafast laser-assisted etching, temperature sensor
Acknowledgements: This work is part of the project PID2022-137269OB-C21 funded by MCIN/AEI/10.13039/501100011033, FEDER "A way to make Europe"

References:

[1] M. Hermans et al., "Selective, laser-induced etching of fused silica at high scan-speeds using KOH," JLMN-Journal of Laser Micro/Nanoengineering, vol. 9, no. 2, pp. 126 – 131, June 2014.
[2] M. Ochoa et al., "Polarisation-independent ultrafast laser selective etching processing in fused silica," Lab on a Chip, vol. 23, no. 7, pp. 1752 – 1757, Feb. 2023.
[3] R. A. Perez-Herrera et al., "Multiparameter sensor based on a multi-interferometric serial configuration for temperature and strain measurements," IEEE J. Sel. Top. Quantum Electron., vol. 27, no. 6, pp. 1 – 4, Nov.-Dec. 2021.

Polarization-controllable multiwavelength L-band fiber optic ring cavity laser

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ABSTRACT

Inthiswork,apolarization-controllabledual-wavelengthL-bandfiberringlasercavityisexperimentallydemonstrated. The experimental setup of the proposed fiber ring cavity is shown in Fig. 1 (a). The cavity ring includes an L-band booster semiconductor optical amplifier (BOA), one 3-port optical circulator (CIR) and a 75:25 optical coupler (OC) employed both for closing the ring cavity and extracting part of the signal from the ring to the output port.
As it is well known, one of the main problems in multiwavelength ring lasers is that the oscillation threshold power for each wavelength is different due to the non-uniform shape of the gain-media profile [1]. To overcome this issue, instead of using variable attenuators (VA) to adjust the cavity losses on each wavelength [2, 3], a polarization-controller (PC) was connected to the second port of the CIR followed by an array of two FBGs centered at the L-band in a reflective configuration. The emission lines at the output of the fibre ring laser correspond to the central wavelengths of the FBGs in the array, which are located at 1591.6 nm and 1560 nm. By adjusting the polarization state of the input signal to the array, the system can be switched among different wavelength lasing configurations. The output spectra for a single-wavelength and dual-wavelength configurations are presented in Figure 1 (b) and Figure 1 (c), respectively. As it can be observed, the peak optical powers obtained are 1.55 dBm for the single-wavelength configuration and -1.86 dBm and -1.89 dBm for the dual-wavelength configuration, with an optical signal to noise ratio superior to 48 dB in all cases. Scalability for additional wavelengths can be achieved by cascading extra FBGs into the array, being possible the generation of additional wavelength combinations at the system output through meticulous manipulation of the polarization state at the input of the array.

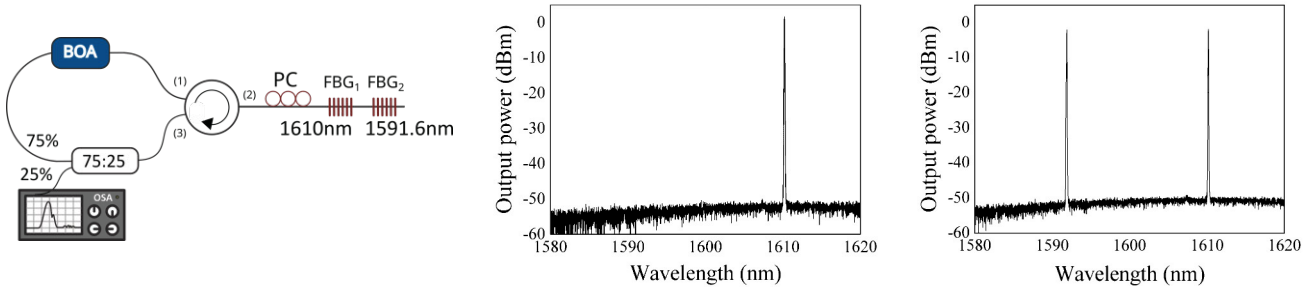

Figure 1. Proposed dual-wavelenght L-band fiber optic ring laser cavity (a), output power spectrum for the single-wavelength configuration (b) and for the dual-wavelength configuration

Keywords: booster optical amplifier, fiber Bragg grating, multiwavelength lasing, optical fiber ring laser, polarization control.

Acknowledgements: This research was supported by the Public University of Navarre Collaboration grants. This work is part of the project PID2022-137269OB-C21 funded by MCIN/AEI/10.13039/501100011033, FEDER “A way to make Europe”.

References:

[1] R. A. Perez-Herrera et al., "L-Band Multiwavelength Single-Longitudinal Mode Fiber Laser for Sensing Applications," in Journal of Lightwave Technology, vol. 30, no. 8, pp. 1173-1177, April15, 2012, doi: 10.1109/JLT.2011.2174138.
[2] S.-K. Liaw et al., “Power equalized wavelength-selective fiber lasers using fiber Bragg gratings,” in Optics Communications", vol. 155, no. 4-6, pp. 255-259, 1998, doi: 10.1016/S0030-4018(98)00406-4.
[3] H. Ahmad et al., “S–C–L triple wavelength superluminescent source based on an ultra-wideband SOA and FBGs,” in Quantum Electronics, vol. 43, no. 10, pp. 923-926, 2013, doi: 10.1070/QE2013v043n10ABEH015028.

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Frequency stabilization of an extended-cavity diode laser using polarization spectroscopy

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ABSTRACT

With the use of single-mode lasers [1], high-resolution spectroscopy offers the possibility to practically suppress spectral line broadening due to the Doppler effect. Among the high-resolution laser techniques are Saturated Absorption Spectroscopy (SAS) and Polarization Spectroscopy (PE) [2-4]. While the SAS technique monitors the decrease in absorption experienced by a test beam due to transition saturation caused by a pumping beam, the PE signals obtained result mainly from the change of the polarization state of the test laser radiation induced by the polarized pumping laser radiation. Due to the optical pumping laser radiation, both a change in the absorption coefficient α and a change in its refractive index n are produced in the sample. In this technique, the shape of the signal obtained with PE allows it to be used as a frequency discriminator and can be used as an error signal in a Proportional-Integral-Derivative (PID) controller to stabilize the laser frequency at an atomic transition. In this work, the free Doppler broadening spectrum of a rubidium gas was obtained using the polarization spectroscopy (PE) technique. The measurements performed include the characterization of the amplitude and slope of the most intense peak of the polarization signal obtained, as a function of the pumping beam power. In addition, data on the frequency stability of an extended cavity laser using this technique are presented. Figure 1 shows the spectra of the hyperfine structure of the Rubidium in the transition $F_g = 2 \rightarrow F' = \{1, 2, 3\}$ obtained with the SAS and PE techniques [5].

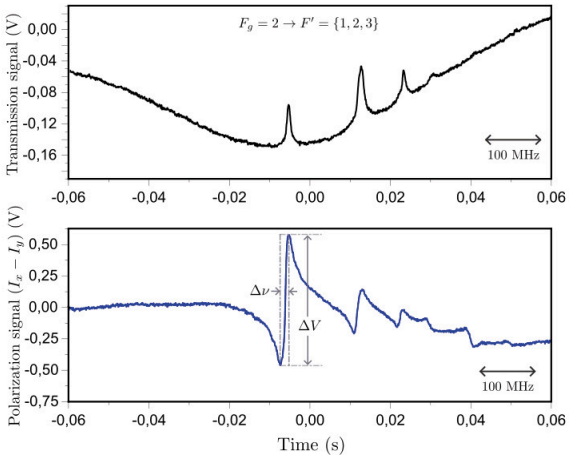

Figure 1. Comparison between the Saturated Absorption Spectrum (Above) and the Polarization Spectrum (Below).

Keywords: (Polarization Spectroscopy, Saturation Absorption, Laser Stabilization)

Acknowledgements: Atlántico University (Colombia), Minciencias, and Physics Institute Sao Carlos (Brasil).

References:

[1] P. Kumar Basu, B. Mukhopadhyay, R. Basu, "Semiconductor Laser Theory", CRC Press, 2016
[2] W. Demtröder, "Laser Spectroscopy: Basic Principles", Vol.1, 5Th Ed. Springer-Verlag, 2014
[3] C. E. Wieman and T. W. Hänsch, "Doppler-free laser polarization spectroscopy," *Collect. Pap. Carl Wieman*, vol. 36, no. 20, pp. 12–15, 2008, doi: 10.1142/9789812813787_0003.
[4] D. W. Preston, "Doppler-free saturated absorption: Laser spectroscopy," *Am. J. Phys.*, vol. 64, no. 11, pp. 1432–1436, 1996, doi: 10.1119/1.18457.
[5] J. C. Álvarez, Thesis: "Estudio de transiciones en las estructuras fina e hiperfina en especies atómicas en fase gaseosa a través de Espectroscopía Laser de alta resolución: "Espectroscopía de Absorción Saturada o Espectroscopía de Polarización", Universidad del Atlántico, 2023.

Development of test methodologies for characterising light guides for use in automotive interiors

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ABSTRACT

As a result of technological advances, there are now more cost-effective and efficient solutions for creating colourful and dynamic lighting using LEDs and light guides. Unsurprisingly, automotive interior lighting has also evolved, serving new purposes that enhance the comfort and safety of the driver and passengers. Lighting can now guide attention, pinpoint hazards, and alert the driver, playing a crucial role in the functionality of new semi-autonomous vehicles [1, 2]. Despite the recent advancements in automotive interior lighting, the acquisition of relevant photometric data to create lighting systems suitable for their purpose remains a matter of concern. To overcome this issue, it is crucial to ensure the reliability, accuracy, and consistency of the data, by implementing consistent measurement protocols and procedures across diverse laboratories. These procedures are described in standards defined by organizations such as the CIE (Commission Internationale de l'Eclairage), ISO (International Organization for Standardization), or even government regulations defined by the UNECE (United Nations Economic Commission for Europe) or SAE (Society of Automotive Engineers). However, with the exception of Volkswagen, which established a standard (PV 8002) in 2023 that delineates the testing procedures for interior lighting, there currently exist no standards that define the methodology for characterizing and validating light guides applied to vehicle interiors. The existing standards only cover electrical and photometric measurements for lamps, luminaires, and LED modules used in general interior lighting applications. [3, 4]
The objective of the present work is to develop a testing method for evaluating and validating light guides used in vehicle interiors. This method will be based on existing standards and will respond to the needs of automotive interior lighting manufacturers. As a preliminary investigation, two backlit door panels (ambient lighting) and other lighting based on light guides were subjected to testing in accordance with the methodology. This lighting is designed to create a visually appealing environment and help locate controls in the dark. It needs to be visible enough to find the nearest controls, with minimum requirements for luminance, colour, and uniformity. Therefore, luminance and colour tests were conducted to ascertain whether the samples in question met the requirements imposed by the original equipment manufacturer (OEM). The results show an agreement regarding the colour coordinates, but a lower luminance than expected, possibly due to the coating since the requirement refers to the luminance inside the perforation.

Keywords: automotive interior lighting, colour, light guide, luminance.

Acknowledgements: Rita P. Moreira would like to give special thanks to Simoldes Plásticos S.A. for providing the light guides for testing.

References:

[1] Blankenbach K, Hertlein F, Hoffmann S, "Advances in automotive interior lighting concerning new LED approach and optical performance", J Soc Inf Display, March 2020; pp. 1–13. Accessed: May 13, 2024. [Online]. Available: https://doi.org/10.1002/jsid.887
[2] M. J., "The (R)Evolution of Car Interior Lighting", RS DESIGNSPARK, Accessed: May 13, 2024. [Online]. Available: The (R)Evolution of Car Interior Lighting (rs-online.com)
[3] T. S., "How to Design Exterior & Interior Automotive Lighting Systems", SYNOPSYS, Accessed: May 13, 2024. [Online]. Available: How to Design Exterior & Interior Automotive Lighting Systems | Synopsys Blog
[4] Leschhorn G, Young R, Handbook of LED and SSL Metrology. Munich, Germany: Instrument Systems GmbH, 2017.

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Design of optical system components for small-UAV LiDAR applications

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ABSTRACT

Small unmanned aerial vehicle (UAV) rely on cameras for navigation purposes, such as obstacles avoidance. However, cameras require ambient light to proper collect data, and when flying at high speeds cannot operate properly, disabling these obstacle avoidance measures. One way to address this problem is by using light detection and ranging (LiDAR) sensors. Better navigation instruments to use in aerospace applications such as small-UAVs but also in small satellites, meteorological ballons, ballistic missiles, etc., are of very high interest due to the forementioned. However, these sensors are often expensive and bulky. These small-UAV are chosen for their low-cost and usually have small payloads which actively affects the flight-time. There is a need to miniaturize LiDAR, while maintaining performance but also reducing the price, for a broader adoption in the market. One way to reduce the weight and production costs is by using optical polymer lens. One way to reduce the volume is decreasing the size of the optics, with custom aspherical optics. In this work, to decrease the stacking of the optics an optical smartphone design is applied to a LiDAR. Three solutions were analysed, with a root-mean square (RMS) spot size, modulation transfer function (MTF) and distortion comparison. To evaluate the performance of the systems in operation, a thermal study for -25 °C, 25 °C, 60 °C and 125 °C was conducted for all the solutions. A tolerance analysis was also conducted, evaluating the variations in performance introduced by the manufacturing and assembling errors. The three solutions performance trade-offs are later compared.

Keywords: ADAS, aerospace, asphere lens, compact system, LiDAR, UAV, wide FoV, Zemax optical design.

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Vegetation health evaluation using cost-effective aerial reflectance measurements

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ABSTRACT

The normalized difference vegetation index (NDVI) is often used as a health indicator for plants, but also as a water content indicator. The NDVI relates the red reflectance (REDR), due to the chlorophyll absorption and the near-infrared reflectance (NIRR), due to the cellular structure scattering. NDVI is calculated using NDVI= (NIRR − REDR)/ (NIRR + REDR). Using a cost-effective commercial-off-the-shelf (COTS) drone (DJI MAVIC 2 PRO), cost-effective COTS filters (Kolari Vision DJI Mavic 2 Pro Full-Spectrum IR Lens Filter Set), in-house software and built calibration panel allows to easily obtain reflectance values for specific wavelengths (limited by the COTS filters). Using these results is then possible to retrieve the forementioned NDVI. Comparison tests using field samples can be used to validate and further increase precision of the results. These tests can be also easily done using an acetone solution to retrieve the chlorophyll and spectrophotometer to analyze its composition. To attest the water content a simple weighting and subsequent drying of the samples can be used to obtain a very accurate value to compare and calibrate the results.

Keywords: Cost-effective, drone NDVI, NIR, reflectance, vegetation health, water content.

Optical Deflectometry-Based Surface Inspection System For Combustion Device Covers

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ABSTRACT

First impressions of combustion equipment often dictate purchase decisions, making exterior quality control crucial. Automating this surface inspection process has been challenging but, is essential for reducing resources spent on correcting defects and minimizing human error. In the automotive industry, surface inspection techniques like deflectometry and fringe projection are widely used [1]. These methods enhance defect detection by capture the reflected deformed images of a sinusoidal patterns. The key difference between the two lies in the type of surface being analyzed. For specular surfaces, which reflect light directly, a diffuse light source is necessary (deflectometry). Conversely, rough surfaces require direct light projection to observe only the diffuse reflection (fringe projection) [1,2].
Since, after painting, combustion device covers become specular, the technique used for surface inspection is deflectometry. Initial tests, as shown in Figure 1, reveal defects such as dents and cavities under different lighting conditions. We are currently developing a comprehensive solution addressing challenges like movement of the surface being analyzed and the limited space near the production line.

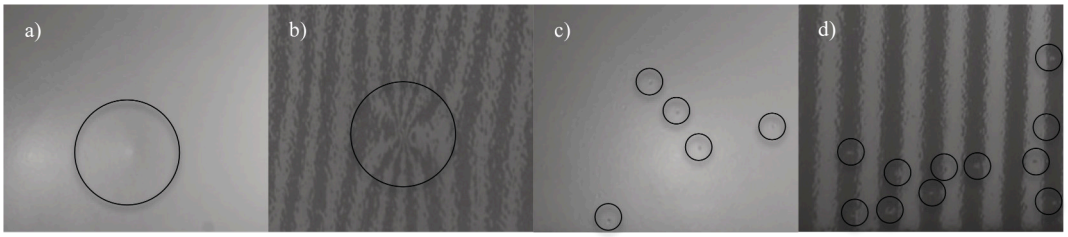

Figure 1. Two different defects with diffuse light. Dent illuminated with a) white and b) structured light. Cavities illuminated with c) white and d) structured light.

Keywords: Quality Control; Deflectometry; Computer Vision; Optical Inspection; Surface Inspection

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References:

[1] M. Hödel, L. Hoegner, and U. Stilla, "Review on photogrammetric surface inspection in automotive production," in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, Jun. 2021, vol. 43, no. B2-2021, pp. 511–518, doi: 10.5194/isprs-archives-XLIII-B2-2021-511-2021.
[2] J. Burke, A. Pak, S. Höfer, M. Ziebarth, M. Roschani, and J. Beyerer, "Deflectometry for specular surfaces: an overview," *Adv. Opt. Technol.*, vol. 12, Jul. 2023, doi: 10.3389/aot.2023.1237687.

Accommodative Response and Ocular Aberrations Among University Students

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ABSTRACT

The relationship between accommodation and ocular aberrations is well known, as is the link between near-vision tasks and accommodation and convergence. As accommodation changes the crystalline lens's optical properties by altering surface curvatures and thickness, ocular aberrations are expected to change with different levels of accommodation. The calculus of the accommodative response through the measurement of ocular aberrations with different accommodation stimuli has been used to study the impact of several conditions in accommodation.
In this study, ocular aberrations measurements are used to evaluate the impact of near vision tasks in accommodative response in university students during their academic years. The Wave Analyzer Medica (WAM800, Essilor Instruments USA) was used to measure the ocular wavefront aberrations for a 3-mm zone for both far and near vision.
Fifty-four subjects participated in the study. The mean age of the subjects was 20.89±2.94 years, with a range between 18 years and 37 years. Forty subjects were female (74%), with 14 males (26%). Results indicated statistically significant changes in Z (2, 0), Z (3, 1), Z (4, 0), the root mean square (RMS) of the low order aberrations (LOA), and Total RMS between first-year and third-year students ($p < 0.05$). Additionally, the accommodative response for the same accommodative stimulus significantly increased over the three years at the university ($p = 0.01$).
The result suggested that the accommodative effort required during the university course may lead to changes in the ocular accommodation response and a consequent decrease in ocular optical quality.

Keywords: Zernike coefficients; Low order aberration; Higher order aberrations; Near Vision.

Acknowledgments: his work was supported by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding UIDB/04650/2020.

Impact of virtual reality on the visual system

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ABSTRACT

Virtual reality has emerged as an innovative technology that aims to change how we interact with the physical and digital world. With roots in science fiction, it has developed into a sophisticated platform with the potential to redefine how we experience various sectors, from entertainment to education, medicine, and industry.
The primary aim of this study was to assess the potential impact of virtual reality on vision. Its objective was to analyze the influence of this technology on the visual system of young adults, evaluating visual parameters such as accommodation and binocular vision before and after exposure to virtual reality.
The findings of this study reveal a noticeable effect of virtual reality on the participants` accommodation and convergence. There was a substantial increase in positive relative accommodation (ARP), negative relative accommodation (ARN), amplitude of accommodation, accommodative facility, phoria and values for the breaks and recoveries of positive and negative fusional reserves.
The onset of symptoms with the use of virtual reality was also observed, and a relationship was found between their appearance and some parameters of the visual system, making it possible to identify factors that potentiate the appearance of symptoms.
By providing a comprehensive understanding of the effects of virtual reality on the visual system, this study underscores the importance of considering these factors when designing and using these technologies. It paves the way for the development of devices that minimize the impact on the visual systems of their users, a crucial consideration in the era of virtual reality.

Keywords: Virtual reality, vision, ocular accommodation, convergence

Acknowledgements: this work was supported by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding UIDB/04650/2020

Ocular aberrations modulate the accommodative response estimated across different refractive errors

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ABSTRACT

The relationship between accommodation and ocular aberrations is well known, as is the link between refractive error and ocular accommodation. Moreover, near work seems to be associated with myopia or may be a precursor to myopia. Since accommodation seems to be the common element, it was hypothesized that by estimating the accommodative parameters from the ocular aberrations, different responses could be found between the different ametropias.
The accommodative response was calculated from dynamically measured ocular aberrations for different accommodative stimuli (0.00D; 0,98D; 2.38D, and 4,54D) for both the stimulus and relaxation of accommodation. Those parameters were analyzed for myopes (N=21), hyperopes (N=15), and emmetropes (N=36) eyes. In addition, the myopes were divided according to the age of onset and whether their myopia was stable or progressing.
No statistically significant differences were found between the different ametropias for the accommodative response to all stimuli. However, after accommodating the 2.38D and 4.54D stimuli, the hyperopes were unable to relax their accommodation to the initial values, maintaining a residual accommodation value of 0.73D (p=0.001) and 0.62 D (p=0.003), respectively.
When analysing the residual accommodation it was found that those with progressive myopia had a residual value, after removing the 2.38D accommodative stimulus, of 1.05D against 0.17D of those with stable myopia (p=0.032). Those with progressive myopia, after accommodating to the 2.38D and 4.54D stimuli, were unable to relax their accommodation to the initial values, maintaining a residual accommodation value of 1.05D (p=0.008) and 0.56 D (p=0.004), respectively. (Figure 1).

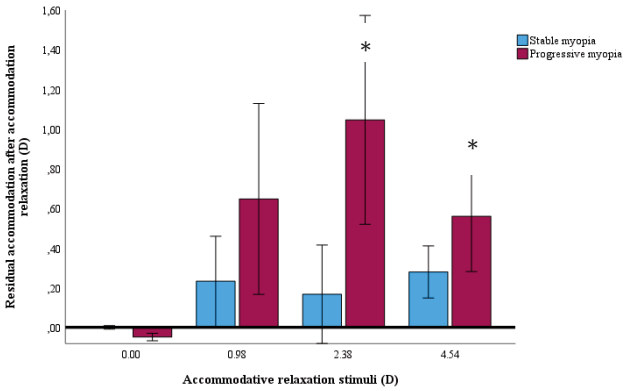

Figure 1. Residual accommodation after the relaxation of accommodation for the different stimuli. (* p<0.05)

In conclusion, the study of the accommodative behaviour obtained from the dynamic measurement of the ocular wavefront aberrations during accommodation changes can have a major role in understanding the onset and progression of different refractive errors.

Keywords: ocular accommodation, ocular aberrations, myopia, refractive error

*Acknowledgements:*his work was supported by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding UIDB/04650/2020. The author Jessica Gomes is also supported by the PhD grant 2020.08737.BD from FCT.

Fabrication and characterization of a refractometric sensor based on optical fibers coated with oxidized graphene

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ABSTRACT

In this research we have developed an evanescent field optical sensor to measure refractive index of liquids using knot-shaped optical fibers coated with oxidized graphene. The developed device has the shape of a knot and was manufactured on a commercial multimode optical fiber, obtaining different knots with different diameters. The coating of the fiber surface with oxidized graphene was achieved through the technique of immersion of the knot in oxidized graphene in the liquid phase using isoamyl acetate as a solvent. The technique was optimized using heat treatment to guarantee a homogeneous coating on the fiber surface. To obtain oxidized graphene, a green synthesis technique was used and for the characterization of the material, Ultraviolet absorption spectroscopy and Raman spectroscopy techniques were used. To characterize the device as a refractive index sensor, it was possible to measure the power transmitted by the optical fiber in the range of 400-1000 nm, identifying changes in wavelength and intensity depending on the changes in refractive index.

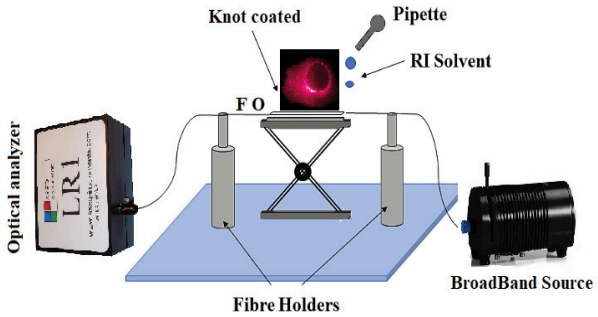

Figure 1. Experimental setup developed

During the optical characterization, the device was evaluated in the visible range using a halogen light source and an optical analyzer to measure the transmitted signal, observing changes in the transmission spectra from the refractive index changes. During this stage, spectral shifts towards shorter wavelengths were detected with the increase in the refractive index, at the same time increases in the transmitted power were identified with the increase in the refractive index of the solution. In the evaluation of the performance parameters, the sensitivity of the device was determined, obtaining a sensitivity of 397.8 nm/RIU for the best sample obtained. The results reveal that the developed device could be optimized in order to explore its advantages for the detection of chemical and biological agents of interest.

Keywords: Knot-shaped fiber optic, refractometric sensor, coated fiber

References:

[1] Yan, S., Pu, S., Zhang, Y., Yuan, M., & Zhang, C. Sensing properties of graphene-oxide-functionalized single-mode–no-core–single-mode fiber structure. *Results in Physics*, *25* (104310), 104310. (2021)
[2] Rosli, M. A. A., Arasu, P. T., Lim, H. N., & Noor, A. S. M. Dynamic response of tapered optical fiber coated with graphene oxide for detecting aqueous ethanol. *IEEE 6th International Conference on Photonics (ICP)*, 1–3. *(2016)*
[3] Hernaez, M., Zamarreño, C., Melendi-Espina, S., Bird, L., Mayes, A., & Arregui, F. Optical fibre sensors using graphene-based materials: A review. *Sensors (Basel, Switzerland)*, *17*(12), 155. (2017).

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Excitation of Localized Surface Optical Plasmon Resonances LSPR in PMMA Capillary Fibers Coated with Ag Nanoparticles for Sensing Applications

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ABSTRACT

A sensor based on the physical principle of localized surface plasmon resonance (LSPR) excitation is presented for the measurement of refractive indices using a Polymethylmethacrylate (PMMA) capillary fiber. LSPR is excited in the capillary fiber when the wavelength of the radiation propagating on the walls of the capillary is comparable to the size of the nanoparticles deposited on its surface, leading to localized collective oscillations of the electrons on the surface of the capillary, when they manage to interact with the evanescent optical field in the structure [1]. In the device coating stage silver nanoparticles (AgNPs) were used, obtained through the green synthesis technique, where the AgNO3 silver nitrate solution at 1mM was mixed using magnetic stirring with the aqueous extract of leaves of the Bougainvillea Spectabilis plant during one hour at a temperature of 90 °C [2]. The developed device uses a Polymethylmethacrylate (PMMA) capillary fiber with an average wall thickness of 220 μm and an average external diameter of 850 μm, attached to a 1.0 mm diameter PMMA fiber using epoxy resin. The AgNPs were deposited through the immersion technique.
The experimental setup consists of an optical detector as a mechanism for interrogating the signal transmitted in the device in terms of refractive index changes and a light source in the range of 350-890 nm. During the experiment, a plastic optical fiber was attached to the ends of the coated capillary fiber, allowing light to propagate on the walls of the coated capillary fiber. In this way, the excitation of surface optical plasmon resonances located was possible at resonant wavelengths between 473 nm and 485 nm for refractive indices of 1.3478 RIU and 1.3795 RIU, respectively. The device allowed detecting variations in the refractive index of the order of 10^{-2} RIU in quantities of analyte of the order of milliliters. During the characterization of the device, a shift of the plasmon resonance wavelengths towards long wavelengths with increasing refractive index will be observed. During the experimental development, it was possible to achieve reproducibility of the measurements with a linear trend sensitivity of the order of 346.54 nm/RIU.

Keywords: Optical plasmon, Capillary fibers, Ag Nanoparticles, Polymethylmethacrylate

References:

[1] M. Chauhan, V. K. Singh, "Review on recent experimental SPR/LSPR based fiber optic analyte sensors", Optical Fiber Tecnology, 64, 102580 (2021)

[2] S. Horta-Piñeres, M. Cortez-Valadez, D. A. Avila, J. E. Leal-Perez, A. Hurtado-Macías, M. Flores-Acosta, C. O. Torres, "Green synthesis of silver nanoparticles via Bougainvillea Spectabilis (leaves and stem) for pyridoxine SERS sensing", Appl. Phys. A, Vol. 128, 1090 (2022).

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Optical characterization of transition-metal activated microwave-assisted hydrothermal synthesized Zn_2GeO_4 nanorods

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ABSTRACT

Zinc germanate, Zn_2GeO_4 (ZGO), is a semiconductor with a wide direct band gap within the range of 4.4 – 4.9 eV [1, 2] that has attracted the interest of the scientific community due to its potential use in a wide variety of scientific and technological applications, including solid-state phosphors, anticounterfeiting, bioimaging and biosensing [3,4]. Despite its interest, there is still intense debate in the literature regarding the nature of the optically active defects present in the material, as is the case of the wide bluish-white emission band reported in nanorods and that has been attributed to the recombination of intrinsic defects involving oxygen vacancies [5]. In this work, undoped, Mn and Cr-doped ZGO nanorods were synthesized at 170 ºC by microwave-assisted hydrothermal method. These as-synthesized ZGO nanorods were also thermally annealed at 400 ºC in air. The as-synthesized and annealed rods were optically characterized by photoluminescence (PL), PL excitation (PLE), Raman and diffuse reflectance spectroscopies. All the samples show a bluish-white light, which we have identified as the result of two emitting defects: one emits light in the blue region due to intrinsic defects, while the other corresponds to the $^4T_1 \rightarrow {}^6A_1$ green emission of the Mn^{2+} ions in cation sites. The presence of the Mn^{2+} luminescence in all the studied samples indicates that the purity of the used precursors cannot be ruled out to establish the optical characteristics of the ZGO host. Besides manganese, chromium ions in the tri- and tetravalent charge states were optically identified. Hence, in addition to the widespread distribution of inherent intrinsic defects in the oxide, it is essential to thoroughly examine the impact of the presence of optically active transition metal ions. These extrinsic impurities may exist as trace contaminants or may have been intentionally introduced into the matrix as dopants.
This research will enhance the understanding of the optical ZGO properties in the presence of intrinsic and extrinsic defects, including their role in the observed blue and green persistent luminescence.

Keywords: Zn_2GeO_4 nanowires; hydrothermal synthesis; photoluminescence; persistent luminescence; intrinsic and extrinsic defects

Acknowledgements: This study has the support of the Institute for Nanostructures, Nanomodelling and Nanofabrication (i3N), through projects UIDB/50025/2020 & UIDP/50025/2020 & LA/P/0037/2020, IonProGO 2022.05329.PTDC project, DOI: 10.54499 / 2022.05329, funded by the Foundation for Science and Technology. J. Rodrigues acknowledges FCT for Programme Stimulus of Scientific Employment–Individual Support (grant 2022.00010.CEECIND/CP1720/CT0023, DOI: 10.54499/2022.00010.CEECIND/CP1720/CT0023). This study was carried out as part of project 2023.00054.RESTART, funded by the Foundation for Science and Technology. M. S. Batista thanks i3N and FCT for the PhD grant (UI/BD/152567/2022).

References:

[1] S. Luo *et al.*, Ultrawide bandgap willemite-type Zn_2GeO_4 epitaxial thin films, Appl. Phys. Lett., 122, 031601(1)-(7), Jan. 2023.
[2] J. Dolado *et al.*, Understanding the UV luminescence of zinc germanate: the role of native defects, Acta Mater., 196, 626–634, Jul. 2020.
[3] Z. Yang *et al.*, Manganese-doped zinc germanate phosphors with vivid luminescent properties for anti-counterfeit applications, Opt. Mat., 142, 114036, Jun. 2023.
[4] F. Chi *et al.*, Multimodal temperature sensing using Zn_2GeO_4:Mn^{2+} phosphor as highly sensitive luminescent thermometer, Sensors and Actuators B: Chemical, 296, 126640, April 2019.
[5] Z Gu *et al.*, Luminescent Zn_2GeO_4 nanorod arrays and nanowires, Phys. Chem. Chem. Phys., 15, 7488–7493, Jan. 2013.

Liner Cavity Fiber Laser configurations for refractive index measurements

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ABSTRACT

Different configurations based on linear cavities fiber lasers were experimentally demonstrated– Figure 1. The laser gain was provided by a commercial bidirectional Erbium-Doped Fiber Amplifier (EDFA) and the linear cavity was obtained using a combination of two commercial Fiber Bragg Gratings (FBGs).

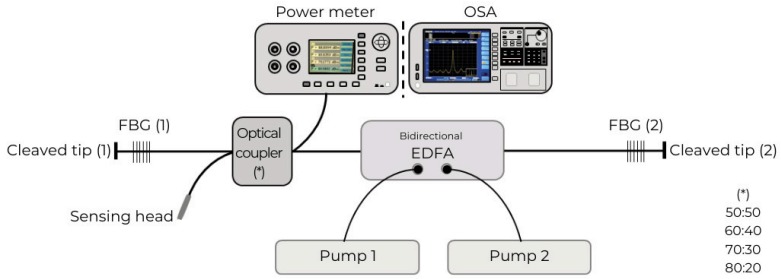

Figure 1. Experimental setup configurations of the proposed fiber laser systems.

The difference in each configuration was related to the coupling ratio of the optical coupler used to extract the system signal to an Optical Spectrum Analyzer (OSA) and/or to an optical power meter, namely, 50:50, 60:40, 70:30 and 80:20. In all the configurations, the sensing head corresponded to a standard Single-Mode Fiber (SMF 28e) tip, that worked as an intensity sensor to measure standard liquid solutions of paracetamol with a refractive index range of 1.3626 to 1.3846 RIU. In the characterization of the systems, it was found that all configurations reached the laser condition, with the presence of both, stimulated emission, and Amplified Spontaneous Emission (ASE) [1]. Regarding the sensitivity to refractive index variations, the configurations proposed only allowed to performed measurements using a threshold pump power. The configurations using the optical couplers 70:30 and 80:20 allowed to perform paracetamol refractive index measurements with the highest and closest sensitivities of (-23.94 ± 0.63) nW/RIU and (-23.89 ± 0.65) nW/RIU, respectively. These results allow to conclude that the proposed linear fiber laser configurations only work to perform paracetamol refractive index measurements if the stimulated emission effect is not strong enough to suppress the ASE effect.

Keywords: fiber lasers, linear cavity, fiber tip, paracetamol, refractive index.

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References:

[1] L. Ryglowski, K. Cyprych, J. Mysliwiec " The differentiation procedure between amplified spontaneous emission and lasing phenomena," Optics Communications, vol. 510, 127939, May 2022.

Plasmonic immunosensors based on spoon-shaped waveguides for fast and on-site ultra-low detection of ochratoxin A in coffee samples

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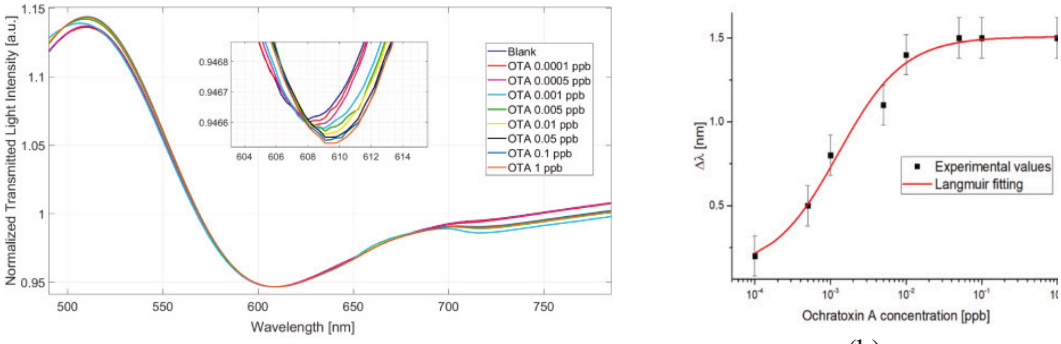
ABSTRACT

The high toxicity and occurrence of ochratoxin A (OTA) in grains and foods has been a growing concern due to the impacts on health and the economy in many countries. In this sense, simplified devices with high sensitivity and specificity for local monitoring are enthusiastically pursued. In this work, we report for the first time the detection of ochratoxin A in coffee samples using a spoon-shaped waveguide immunosensor. The biosensor was built with the surface of the spoon-shaped waveguide covered by a 60 nm layer of gold to enable the SPR phenomenon. An optical immunosensor based on SPR phenomena, obtained via spoon-shaped waveguides, was successfully developed for the ultra-low detection of OTA. The calibration curve provided a linear range from 2.10^{-4} ppb to 5.10^{-3} ppb (fig. 1a,b). The immunosensor demonstrated high selectivity in detecting OTA when tested with Ochratoxin B. Assays on a soluble coffee sample demonstrated that the biosensor does not suffer matrix interference and is highly recommended for real samples. Furthermore, the developed biosensor represents a promising analytical device for coffee quality analyses, as it is portable, simple, and suitable for onsite detection of target analytes without microfluidic systems.



(a) (b)

Figure 1. a) SPR spectra relative to OTA detection at different concentrations (0–1 ppb) in PBS. b) Variation in resonance wavelength calculated with respect to the blank (Δλ) versus OTA concentration in PBS and Langmuir fitting of the experimental data. The error bars were calculated as standard deviation of the dataset (n = 3).

Keywords: Optical biosensors. Spoon-shaped waveguides. Surface plasmon resonance. Ochratoxin A.

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Optical Fiber Sensing Design to Simultaneously Monitor Relative Humidity and Temperature

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ABSTRACT

Relative humidity and temperature are significant parameters that should be monitored and adjusted in a wide range of applications, including food quality and human comfort [1]. The simultaneous measurement of humidity and temperature with optical fiber sensors based on a single fiber Bragg grating (FBG) or Fabry-Perot interferometer (FPI) sensing configuration proves unattainable due to the sensor's cross-sensitivity [2, 3].
In this work, we propose an optical fiber sensor based on a hybrid design of an FPI and FBG for simultaneous monitoring of relative humidity and temperature. The hybrid sensor was fabricated by splicing a photosensitive single-mode fiber, where an FBG was inscribed, to a hollow core fiber tip. The hollow core fiber section was cleaved to a desired length, and a UV-cured polymer was applied just on the end of the hollow core fiber section creating a double FP cavity, resulting in the hybrid sensor design shown in Figure 1. As the FBG sensor is only sensitive to temperature shifts and the FPI produced by the UV-polymer was sensitive to relative humidity and temperature, dual parameter sensing can be performed. The sensor's calibrations were determined by placing it in a climatic chamber with a constant temperature of 40.0 ºC, while the relative humidity was varied from 50.0 %RH to 90.0 %RH, in 5.0 % steps, and with a constant RH, changing the temperature between 20.0 ºC up to 60.0 ºC, in 5.0 ºC steps. After a dedicated data analysis of the spectral responses, a standard sensitivity of ~9.0 pm/ºC was attained for the FBG sensor and a sensitivity of 6.4 pm/%RH, and -29.4 pm/ºC resulted from the peak of the FP cavity. In this way, the discrimination of both parameters was achieved by applying the matrixial method of sensitivities.

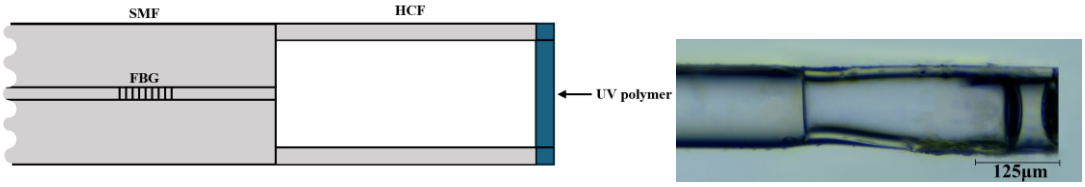

Figure 1. Schematic of the proposed hybrid optical fiber sensor for relative humidity and temperature discrimination.

Keywords: Hybrid optical fiber sensor, UV-cured polymer, relative humidity, temperature.

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References:
[1] C. He, et al. "Optical fibre sensor for simultaneous temperature and relative humidity measurement: Towards absolute humidity evaluation" Sens Actuators B Chem vol. 344, 130154, 2021, doi: 10.1016/j.snb.2021.130154;
[2] B. Sun, et al., "Simultaneous measurement of pressure and temperature by employing Fabry-Perot interferometer based on pendant polymer droplet," Opt Express, vol. 23, no. 3, p. 1906, 2015, doi: 10.1364/oe.23.001906;
[3] X. Zhang, et al., "Strain and temperature discrimination by using temperature-independent FPI and FBG," Sens Actuators A Phys, vol. 272, pp. 134–138, 2018, doi: 10.1016/j.sna.2018.01.060.

Design and fabrication of asymmetric Mach-Zehnder interferometers based on EpoClad and EpoCore strip waveguides

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ABSTRACT

Integrated polymeric optical interferometers offer the possibility of developing sensors with low cost, scalability, and easy integration. In 2016, Hofmann et al. [1] presented a new Mach-Zehnder interferometer design that avoids the need for the fabrication of an interaction window, taking full advantage of the entire interferometer area. The basic sensory principle is built upon an asymmetric change in the effective refractive index in the two arms of similar materials, due to their different proportions causing a phase variation in the output signal (see equation on the right side of Fig. 1). In this work, we present fabrication results by e-beam lithography for integrated asymmetric Mach-Zehnder interferometers designed for an operation wavelength of 650 nm, based on strip waveguides made of EpoClad and EpoCore polymers [2]. We also introduce an optimization method based on mode-solver simulations that returns the optimal fabrication dimensions of the interferometer, avoiding high-order modes and enhancing single-mode mode confinement. Ultimately, the goal of this work is to evaluate the use of these polymers and interferometer design for label-free biosensing.

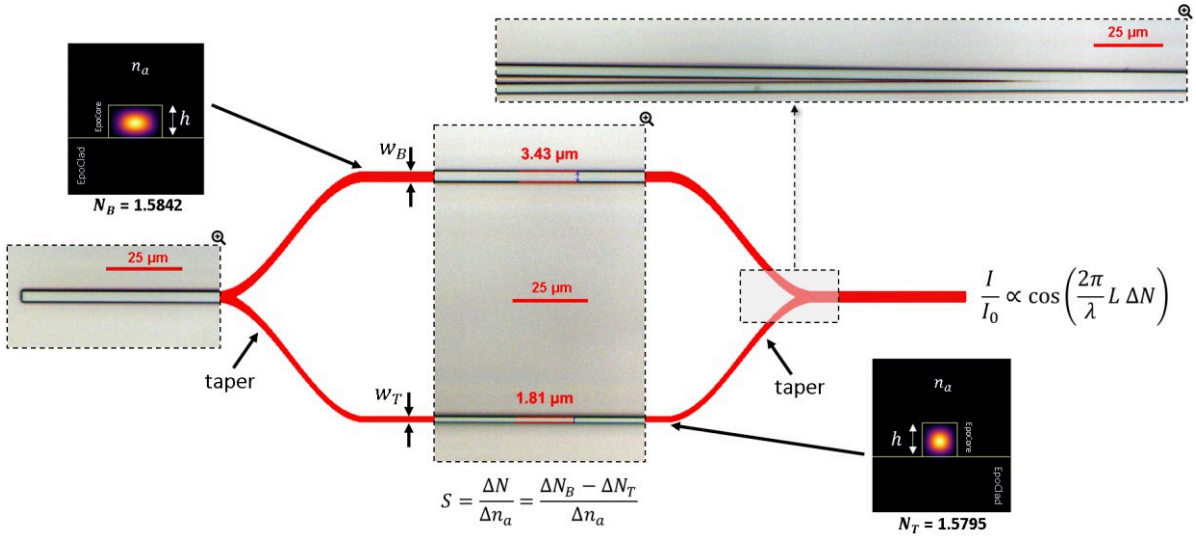

Figure 1. Asymmetric Mach-Zehnder interferometer based on strip waveguide (not to scale). The dashed rectangles correspond to optical microscope images of one of the fabricated samples. The rectangular boxes with black backgrounds correspond to the simulated modes of both arms with respective effective refractive indices (bottom). w_B, w_T: Width of the broader (3.4 µm) and thinner arms (1.8 µm). N_B, N_T: Effective refractive index of the broader and thinner arm for $n_a = 1.33$. S: Sensitivity ($\sim 2 \times 10^{-3}$ RIU for $\Delta n_a = 0.03$). ΔN_i $(i = T, B)$ is the difference between the effective refractive index for two different analytes in arm i. Δn_a: Difference in analyte refractive index n_a. h: Height (1.8 µm).

Keywords: Waveguides, Polymer waveguides, Integrated optical devices, Interferometry.
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References:

[1] M. Hofmann et al., "Asymmetric Mach–Zehnder interferometers without an interaction window in polymer foils for refractive index sensing," Appl. Opt., vol. 55, no. 5, pp. 1124-1131, February 2016.
[2] F. J. Gordo, et al. "Design and manufacture of an all-polymeric integrated multimode interferometer for visible photonics." Opt. Express, vol. 30, no. 17 pp. 31147-31156, August 2022.

Accelerometers based on fiber Bragg gratings for wind turbine blades structural health monitoring

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ABSTRACT

The growing need to develop green energy sources has spurred significant investments in the wind energy industry. Currently, efforts had been made to enhance the energy harvesting, and a consequence is the increasing blade length. However, with larger blades it becomes essential to use Structural Health Monitoring (SHM) techniques to monitor their structural integrity [1]. Optical fiber-based accelerometers are shown to be a promising solution to perform SHM in such structures, mainly due to their immunity to electromagnetic interference, high sensitivity, and lightweight nature [2].
In this work, an optical fiber-based accelerometer tailored for monitoring wind turbine blade vibrations is presented. Its key features include an operation range of 0 - 30 Hz, a working temperature and relative humidity −20 to +50 °C and 35 - 85% RH, respectively, and it's all made of non-conductive materials (achieved by using only ABS (Acrylonitrile Butadiene Styrene) material and 3D printing).

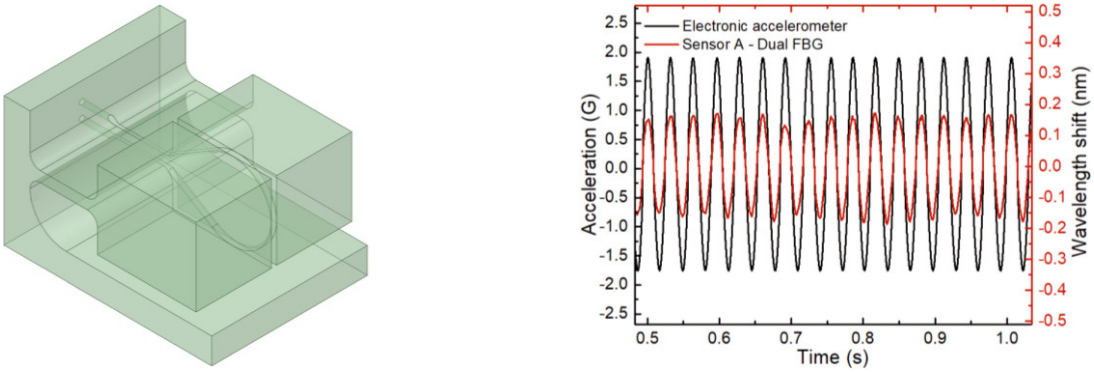

Figure 1. 3D schematic representation of the optical accelerometer prototype (on the left), and optical vs electronic data acquired during sensor's acceleration characterization at 30 Hz (on the right).

The optical accelerometer comprises two Fiber Bragg Gratings (FBGs) written in a single-mode fiber with Bragg wavelengths centered at approximately 1540 and 1554 nm, and its acceleration sensitivity was enhanced by positioning both FBGs symmetrically, in a dual-sensing configuration, allowing to attain a mean value of 77 ± 13 pm/G.

Keywords: Accelerometers, FGBs, Fiber Optical Sensors, Optical fibers, SHM.

References:

[1] V.R. Gharehbaghi, E. Noroozinejad Farsangi, M. Noori, T.Y. Yang, S. Li, A. Nguyen, C. Málaga-Chuquitaype, P. Gardoni, S. Mirjalili, A Critical Review on Structural Health Monitoring: Definitions, Methods, and Perspectives, Archives of Computational Methods in Engineering 29 (2022) 2209–2235. https://doi.org/10.1007/s11831-021-09665-9.
[2] I. Floris, J.M. Adam, P.A. Calderón, S. Sales, Fiber Optic Shape Sensors: A comprehensive review, Opt Lasers Eng 139 (2021). https://doi.org/10.1016/j.optlaseng.2020.106508.

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