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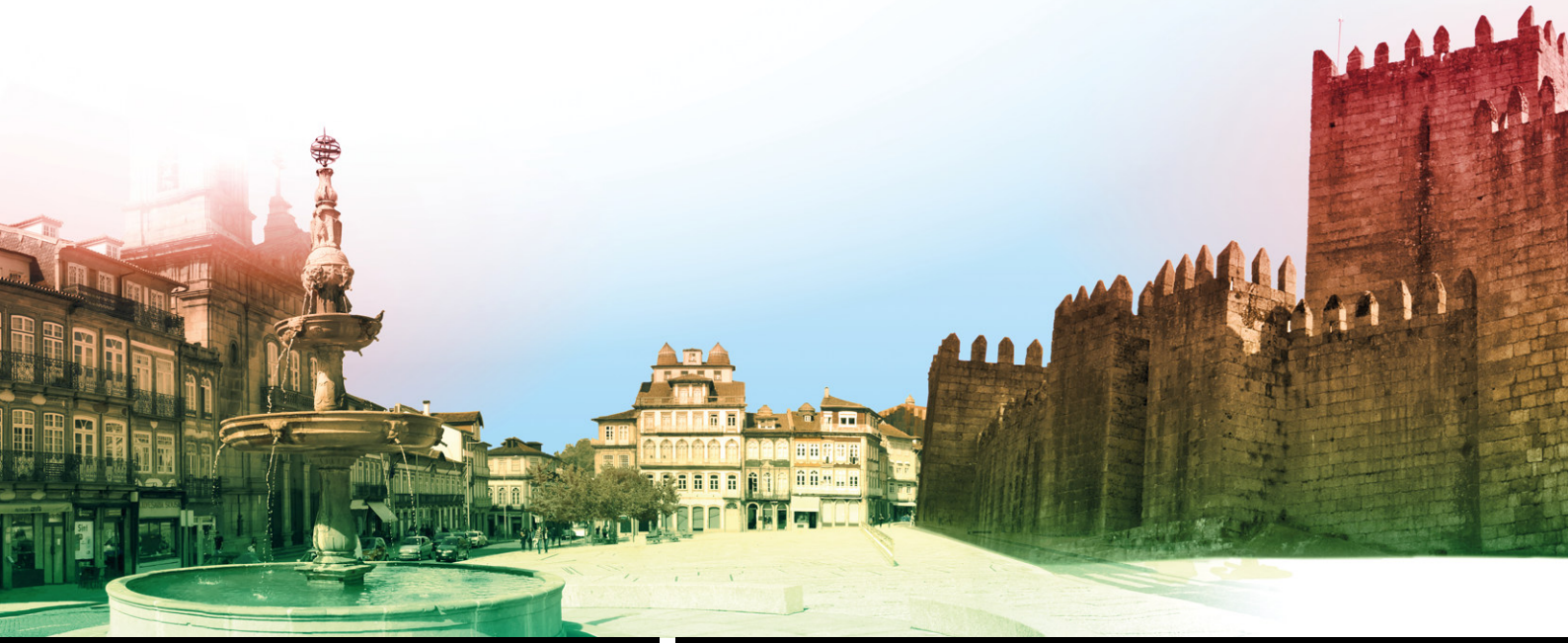

Guimarães, Portugal,
July 18-22, 2022

V International Conference on
Applications of Optics and Photonics

BOOK OF ABSTRACTS

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

SPOF
Portuguese Society for
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BOOK OF ABSTRACTS

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Foreword

After two and half years of confinement and major constraints due to the global Covid19 pandemic, the Portuguese Optics and Photonics community and friends from all over the world are going to meeting again in-person for another exciting and enjoyable AOP conference.

In spite the difficulties and challenges that we all are still facing, the renewed and recharged enthusiasm and commitment of the Portuguese Optics and Photonics community and all the around two hundred participants at the conference ensure the great success of the 5th International Conference on Applications in Optics and Photonics, AOP2022, that will take place July 18 to 22, 2022, at the welcoming UNESCO World Heritage historical city of Guimarães in the beautiful northwest of Portugal.

Since 2011 in nearby bi-millennial town of Braga with our first conference, AOP2011, followed by the AOP2014 conference in Aveiro, the AOP2017 at the University of Algarve in Faro, and the last edition, AOP2019, at the University of Lisbon in mid 2019, the conferences of the Portuguese Society for Optics and Photonics successfully celebrate Optics and Photonics and its remarkable contribution to the development of our societies and humankind.

Five plenary, 23 keynote and 17 invited lectures by world renowned researchers and schoolars 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. The state-of-the art on the widest range of O&P subjects will be reviewed foreseeing and discussing the future of research in Optics and Photonics.

In the open friendly informal environment that characterizes our conferences, a social program with several opportunities for in-person informal interaction will further allow the lively exchange of knowledge and experiences renewing relationships and fostering the establishment of the widest range of cooperation projects and relationships with colleagues and institutions from Portugal and from all around the world.

As chairperson of the conference and president of the Portuguese Society for Optics and Photonics, SPOF, it is my pleasure and honor to welcome you to the sunny city of Guimarães for a most enjoyable and productive Optics & Photonics week!

Universidade do Minho, July 5, 2022.

Manuel Filipe Pereira da Cunha Martins Costa

AOP 2022 – General Program

Monday (July 18)	Tuesday (July 19)	Wednesday (July 20)	Thursday (July 21)	Friday (July 22)
	8:30 - 8:55 **Registration**	8:30 - 8:55 **Registration**		
	8:55 - 9:40 **Plenary session**	8:55 - 9:40 **Plenary session**	9:10 - 10:10 **Registration**	9:10 - 9:45 **Registration**
	9:45 - 10:45 **Paralell sessions**	9:45 - 10:45 **Paralell sessions**	10:10 - 11:10 **Paralell sessions**	9:45 - 11:20 **Paralell sessions**
	10:45 - 11:15 **Coffee break**	10:45 - 11:15 **Coffee break**		
11:00 - 13:45 **Registration**	11:15 - 12:30 **Paralell sessions**	11:15 - 12:30 **Paralell sessions**	11:15 - 12:30 **Paralell sessions**	11:20 - 12:30 **Awards & Closing ceremony**
13:45 - 14:25 **Opening ceremony**	12:30 - 14:15 **Lunch**	12:30 - 14:10 **Lunch**	12:30 - 14:15 **Lunch**	
14:25 - 15:55 **Plenary session**	14:25 - 16:00 **Paralell sessions**	**Social Program - Visit to Braga**	14:25 - 15:10 **Plenary session**	
			15:15 - 16:30 **Paralell sessions**	
15:55 - 16:25 **Coffee break**	16:00 - 17:30 **Coffee break & Poster session**		16:30 - 17:00 **Coffee break**	
16:30 - 17:45 **Paralell sessions**			17:00 - 18:30 **Paralell sessions**	
18:15 - 19:30 ***Social Program***	18:00 - 19:30 ***Social Program***		18:30- 19:30 **SPOF' General Assembly**	
		19:30 - 22:30 **Conference Dinner**	18:30 - ... ***Social Program***	

AOP 2022 – Detailed Program

MONDAY, JULY 18

13:45 - 14:25 - Oppening Session

The Vice-Mayor of Guimarães, Dr. Adelina Paula Pinto
Prof. Dr. Humberto Michinel (Secretary General of ICO)
Prof. Dr. Gilles Pauliat (President of EOS)
Prof. Dr. Cesar Costa Vera (Counselour of RIAO)
Prof. Dr. Luis Plaja (President of SEDOPTICA)
Prof. Dr. Manuel Filipe Costa (Chairperson and president of SPOF)

14:25 - 15:55 - Plenary Sessions

Pl1 & Pl2 - Room Flores - Chair(s): António Lobo

6676 (Plenary)	**Trends in Optical Coherence Tomography**	Adrian Podoleanu
6534 (Plenary)	**The role of the laser technologies on the fabrication of organ-on-a-chip devices.**	Maria Teresa Flores Arias

Coffee Break

16:30 - 17:50 - Parallel Sessions

Mo.1.a - Room Flores - Chair(s): Hugo Pires

6816 (Keynote)	**A touch of symmetry: High-harmonic generation from low-dimensional crystals.**	Luis Plaja
6595 (Invited)	**Towards 5-cycle, multi-mJ-level mid-IR capability at the L2I**	Joana Alves
6707	**Scanning the flying focus of a tabletop vortex EUV beam**	Patricia Estrela
6736	**Various routes for VIS-to-UVC upconverted emission enhancement in lanthanide-doped nanoparticles**	Patryk Falat

16:30 - 17:45 - Parallel Sessions

Mo.1.b - Room Sete Cidades - Chair(s): António Lobo

6727	**Plasmonic/magnetic liposomes based on nanoparticles with multicore-shell architecture for chemo/thermotherapy**	Ana Rita Oliveira Rodrigues
6669	**Manganese ferrite nanoparticle clusters covered with gold nanorods for application in cancer phototherapy**	Irina Soraia Rainho Rio
6542	**Fiber optic sensor for real-time monitoring of cryosurgery depth**	Aris Ikiades
6686	**Pressure and Angle Sensors with Optical Fiber for Instrumentation of the PrHand Hand Prosthesis**	Camilo Arturo Rodríguez Díaz
6691	**Development of tissue-mimicking phantoms for jaundice assessment device validation**	Fernando Sacilotto Crivellaro

16:30 - 17:50 - Parallel Sessions

Mo.1.c - Room S. Miguel - Chair(s): Justo Arines

6185	**Atmospheric Dispersion Correction for High-Resolution Spectrographs: Past, Present, and Future**	Bachar Wehbe
6411	**Comparison between the scanning pentaprism and the Hartman method for wavefront analysis**	Nuno Gonçalves
6509	**Imaging sensors for spacially resolved solar spectroscopy instrument**	Inês Leite
6513	**Characterization of Light Diffraction by a Digital Micromirror Device**	Cédric Pereira
6611	**Development of optical characterization and testing instrument for Sentinel-5 Earth Observation mission**	Juliana Kuhlmann Abrantes

Social Program

TUESDAY, JULY 19

8:55 - 9:40 - Plenary Session

Pl3 - Room Flores - Chair(s): Giulia Fulvia Mancini

6622 (Plenary)	**Topological Optical Clusters**	Humberto Michinel

9:45 - 10:45 - Parallel Sessions

Tu.1.a - Room Flores - Chair(s): Jorge Vieira

6555 (Keynote)	**Time-refraction and temporal optical processes**	Jose Tito Mendonca
6507	**Model Hamiltonians of open quantum optical systems: Evolvement from hermiticity to commutativity**	Konstantin Zloshchastiev
6803	**Investigation of cold atom turbulent dynamics through a spatially resolved pump-probe diagnostic.**	Ruggero Giampaoli

9:45 - 10:45 - Parallel Sessions

Tu.1.b - Room Sete Cidades - Chair(s): Joel Borges

5964 (Invited)	**Dots-in-Host Semiconductors for Improved Light Management**	Miguel Diogo Furtado Alexandre
6533 (Invited)	**Label-Free Multiparametric Analysis Using Photonic Crystal-Based Biosensors**	Galina Nifontova
6587	**Study of the impact on the absorption of III-V semiconductor nanopillars coated with dielectric-metal shells**	Joao Pedro Pinheiro Lourenço

9:45 - 10:45 - Parallel Sessions

Tu.1.c - Room S. Miguel - Chair(s): Sandra Franco

6530	**Synchronous and asynchronous 3D examination of the eye with a slit lamp**	Justo Arines
6529	**Teaching Optometry: setup for understanding the subjective refraction protocol and patient answers**	Justo Arines
6504	**A Pilot Outreach Program for Optics and Photonics: Develop the Advanced and Pioneering Concepts**	Haider M. Al-Juboori

Coffee Break

11:15 - 12:30 - Parallel Sessions

Tu.2.a - Room Flores - Chair(s): Mikhail Vasilevskiy

6592 (Keynote)	**Optical properties of low dimensional materials**	Pawel Hawrylak
6600 (Keynote)	**Superradiant optical shocks in arbitrarily diluted media**	Jorge Vieira
6656 (Invited)	**Reversible and non-reversible effects of silver nanoparticles on the photoluminescence properties of quantum emitters**	Victor Krivenkov

11:15 - 12:30 - Parallel Sessions

Tu.2.b - Room Sete Cidades - Chair(s): António Lobo

6567 (Keynote)	**Multi-wavelength optical phase unwrapping using low coherence Mirau interferometer**	Amalia Martínez-García
6488	**White light interferometer for Fabry-Perot cavities sensors with absolute physical measurement**	João Manuel Gonçalves Pereira dos Reis
6711	**A Low-cost Portable Interrogator for Dynamic Monitoring of Wavelength-Based Sensors**	Camilo Arturo Rodríguez Díaz
6715	**Development of a Low-Cost Interrogation System Using a MEMS Fabry-Pérot Tunable Filter**	João Carlos Costa Araújo

11:15 - 12:30 - Parallel Sessions

Tu.2.c - Room S. Miguel - Chair(s): Maria Teresa Flores-Arias

6701	**Single-cycle laser pulses through nonlinear pulse compression**	Mariana Silva
6606	**Pulse broadening and compression of visible spectral range laser in a Herriott cell**	Victor Hariton
6681 I(nvited)	**YCOB based ultrabroadband optical parametric amplification with a sub-picosecond pump source**	Hugo Pires
6486 (Invited)	**High contrast front-end for a petawatt laser system designed for electron acceleration and high intensity laser-matter applications towards advanced compact particle accelerators**	Mario Galletti

Lunch

14:25 - 15:55 - Parallel Sessions

Tu.3.a - Room Flores - Chair(s): António Baptista

6527 (Keynote)	**Engineering the pupil for wavefront masking**	Justo Arines
6709	**What is the impact of accommodative insufficiency on the optical quality of the eye?**	Jessica Rafaela Moreira Gomes
6528	**Low cost adherent lenses for presbyopia**	Justo Arines
6589	**Assessment of central and peripheral accommodative lag by aberrometry**	Kishor Sapkota
6479	**Comparison between central corneal thickness, anterior chamber depth and axial length values with and without contact lenses**	Hugo Pena-Verdeal

14:25 - 16:00 - Parallel Sessions

Tu.3.b - Room Sete Cidades - Chair(s): Elisabete Freitas

6744 (Keynote)	**Subaquatic laser induced plasma-assisted ablation for channels and wells fabrication on glass substrates**	Carmen Bao
6695 (Invited)	**Optimization of pulsed laser deposition process of superconducting YBa2Cu3O7-δ films**	Mohd Mustafa Awang Kechik
6828	**Optical, structural, morphological and chemical properties of doped TiO2 nanoparticles with FeCl3**	Cátia Juliana Pereira Afonso
6813	**Thermochromism applied to Transportation Engineering: asphalt roads and paints**	Orlando de Sousa Lima Júnior
6723	**Photocatalytic degradation of Malachite green using magnetic zinc and magnesium ferrite nanoparticles functionalized with silver under visible light irradiation**	Ricardo Jorge Cunha Fernandes

14:25 - 15:55 - Parallel Sessions

Tu.3.c - Room S. Miguel - Chair(s): Ana Rita Rodrigues

6837 (Keynote)	**Ultrafast spectroscopy of biomolecules in the ultraviolet range**	Rocío Borrego-Varillas
6607	**Assessment of lipid formulations to develop multi-stimuli-responsive solid magnetoliposomes using fluorescence-based methodologies**	Beatriz Dias Cardoso
6724	**Highly selective, compact and efficient vertical in-coupling for interferometric optical biosensors**	Ursula Fernanda Salazar Roggero
6734	**Development of an Escherichia coli optical biosensor with computational validation**	Alex Dante

16:00-17:30 - Poster Sessions & *Coffee Break*

Tu.T - Room Funchal - Chair(s): Manuel Filipe Costa | Iran Rocha Segundo *(max. poster size - A0)*

6696	**Design and simulation of 3D printed freeform optics elements**	Ana Rocha
6666	**Amorphous Silicon Photonic Integrated Circuit for beam steering in Lidar applications**	Alessandro Fantoni
6731	**Ocular accommodation and wavefront aberration in university students**	Alshaarawi M.A. Salem
6579	**Effect of accommodation on coma at central and peripheral retina**	Kishor Sapkota
6548	**Influence of absorptive tinted filter lenses on contrast sensitivity in healthy participants under three different environmental conditions**	Jacobo Garcia-Queiruga
6547	**Meibomian gland loss area and its relationship with eyelid margin hyperemia and MG orifice plugging**	Jacobo Garcia-Queiruga
6546	**Differences in the values of Anaglyphs, vectograms and cheiroscopes on participants with low, normal, and high AC/A ratio**	Hugo Pena-Verdeal
6545	**Comparison of three methods for measuring far and near vision heterophoria in free space**	Hugo Pena-Verdeal
6481	**Analysis of the Interferential Lipid Pattern change through 4 and 6 years in Dry Eye Disease patients**	Hugo Pena-Verdeal
6720	**Hyperspectral Colorimetry of in-vivo dental structures**	María de la Natividad Tejada Casado
6615	**Reservoir computing with nonlinear optical media**	Tiago David da Silva Ferreira
6732	**Detection of Acetic Acid Using a Balloon-type Optical Fibre Sensor**	Ana Isabel Freitas

6726	**Autonomous Optical Tweezers: from automatic trapping to single particle analysis**	Felipe Coelho Moreira Ribeiro Coutinho
6718	**Absorption and scattering coefficients in the 240-780nm range of daily disposable contact lenses**	Javier Ruiz López
6716	**Guiding losses estimation in hydrogel-based waveguides**	Juan Antonio Vallés
6708	**Noise analysis in self-interference incoherent digital holography**	Elena Stoykova
6689	**Thermoelectric imaging using photothermal radiometry of carriers, photoluminescence mapping in aged samples of GaAs:Sn**	Samuel Eligio Zambrano Rojas
6679	**Methods of optical fibre probes machining for holographic micro-endoscopy**	Miroslav Stibůrek
6651	**Integrating Laser induced breakdown spectroscopy and photogrammetry towards 3D element mapping**	Pedro Miguel Oliveira Rodrigues
6649	**Listening plasmas in Laser Induced Breakdown spectroscopy**	Rafael Anjo Cavaco
6644	**Multimodal approach to mineral identification: merging Laser induced breakdown spectroscopy with hyperspectral imaging**	Tomás José Moreira Lopes
6640	**Drying Patterns of Cerebrospinal Fluid as Indicator for Alzheimer's Disease by a Machine Learning Framework**	Laura Arévalo Díaz
6629	**Low-Cost Ultrafine Motion Control System Design for Nano Positioning and Beam Steering**	Gaurav Rajput
6628	**Color interferometry using the fractional Fourier transform**	Juan Manuel Vilardy Orrtiz
6627	**Real color fractional Fourier transform holograms using fiber optics**	Juan Manuel Vilardy Orrtiz
6621	**Towards real-time identification of trapped particles with UMAP-based classifiers**	Joana Magalhães B. Teixeira
6620	**Raman based DTS using a 1064 nm pump**	Joana dos Santos Saraiva Vieira
6612	**Robust calibration models for the mining industry: from spectral similarity to multimodal analysis**	Nuno Miguel Azevedo Silva
6572	**Nonlinear encryption for multiple images based on a joint transform correlator and the Gyrator transform**	Ronal A. Perez
6571	**Double image encryption system using a nonlinear joint transform correlator in the Fourier domain**	Ronal A. Perez
6570	**Convolution, correlation and generalized shift operations based on the Fresnel transform**	Juan Manuel Vilardy Orrtiz
6526	**Electricity generation from solar irradiation using the Seebeck effect**	Johonfri Mendonza Cantillo
6524	**Multiplexed holographic lenses applied to solar concentrators and passive solar trackers**	Eder Manuel Alfaro Alfaro
6490	**GUI-Based Phase Retrieval Algorithm for the Reconstruction of the Longitudinal Component of Electromagnetic Beams**	Marcos Aviñoá Pérez
6474	**Percentage estimate of the coffee seeds germination using processing of dynamic speckle images**	Juan Manuel Vilardy Orrtiz
6929	**Optical generation of surface plasmons in graphene with femtosecond laser pulses**	Rui Jorge Pinto DIas
6537	**Au-ZnO thin films: Influence of gold concentration and annealing on the microstructure and plasmonic response**	Patrícia Alexandra P. da Silva
6699	**Diffractive optical element fabrication at chalcogenide thin film surface**	Vadims Kolbjonoks
6557	**Hand grip strength using an FP sensor embedded in 3D printed cantilever**	Susana Novais
6488	**White light interferometer for Fabry-Perot cavities sensors with absolute physical measurement**	João Manuel G. Pereira dos Reis

6619	**Fabry-Perot cavity based on silica tube with steel for Physical parameters measurements**	Cristina do Carmo G. Cunha
6510	**Simulation and development of a prototype for high precision surface metrology**	Sílvia Rodrigues Costa
6508	**Development of plasmonic thin films for new biodetection approaches**	Diana Meira

Posters online

6690	**Ionisation of camphor molecule doped in helium nanodroplets by EUV and soft X-ray photons**	Sanket Sen
6700	**Effect of bandwidth on Two Plasmon decay instability**	Sonali Khanna
6697	**Electron spectrum and angular distribution from aerosol jet collimated by an aerodynamic lens**	Ravishankar Sugumar
6556	**Relativistic electron acceleration at non-relativistic intensities using sub-lambda targets**	Ratul Sabui

Social Program

WEDNESDAY, JULY 20

8:55 - 9:40 - Plenary Session

Pl4 - Room Flores - Chair(s): Sandra Franco

6500 (Plenary)	**Peripheral optics in the eye: from myopia to cataracts**	Pablo Artal

9:45 - 10:45 - Parallel Sessions

We.1.a - Room Flores - Chair(s): António Baptista

5998 (Keynote)	**Some recent advances in color science**	Manuel Melgosa
6721	**Color prediction of monolithic and layered dental resin composites of varying thicknesses**	María de la Natividad Tejada Casado
6717	**Effect of thickness and printing angle on color of 3D printing dental restorative polymer-based materials.**	Javier Ruiz López

9:45 - 10:45 - Parallel Sessions

We.1.b - Room Sete Cidades - Chair(s): Paulo Tavares

6713 (Keynote)	**Standardization of Diffractive Optical Surfaces**	Michael Pfeffer
6601 (Invited)	**Optical design for Sport Optics**	João Tiago Costa Silva

9:45 - 10:45 - Parallel Sessions

We.1.c - Room S. Miguel - Chair(s): Jorge Vieira

6860 (Keynote)	**Photon bubble turbulence in cold atomic gases: astrophysics in the lab**	Hugo Terças
6616	**Experimental turbulent states with paraxial fluids of light in photorefractive media**	Tiago David da Silva Ferreira
6047	**Expansion Dynamic and Characterization of Stagnation Layer in Laterally Colliding Plasmas: Dependence of Observation Bandwidth and Plasma Plume Separation**	Haider M. Al-Juboori

Coffee Break

11:15 - 12:15 - Parallel Sessions

We.2.a - Room Flores - Chair(s): Nuno Azevedo Silva

6817 (Keynote)	**On the total estimation of the electromagnetic field in the focal area with no interaction with the media**	David Maluenda Niubó
6632	**Contribution to the improvement of the correlation filter method modal analysis with a spatial light modulator**	David Benedicto Baselga
6056	**Design concepts of a new imaging system for a high-intensity XUV source beam by colour centres excitation in lithium fluoride crystals**	Haider M. Al-Juboori

11:15 - 12:30 - Parallel Sessions

We.2.b - Room Sete Cidades - Chair(s): Susana Novais

6685	**Rubber vulcanization method for FBG pressure sensors**	Camilo Arturo Rodríguez Díaz
6722	**A FBG based sensor for horizontal displacement measurements of a small scale tailing dam model.**	Willian Lima de Oliveira Filho
6950	**Fatigue crack growth monitoring using Electronic Speckle Pattern Interferometry**	Frederico Preto Direito
6704	**Innovative hybrid optical sensing design to simultaneously discrimination of pressure and temperature**	Fábio Henrique Baptista de Freitas
6682	**A Fiber Bragg Grating based Accelerometer for Monitoring the Vibration of an Industrial Engine Prototype: A Preliminary Study**	Camilo Arturo Rodríguez Díaz

11:15 - 12:30 - Parallel Sessions

We.2.c - Room S. Miguel - Chair(s): José António Rodrigues

6725 (Invited)	**Azobenzene based on-fiber waveplates for polarization control**	Paulo António M. F. Ribeiro
6593	**Optimal filtering of measured Mueller matrices using full Poincaré polarimetry**	Juan Carlos Suárez-Bermejo
6591	**Estimation of Zernike polynomials for a highly focused electromagnetic field using polarimetric mapping images and neural networks**	Kavan Ahmadi
6968	**The development of test station to characterize the capabilities of emission of LiDAR**	Nelssom Fernandez da Cunha
6523	**Implementation of a Scheimpflug Lidar for Assessment of Native Aerofauna in Tropical Forests in Ecuador**	Cesar Costa-Vera

Lunch

Social Program

THURSDAY, JULY 21

10:10 - 11:15 - Parallel Sessions

Th.1.a - Room Flores - Chair(s): Bruno Romeira

(Keynote)	**To be announced**	Bert Offrein
6531 (Invited)	**Neural network computing with large-area lasers**	Xavier Porte
6774	**Photonic Neuromorphic Computing with Vertical Cavity Surface Emitting Lasers**	Antonio Hurtado

10:10 - 11:10 - Parallel Sessions

Th.1.b - Room Sete Cidades - Chair(s): Amalia Martínez-García

6584	**Dynamic speckle Imaging with SVD compression**	Mikhail Levchenko
6512	**Data Augmentation in 3D Object Detection for self-driving vehicles: the role of original and augmented training samples**	Xavier Santos
6145	**Intrinsic temperature-compensated fibre optic current/ magnetic sensor**	Paulo Robalinho
4733	**Considerations involving the determination of the band gap energy by diffuse reflectance spectroscopy**	Iran Gomes da Rocha Segundo

Coffee Break

11:15 - 12:30 - Parallel Sessions

Th.2.a - Room Flores - Chair(s): Ana Rocha

6578	**Coupled two-cores integrated waveguides modal analysis**	David Benedicto Baselga
6661	**Analysis of power transfer between two multi-core fibers with long-period gratings**	Liliana Mendes Sousa
6564	**Indoor Guidance of Automated Guided Using Visible Light Communication**	Paula Maria Garcia Louro
6544	**Cooperative Traffic Control using Visible Light Communication**	Manuel Augusto Vieira
6532	**Visible Light Communication-based Indoor Navigation for Mobile Users in Large Buildings**	Manuela Vieira

11:15 - 12:35 - Parallel Sessions

Th.2.b - Room Sete Cidades - Chair(s): José Manuel Baptista

6804 (Keynote)	**Photonic tools for single cell analysis**	Pedro Alberto da Silva Jorge
6650 (Invited)	**Generation of high-frequency photoacoustic pulses to enhance skin permeation of active molecules**	Celso Paiva João
6730	**Multifunctional liposomes containing magnetic and gold nanoparticles for cancer therapy**	Mélanie R. Pereira (Ana Rita Oliveira Rodrigues)
6641	**Detection of Alzheimer's by Machine Learning-assisted Vibrational Spectroscopy in Human Cerebrospinal Fluid**	Laura Arévalo Díaz

11:15 - 12:30 - Parallel Sessions

Th.2.c - Room S. Miguel - Chair(s): Bruno Romeira

6693 (Keynote)	**Insect-Brain inspired Neuromorphic Nanophotonics**	Anders Mikkelsen
6610 (Invited)	**Dendritic-like computation using multimode optical fibers**	Miguel C. Soriano
6586 (Invited)	**High-speed Silicon Photonic neuromorphic computing enabled by hardware-aware deep learning methods**	Miltiadis Moralis-Pegios
6636	**Optical Computing with Extreme Learning Machines**	Nuno Miguel Azevedo Silva

Lunch

14:25 - 15:10 - Plenary Session

Pl5 - Room Flores - Chair(s): Humberto Michinel

6568 (Plenary)	**Ultrafast ptychography: from tabletop HHG to Free Electron Lasers**	Giulia Fulvia Mancini

15:15 - 16:30 - Parallel Sessions

Th.3.a - Room Flores - Chair(s): Paulo Ribeiro

7071 (Keynote)	**Ultra-fast Laser-induced Molecular Dissociations on Plasmonic Nanoparticles Driven by Tailored Optical Fields: Mass Spectrometric Evaluations**	Cesar Costa-Vera
6660	**Hollow square core fiber sensor for physical parameters measurement**	Diana Sofia Antunes Pereira
6735	**Silicon Nitride Interferometers for Optical Sensing with Multi-micron Dimensions**	João Costa
6733	**Fiber Loop Mirror temperature sensor interrogated with different techniques**	António Vaz Rodrigues
6522	**Plasmonic and Thermal Properties of Nanostructured Systems Probed with Low-cost Optical Setups**	Cesar Costa-Vera

15:15 - 16:30 - Parallel Sessions

Th.3.b - Room Sete Cidades - Chair(s): Rogério Nogueira

6465 (Keynote)	**Highly Sensitive Plasmonic Sensors and Biosensors realized via Polymer Waveguides**	Nunzio Cennamo
6551 (Keynote)	**Improving plasmonic sensing with suspended core fibres and metallic nanostructured inclusions**	José Manuel Baptista
6639	**Strongly coupled plasmonic systems on optical fiber sensors**	Paulo Sérgio Soares dos Santos

15:15 - 16:30 - Parallel Sessions

Th.3.c - Room S. Miguel - Chair(s): José Figueiredo

6740 (Keynote)	**Room-Temperature Electroluminescence in RTDs: Towards a Universal Model**	Elliot R Brown
6574	**Dual-functioning emitter-receiver III-V unipolar and bipolar microLEDs for on-chip neuromorphic photonic circuits**	Bejoys Jacob
6625	**Resonant Tunnelling Diode – Photodetectors for spiking neural networks**	Joao Pedro Pinheiro Lourenço
6692	**Towards spiking laser diodes on a III-V/Si nanophotonic platform for neuromorphic applications**	Ekaterina Malysheva

Coffee Break

17:00 - 18:30 - Parallel Sessions

Th.4.a - Room Flores - Chair(s): Pedro Jorge

6953 (Keynote)	**Optical nanoantennas: from sensing to killing cancer**	Pablo Albella Echave
6667 (Keynote)	**Au nanoparticles/semi-conductor thin film prepared by laser annealing and sol-gel**	Olivier Soppera
6727	**Plasmonic/magnetic liposomes based on nanoparticles with multicore-shell architecture for chemo/thermotherapy**	Ana Rita Oliveira Rodrigues

17:00 - 18:00 - Parallel Sessions

Th.4.b - Room Sete Cidades - Chair(s): Orlando Frazão

6535	**Gas detection with high-resolution LSPR spectroscopy**	Maria Manuela Carvalho Proença
6714	**Photonic Crystal Design for Bloch Surface Wave Sensing**	Bernardo Santos Dias
6673	**Advanced refractive index sensor using 3-dimensional metamaterial based nano antenna array**	Sneha Verma
3724	**Humidity and touch sensing by capacitive-type sensors obtained by electrochemical anodization**	Iran Rocha Segundo
7103	**25G Receiver and Analysis of Filters Frequency Response**	Adebayo Abejide

17:00 - 18:30 - Parallel Sessions

Th.4.c - Room S. Miguel - Chair(s): José Figueiredo

6613 (Keynote)	**Brain-inspired nanophotonic spike computing**	Bruno Miguel Patarata
(Keynote)	**To be announced**	Edward Wasige
6706	**Two-photon polymerization simulation and fabrication of 3D microprinted suspended waveguides for on-chip optical interconnects**	Artur Andrishak
6671	**Subwavelength structures for taper waveguides**	Paulo Lourenço
6623	**MMI Splitters and Combiners for Multi-Micron Amorphous Silicon Nitride Rib Waveguides**	Daniel Gonçalves Pita Santos de Almeida

FRIDAY, JULY 22

9:45 - 11:00 - Parallel Sessions

Fr.1.a - Room Flores - Chair(s): Pedro Jorge | Beatriz Dias Cardoso

6654 (Keynote)	**Molecularly imprinted nanoparticles: plastic antibodies for optical sensing platforms.**	Alessandra Maria Bossi
7135 (Keynote)	**Nanoscopy, Metabolic Imaging and Intracellular Sensing based on Nanophotonics and Nonlinear Microscopy**	Jana Nieder
6536	**Dehydropeptide-based plasmonic lipogels as bionanosystems for controlled drug release**	Sérgio Rafael da Silva Veloso
6659	**Nanoscale distance sensing using fluorescently-labelled DNA origami tetrahedra on Graphene**	João Duarte Gonçalves Azevedo
6729	**Development of pH-sensitive magnetoliposomes containing shape anisotropic magnetic nanoparticles for applications in dual cancer therapy**	Ana Rita F. Pacheco

9:45 - 11:20 - Parallel Sessions

Fr.1.b - Room Sete Cidades - Chair(s): Susana Silva | Orlando Frazão

6561 (Invited)	**Optical harmonic Vernier effect: properties and applications**	André Rodrigues Delgado Coelho Gomes
6684	**Optofluidic fibre sensor for the real-time measurement of refractive index**	João Micael da Silva Leça
6657	**Simultaneous measurement of displacement and temperature using balloon-like hybrid fiber sensor**	João Pedro Fidalgo Santos
6712	**Characterization of a D-shaped photonic crystal fiber with two silver-Al2O3 nanowire metamaterial layers**	Amanda de Freitas Romeiro
6703	**Optical fiber sensor based on balloon-like interferometer structure and 3D printer for displacement sensing**	Victor Henrique R. Cardoso
6710	**Evaluation of the orientation impact in thermal behavior of cylindrical Li-ion batteries in different cycling conditions using FBG sensors**	Lucca de Carvalho Matuck

9:45 - 11:20 - Parallel Sessions

Fr.1.c - Room S. Miguel - Chair(s): Mohd M. Awang Kechik | Paulo Ribeiro

6694 (Invited)	**Magneto-piezoresistance in magnetorheological elastomer for low range conductive feedback**	Muhammad Kashfi Bin Shabdin
6705	**Investigation on the operation modes of optoelectronic oscillators based on resonant tunnelling diodes**	Tiago Colaço S. da Franca Ferro
6516	**Optimizations of Si PIN Diode Phase-Shifter Combined with RC Equalizer Under Forward Biasing**	Dror Malka
6174	**Impact of Sm on microstructure and Faraday magneto-optical effects of transparent Y2O3 ceramics**	Andrzej Kruk
6662	**Optical Fiber Sensors for Monitoring Cement Paste Carbonation**	Pedro Miguel Madeira da Silva
6830	**Reducing the sunlight impacts in urban areas using asphalt mixtures with phase change materials: a review in Scopus in the last 3 years**	Iran Gomes da Rocha Segundo

Awards and Closing Ceremony 11:25-12:30

Abstracts

Trends in Optical Coherence Tomography

Adrian Podoleanu

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Abstract. The number of publications on optical coherence tomography (OCT) continues to evolve and OCT applications in the eye imaging still dominate the field [1].

The presentation will review technical perspectives of recent developments in optical sources, scanning, tracking and signal processing that with further refinements can be translated to better imaging relevant to medical imaging, biosciences and non destructive testing. The modern OCT technology for ophthalmology relies on spectral (Fourier)-domain OCT. I will introduce an OCT method that radically changes the operation of such technology, where the Fourier transform or equivalent is replaced by multiple electrical processing, with a processor for each optical path difference (OPD) in the sample investigated [2]. This opens opportunities to parallel processing, especially useful for ultra fast tuning lasers in swept source OCT configurations. To this end, I will present recent research on two technologies for ultra fast tuning lasers for fast acquisition of OCT data: dispersive cavity with dual resonanc and time stretch configurations. These are akinetic solutions that promise to extend the sweeping rate of the optical frequency into the multi MHz range.

Keywords: optical coherence tomography, swept sources, broadband sources, 3D imaging, depth resolved imaging

Acknowledgements: The author acknowledges the support of the Marie Curie Training ITN NETLAS-860807, of the Biotechnology and Biological Sciences Research Council (BBSRC) (5DHiResE project, grant number BB/S016643/1) and the National Institute for Health Research (NIHR) Biomedical Research Centre at the UCL Institute of Ophthalmology and Moorfields Eye Hospital NHS Foundation Trust/Grant BRC03, as well as the Royal Society Wolfson Research merit award.

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[1] A. Gh. Podoleanu, Optical coherence tomography, Journal of Microscopy, 247 (3) 209-219, (2012), 1. DOI: 10.1111/j.1365-2818.2012.03619.x

[2] A. Gh. Podoleanu, A. Bradu, Master–slave interferometry for parallel spectral domain interferometry sensing and versatile 3D optical coherence tomography, Opt. Express 21, 19324-19338 (2013, http://dx.doi.org/10.1364/OE.21.019324.

The role of the laser technologies on the fabrication of organ-on-a-chip devices.

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Abstract. Organ-on-a-chip devices play an important role in preclinical studies to study several diseases in controlled laboratory in-vitro conditions that mimics the characteristic of the real situations, reducing the animal experimentation [1]. The capability of fabrication such a device plays an important role in the understanding of different pathologies. These devices need to be biocompatible, so it is mandatory to take attention on the material used as well as its roughness [2]
Laser technologies have emerged in the last decades as a very powerful tool for fabricating different devices. Their versatility to fabricate accurately devices in a wide range of dimensions, the speed of the process as well as the non-contact nature and the non-contaminant properties of the process, have made stand out laser writing among other techniques.
This work presents the potential to fabricate preclinical devices in particular, vessels-like in vitro models with lasers working in pulsed regimes. According to the parameters and the pulse regime of the laser used, we will provide devices with different features (see figure 1).

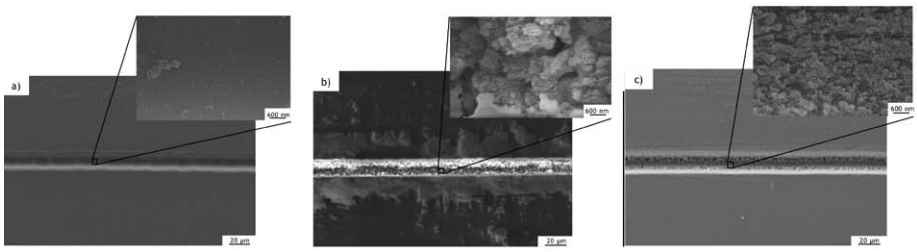

Figure 1. SEM images of a simple channel fabricated with a) nanosecond; b) picosecond and c) femtosecond pulsed laser. Enlarged view show the roughness of the bottom of the channels.

Keywords: pulsed lasers, microfluidic, organ-on-a-chip, preclinical studies, laser ablation

Acknowledgements: It has been partially supported by "Agencia Estatal de Investigación, Ministerio de Economía y Competitividad" (Spain) under contract RTI2018-097063-B-100 and the Consellería de Educación Xunta de Galicia/FEDER (ED431B 2020/29 UE)

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[1] Y. Temiz, R. D. Lovchik, G. V. Kaigala, and E. Delamarche, "Lab-on-a-chip devices: How to close and plug the lab?," Microelectron. Eng. 132, 156-175 (2015).
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A touch of symmetry: High-harmonic generation from low-dimensional crystals.

Luis Plaja

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Abstract. The advent of intense laser sources a few decades ago triggered an intense research on non-perturbative laser-light interactions. One of the most spectacular developments in the field is the discovery of high-harmonic generation (HHG), stemming from the extreme nonlinear interaction. Until recently, HHG has been mainly studied in atomic, molecular gases and plasmas. The experimental demonstration a decade ago of HHG in solids [1] sparkled the interest in the study of the non-perturbative optical phenomena in crystalline solids. Due to their higher electron density, an obvious advantage of solids is the increased efficiency of the process. However, damage thresholds are lower and, therefore, limit the maximum intensity of the driving. This situation is partially amended with the use of mid-infrared drivers that, on one side reduce the intraband carrier excitation and, on the other, introduce higher ponderomotive energies, therefore entering the strong-field regime with lower intensities. One interesting aspect in HHG from crystalline targets is to study the consequences of the crystal symmetries. In this sense, low dimensional crystals offer an extraordinary scenario, as their narrow widths (typically of atomic size) exclude propagation phenomena that may obscure relevant phenomena. In this talk we shall focus on HHG characteristics derived from the crystal-periodic nature of the targets: the translation of well-known coherent optics phenomena, as the Talbot interference, to the nanoscopic ultrasfast realm [2], and the consequences of the recently studied optical nonlinear anisotropy in graphene [3,4], for the generation of structured harmonic light driven with optical vector beams.

Keywords: High-order harmonic generation, solids, Talbot, structured light, graphene.

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Towards 5-cycle, multi-mJ-level mid-IR capability at the L2I

Joana Alves [1,*], Hugo Pires [1], Celso P. João [1,2], and Gonçalo Figueira [1]

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Abstract. Ultrafast and broadband laser sources in the mid-IR spectral domain (2–10 μm) have become highly sought after in the last decade [1]. The interest in these sources is greatly due to the scaling dependence of the ponderomotive potential with $\sim\lambda^2$, evidencing the extension of the cut-off photon energy with the increase in the driving wavelength [2]. Most of the current mid-IR sources in this wavelength range operate at high (50–100 kHz or above) repetition rates and high stability. Although these characteristics are ideal for the research of processes with low cross-sections, energies below the mJ-level are not optimal for driving low-efficiency processes, such as soft X-ray high harmonic generation and for efficient laser wakefield acceleration, making the scaling in the energy of the mid-IR pulses a highly promising and rewarding challenge. Scaling of the ~50 μJ, ~50 fs, ~GW output pulses typically provided by the systems in the first group above by almost 2 orders of magnitude is not trivial. The most efficient approach is through an optical parametric chirped-pulse amplifier (OPCPA) and the use of an energetic pump source synchronized with the seed. In this work, we show the design of a 3 μm ultrafast OPCPA with 5-optical-cycles and 5-mJ capability being implemented at the L2I. This system is pumped by a Yb:YAG multipass amplifier with sub-picosecond Fourier transform-limited (FTL) duration and 100 mJ output energy [3]. This configuration is supported by previously performed numerical amplification and compression studies [4]. Here we address the critical steps for the successful implementation of the system and the main challenges for high-energy few-cycle 3 μm amplification and compression.

Keywords: Mid-Infrared; Ultrafast Lasers; Parametric Amplification; Nonlinear Optics; Materials.

Acknowledgements: This project has received funding from Fundação para a Ciência e Tecnologia under grant PD/BD/135177/2017 and Laserlab Portugal (National Roadmap of Research Infrastructures, PINFRA/22124/2016); European Union's Horizon 2020 research and innovation programme under grant agreement no. 871124 (Laserlab-Europe); it is carried out in the framework of the Advanced Program in Plasma Science and Engineering (sponsored by Fundação para a Ciência e Tecnologia under grant No. PD/00505/2012) at Instituto Superior Técnico.

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Scanning the flying focus of a tabletop vortex EUV beam

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Abstract. The ability to control the properties of light beams has enabled the appearance of multiple technologies. In recent years the study of the manipulation of orbital angular momentum (OAM) of light has been an exciting topic of research. There are many promising applications in various fields using different light wavelengths from visible to x-rays, and even promising applications in plasma accelerators [1].

In the particular case of extreme ultraviolet (EUV) light, one of the most promising applications is the generation of skyrmionic defects, which have been proposed for future magnetic memory devices [2]. Among the many different EUV sources available, high harmonic generation (HHG) in gases is an accessible, tabletop way to generate coherent EUV light with attosecond resolution.

In this work, we obtained high spatial resolution images of OAMs induced in a HHG EUV beam by using Spiral Zone Plates (SZP) [3] of different angular momentum - l. We scanned the beam near the focus of each one of the generated harmonics and recorded each beam profile with a lithium fluoride (LiF) crystal, a well characterised x-ray and EUV detector [4].

Keywords: Spiral Zone Plates, EUV optics, Orbital Angular Momentum, High Harmonics Generation

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Various routes for VIS-to-UVC upconverted emission enhancement in lanthanide-doped nanoparticles

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Up-conversion is an anti-Stokes optical process of a few low-energy photons sequential absorption resulting in one high-energy photon emission, which was reported for the first time by F. Auzel in 1966 in Yb^{3+},Er^{3+}-doped phosphate glasses. [1] After that, the possibility of efficient generation of upconverted emission has been widely investigated for various host matrices doped with lanthanides, since they are renowned for their rich energy level structure, allowing to generate radiation at any desired wavelength. [2] The process gained particular interest as the first upconverting nanostructures emerged in the late 1990s, which was a turning point for *in situ* light generation in prospective biomedical applications, e.g. antimicrobial inactivation or cancer treatment. [3]

Known for its invaluable germicidal properties, UV radiation (100-380 nm) can be induced *via* upconversion process in Tm^{3+}, Gd^{3+} or Pr^{3+}-ions doped nanomaterials. It is possible to be done in two ways, either upon visible radiation excitation, or upon energy transfer from sensitizer ions (e.g. Yb^{3+} or Nd^{3+}) excited with NIR photons to the UV emitting lanthanide ion. [4] However, the efficiency of both processes is relatively low. [5] Therefore, in our work we decided to investigate several routes for enhancing UV emission generated within alkaline-earth yttrium fluoride nanoparticles *via* upconversion process. The experimental part is focused on nanoparticles co-doped with transitions metal ions (Fe^{3+}, Mn^{2+}) and various core-shell nanoarchitectures. The data gathered in the study are highly significant for development of efficient UV emitting nanoparticles for bio-related applications.

Keywords: lanthanides, nanoparticles, UVC radiation, upconversion

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Plasmonic/magnetic liposomes based on nanoparticles with multicore-shell architecture for chemo/thermotherapy

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Abstract. Multifunctional liposomes containing magnetic and plasmonic nanoparticles (magnetic/plasmonic liposomes) are promising nanosystems for cancer therapy. Their structural and physical properties enable a synergistic effect between dual hyperthermia (magneto-photothermia) and local chemotherapy, allowing overheating of cancer cells while increasing drug toxicity [1,2].

In this work, multicore magnetic nanoparticles (NPs) of manganese ferrite were prepared using carboxymethyl-dextran and melamine as agglutinating agents. The NPs prepared exhibit a flower-shape structure and good capabilities for magnetic hyperthermia. Magnetoliposome-like structures containing the multicore NPs exhibit sizes in the range 250 – 400 nm, being suitable for biomedical applications. A new antitumor thienopyridine derivative was loaded in these nanocarriers with a high encapsulation efficiency. The stability of the nanosystem was confirmed, pointing to suitable characteristics of the magnetoliposomes for dual cancer therapy (combined hyperthermia and chemotherapy).

Keywords: magnetic nanoparticles, plasmonic nanoparticles, multicore-shell nanostructures, magnetic hyperthermia, combination therapy

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Manganese ferrite nanoparticle clusters covered with gold nanorods for application in cancer phototherapy

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Abstract. Recently, hybrid nanosystems combining various materials (organic and inorganic) have been developed for the treatment and/or diagnosis of cancer. Among these, photothermal agents have attracted much attention [1]. They can be used in cancer therapy by converting light into heat under NIR laser irradiation, resulting in thermal destruction of cancer cells at tumor sites. Magnetic nanoparticles (MNPs) are also promising agents for cancer therapy, allowing magnetic hyperthermia. Among these, manganese ferrite nanoparticles ($MnFe_2O_4$) stand out for their biocompatibility and magnetic properties when compared to other types of MNPs (e.g. cobalt ferrite, magnetite and nickel ferrite) [2].

Magnetic clusters (MCs) of $MnFe_2O_4$, when surface-functionalized, were shown to be stable against aggregation in model biological fluids and are thus prospective materials for biomedical applications. Further, MCs are known to have better magnetic hyperthermia performance than isolated MNPs [3].

In this work, $MnFe_2O_4$ nanoparticles were synthesized by thermal decomposition. Clusters of these nanoparticles were obtained and covered with gold nanorods. The photothermal capacity of these two types of materials was evaluated separately and for the magnetic/plasmonic nanosystems, aiming to explore in future the synergistic effect between magnetic hyperthermia and photothermia in cancer therapy.

Keywords: magnetic nanoparticles, gold nanorods, clusters, phototherapy, cancer treatment

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Fiber optic sensor for real time monitoring of cryosurgery depth

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Abstract. Cryosurgery is the localized freezing of tissue to remove pathological lesions. It utilizes local fast cooling to extremely low temperatures, followed by a slower thawing process. The technique results in local destruction of cells where long-term inflammation of tissue, due to cryo-injury, triggers an immune response which can last for longer periods.[1,2] It is important to monitor in real-time the freezing depth which currently is not routinely possible and relies on subjective "expert knowledge". Here, we report the use of a fiber optic array sensor, which exploits the optical scattering, and diffusion properties of frozen-unfrozen tissues in cadaver porcine (pig) skin samples, during freezing-thawing cycles to demonstrate a proof-of-principle method to monitor the depth of the frozen region in real time. Furthermore, a preliminary spectral analysis study was conducted on volunteers to investigate the spectral variations of the throwing phase of the cryotherapy procedure.

During freezing, the changes to the optical properties in tissue are related to variations in blood spectral absorption and Mie backscattering which increases as the tissue freezes due to the formation of micro-bobbles and micro-crystals in intercellular fluids [3,4]. Using a fiber array sensor backscatter light was transmitted from the affected area to a detection system, which measured the intensity from each individual fiber. The system was calibrated, by correlating the transmitted to backscattered intensities for different depths of the illumination fiber in ex-vivo porcine skin. The optical depth measurements of the frozen/unfrozen boundary were measured independently with a dermatological ultrasonic probe giving very similar results to a maximum detection depth of 1.4 mm, and a resolution of 0.1 mm. In figure 2 the high intensity corresponding to the frozen tissue reduces during thawing. Additionally, the deferential spectral variation is shown superimposed in the second Figure indicating that spectral variations are primarily related to blood flow alterations.

Keywords: Fiber optic sensors. dermatology, cryosurgery

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Pressure and Angle Sensors with Optical Fiber for Instrumentation of the PrHand Hand Prosthesis

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Abstract. The principal cause of upper limb amputations is related to traumatism (77 %), followed by congenital disorders (8,9 %), cancer (8,2 %), and vascular diseases (5,8%); the last 0,1 % is by unknowledge causes. The prosthesis is an assistive device to help in the activities of daily for the amputee person. However, one of the latest reports shows that in developing countries there are around 30 million people without assistive devices. The PrHand is a hand prosthesis based on soft robotics and complaint mechanisms. It has elastics joints that make fingers extend with an internal elastic tendon, and the finger flexion is performed by one servomotor. The fingers are based on a complaint mechanism that allows having the degrees of freedom (DOF) of flexion, extension, abduction, and adduction; for the two last ones, aircontrolled silicone actuators are used. Additionally, the prosthesis is underacted because it can control up to 15 DOF with one motor and one pump air. This work presents the development of two kinds of sensors for the PrHand prosthesis instrumentation. The sensors are made with polymeric optical fiber (POF), due to its flexibility and low cost, and the working principle is based on intensity variation. The curvature deformations in the fiber and the pressure are going to be represented as voltage changes. The angle sensors are anchored on the fingers and are used for monitoring the interphalangeal joint. For the assessment six opening and closing cycles were made per finger. For the voltage lecture was used a microcontroller and for the measurement of the angle the Kinovea software was used. Regarding force sensors, they are located at the tip of each finger, and for the evaluation was used a compression device that controls the force. As reference was used a strain gauge sensor and the data was taken each 0.5 kg from 0 to 3 kg, considering that in a mechanical study made over the prosthesis 3 kg is the maximum force that the prosthesis can make over an object. For the results were taken the characteristics curves of the sensors, and both show a linear behavior, one most remarkable angle sensor result was with an R^2 of 0,99 and a sensibility of 0,0357 V/° closing and 0,0483 V/° opening. On the other hand, for the force sensor, the most notable result has an R^2 of 0,98, its sensibility was 0,0361 V/N pushing and 0,0368 V/N pulling. In conclusion, was successfully developed two kinds of sensors for the instrumentation of PrHand prosthesis. It is expected to use these variables with algorithms of Machine Learning to improve the detection of objects. One aspect to improve is to control in a better way the sensor construction parameters due to the big influence over the sensor behavior.

Development of tissue-mimicking phantoms for jaundice assessment device validation

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Abstract. The increasing of vital signs continuous monitoring, optically harvested from the skin, have been driven by the wearable devices expansion and the healthcare smart mobile evolution. The context of social restrictions of recently pandemic world scenarios [1] or even the acute hepatitis outbreak, are situations where optical non-invasive skin sensors can play a very important role, improving health services access, efficiency and quality. One important application is the jaundice level assessment in newborn babies. They are routinely monitored for at least for 48h after birth due to the possibility of evolution to critical encephalopathies. For this case, non-invasive optical hand-held sensors called transcutaneous bilirubinometers are commonly used for baby screening [2].

The research and development of these sensors must be supported by tissue-mimicking phantoms, for validation, optimization, calibration, stability and quantitative studies. In the case of human skin, the main chromophores in the optical visible range are melanin, haemoglobin and bilirubin, with specific absorption characteristics. For example, the skin tones are related to variations on the melanin concentration at epidermis, as well as distinct jaundice levels are associated with bilirubin concentration on dermis and subcutaneous tissue. Therefore, reflectance measurements from optoelectronic devices, as the bilirubinometers, can be validated or calibrated by a set of phantoms corresponding to a representative and diverse skin group.

In this work, in order to allow the calibration and validation of optical devices over real sensing situations, there were developed phantoms for 3 skin tones: light, medium and dark. The melanin chromophore was mimicked by managing nigrosin and Intralipid concentration in an agarose substrate. For each skin tone category there were reproduced 4 distinct jaundice levels through the management of bilirubin concentration. The phantoms were evaluated in the visible spectrum through reflectance spectroscopy and compared to different skin databases. The obtained results confirm the qualification of the phantoms for performance analysis of optical reflectance based devices towards jaundice level assessment.

Keywords: Skin, Bilirubin, Melanin, Phantom, Reflectance

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Atmospheric Dispersion Correction for High-Resolution Spectrographs: Past, Present, and Future

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Abstract. Astronomical observations with ground-based telescopes are affected by differential atmospheric dispersion, a consequence of the wavelength-dependent index of refraction of the atmosphere. In high-resolution astronomical instruments, an Atmospheric Dispersion Corrector (ADC) is mandatory to avoid wavelength-dependent losses. The recent developments in the field of Adaptive Optics (AO) systems, improving considerably the performance of telescope resolution, and the arrival of large telescopes with diameters up to 40 m, reinforce the need to revisit the way differential atmospheric dispersion is corrected and how it influences the performance of high-resolution spectrographs. To reach the top-level specifications in the new state-of-the-art astronomical instruments, it is crucial to tackle all the instrumentation-related challenges, in particular the ones related to atmospheric dispersion. The main requirements for an atmospheric dispersion corrector are to perform variable counter dispersion to compensate for that of the atmosphere at a given zenithal angle and to produce zero deviation at a reference wavelength, within the range of interest for all zenithal angles. In this paper, we will highlight the past, and focus on the present, and future of atmospheric dispersion correction mainly driven by the scientific and technical requirements.

Keywords: atmospheric dispersion correctors; atmospheric optics; dispersion; spectrographs

Comparison between the scanning pentaprism and the Hartman method for wavefront analysis

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Abstract. Techniques for wavefront measurement have many applications as optics systems for astronomy and also as verification tests for optical surfaces. The development of large aperture optical systems drives the search for low cost and high-resolution wavefront detection sensors. The Hartman sensor and its variations (i,e the Shack-Hartman sensor) are the current standards for the characterization of low-frequency optical aberrations, such as defocus and spherical.

The scanning pentaprism method is presented as a simple and low-cost method for the verification of such aberrations. In this method, a transverse slice of a wavefront is scanned and separated into a series of sub-wavefronts with smaller apertures. The relative positions of the produced centroids are measured relative to a calibrated position. This allows for the determination of the optical path difference along the slice and consequently the wavefront error. Both techniques were used as tools for collimating a telescope that is part of the on- ground support equipment of ESA PLATO mission. In this work, the results from both methodologies are compared.

Keywords: wavefront, Hartman sensor, scanning pentaprism, PLATO

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Imaging sensors for spacially resolved solar spectroscopy instrument

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Abstract. The study of the Sun is an area still open in several topics of astrophysics, in a field that has seen an expansion in recent years – therefore, it is critical that collected data is thoroughly traceable and accurate to be used in new study cases or predictive models. A ground-based, portable, optimized system, consisting of a Schmidt-Cassegrain telescope coupled to a refractor telescope acting as a pointing telescope, is being designed to provide high resolution imaging of smaller areas on the Sun's surface, being able to obtain disk-resolved, high spectral resolution data, at a relative low cost (compared to large consortium developed instruments[1][2]). The light collected by the telescope will be fibre-fed to a spectrograph – the injection of light in the fibre is critical and requires an imaging sensor to aid the light guiding process. The goal of the present work was to explore the best candidates for the image sensors, their architectures, requirements, and constraints, as well as their expected performance range and signal noise – the distinction between CMOS and CCD based sensors was also made.

Keywords: instrumentation, sun, telescope, solar observations, solar spectroscopy

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Characterization of Light Diffraction by a Digital Micromirror Device

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Abstract. A Digital Micromirror Device (DMD) is a technology developed by Texas Instruments, that consists in a two-dimensional array of micromirrors, which can be individually tilted between two positions. It has been used as a digital video and image processing solution, commonly found in Digital Light Processing (DLP) video projectors. Over the years, DMDs have become popular in different fields: industrial, automotive, medical, government and home user solutions. In the astronomy field, it has been also considered in on-ground space instrumentation and it has been proposed for the development of some astrophysical space instruments. In order to evaluate the actual impact of such device in the instrument optical design, it is important to know how the light behaves when it interacts with a DMD, namely in what regards to the diffraction process when a light beam is reflected by a periodic array of micromirrors. In this study we describe how we simulate the diffraction patterns produced by a periodic array of micromirrors, for coherent and incoherent sources of light. The results from simulations are verified against laboratory experiments, described also in this study.

Keywords: instrumentation, diffraction, digital micromirror device

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Development of optical characterization and testing instrument for Sentinel-5 Earth Observation mission

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Abstract. This paper reports on the design, development and testing of optical ground support equipment (OGSE) for the assembly, integration and testing (AIT) activities, and for the calibration and characterization (C&C) activities of the Sentinel-5 Earth Observation instrument.

Three sets of AIT OGSE were developed, for the UV1, UV2VIS and NIR spectral ranges, with similar design concepts. Each AIT OGSE comprises two modules, assembled in a common mechanical base: ILL OGSE and ILL GSS OGSE. The ILL OGSE provides 7 point sources with divergence defined by rectangular masks and very strict telecentricity values, better than 1.5 arcmin for the ILL UV2VIS. The ILL GSS OGSE images the light of a pinhole onto two different image planes, providing an astigmatic optical beam with divergence also defined by a rectangular mask. In both OGSE, a laser is used as the light source. The light is transported through fibers from the source to the pinholes. A XYZ mechanism is used to align the AIT OGSE with the spatial and spectral object planes of the Sentinel-5 spectrograph.

A sun simulator (SUSI) as part of C&C OGSE of the Sentinel-5 instrument was also developed by LusoSpace. The sun simulator is based on a Xenon continuous light source, an homogenizer and a telescope. A Xenon arc plasma source is significantly non-uniform, both spectrally and spatially. To meet the stringent spatial homogeneity requirements, a large homogenizer based on a kaleidoscope configuration was designed and manufactured. The proper collimation and large exit pupil are achieved through a mirror-based Offner telescope, avoiding large incidence angles, which would affect spatial uniformity and polarization. SUSI covers a very wide spectral range, from 270 to 2385nm, with an irradiance of 80 mW/cm2. SUSI provides an illuminated exit pupil with a very high spatial uniformity. The collimated beam of 0.318º divergence illuminates an exit pupil 151mm diameter with continuous light, and with a spatial non-uniformity better than 1% (according to IEC 60904-9 definition) which is, to the best of the authors' knowledge, the highest level of spatial uniformity for large aperture sun simulators [1].

The OGSEs were successfully tested and delivered. This work will focus on the development of the instruments, and the experimental results of the test campaigns.

Keywords: OGSE, Sentinel-5, Sun Simulator, AIT

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Topological optical clusters

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Abstract. In this work we present, for the first time to our knowledge, numerical evidence of the existence of static regular configurations of vortices[1] embedded in a uniform background. This type of structures can be formed in nonlinear media with self-repulsive interactions such as the so called cubic or Kerr type nonlinearity[2].

We start by showing mathematically how to construct rotating structures by using ansatze with a particular symmetry and we use regular n-polygons with the same centre, each of which with vortices of a particular topological charge on their vertices. Then, we find specific relations between their sizes and the aforementioned topological charges to fulfil a staticity condition. The analytical predictions will be verified with full numerical simulations of the propagation of different sets of initial conditions.

Our results will show that intricate phase interactions yield exotic distributions of the wavefront dislocations that remain stable for long evolutions, without changes in the amplitude profile of the field, which is therefore static, whereas a complex phase structure evolves as the beam propagates. We hypothesize that this surprising behaviour can be heuristically understood as a result of topological "forces" that arrange themselves in such a way that a complex structure is formed that supports itself by the phase gradient profile generated by the sum of all the vortices of the structure. If any of the vortices were removed, the entire structure would rapidly unravel.

Keywords: optical vortices, vortex solitons, cubic-quintic materials, nonlinear Schrödinger equations

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Time-refraction and temporal optical processes

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Abstract. The basic concepts of temporal optics are discussed. Temporal optics is mainly based on the process of time-refraction [1, 2], which complements the usual space-refraction of inhomogeneous media and leads to signal amplification, and to a variety of other optical processes. They include self-and cross-phase modulation, photon acceleration, pulse compression and generation of supercontinuum laser pulses [3]. They can also be used for temporal switching, temporal beam-splitters, and time crystals. Recent work on temporal optics in a Rydberg gas [4], and self-phase modulation using twisted laser pulses [5,6] is also discussed.

Keywords: Temporal optics, photon acceleration, self-phase modulation, supercontinuum

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Model Hamiltonians of open quantum optical systems: Evolvement from hermiticity to commutativity

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Abstract. In the conventional quantum mechanics of conserved systems, Hamiltonian is assumed to be a Hermitian operator. However, when it comes to quantum systems in presence of dissipation and/or noise, including open quantum optical systems, the strict hermiticity requirement is nor longer necessary. In fact, it can be substantially relaxed: the non-Hermitian part of a Hamiltonian is allowed, in order to account for effects of dissipative environment, whereas its Hermitian part would be describing subsystem's energy. Within the framework of the standard approach to dissipative phenomena based on a master equation for the reduced density operator, we study a possible replacement of the hermiticity condition by those based on commutation relations between Hermitian and anti-Hermitian parts of a Hamiltonian. As an example, we consider a dissipative two-mode quantum system coupled to a single-mode electromagnetic wave.

Keywords: quantum optical systems, non-Hermitian Hamiltonians, density operator, open quantum systems, two-level systems

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Investigation of cold atom turbulent dynamics through a spatially resolved pump-probe diagnostic.

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Abstract. Photon bubble turbulence is considered a key mechanism behind enhanced radiation transport in a variety of high energy objects such as accretion disks and massive stars. Analogous conditions – randomised photon propagation, strong radiation-pressure forces – exist in optically thick clouds of cold atoms. Through a novel spatially-resolved pump-probe diagnostic, integrated into a magneto-optical trap, we have been able to overcome line-of-sight integrated measurements and directly access the 2D density distribution across the atomic cloud. We have therefore identified a photon bubble instability and the resulting regime of photon bubble turbulence in cold atoms clouds.

Keywords: Photon Bubbles; Turbulence; Pump-Probe Diagnostics; Spatially resolved measurements; Cold atoms.

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Dots-in-Host Semiconductors for Improved Light Management

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Abstract. Insightful knowledge on quantum nanostructured materials is paramount to engineer and exploit their vast gamut of applications that range from optoelectronics to biology. In this work, a formalism based on the Empirical k.p method [1] was developed for rock-salt semiconductors (PbS, PbSe), to understand the absorption properties of colloidal quantum dots (CQDs) embedded in a wider bandgap semiconductor host. This method depends first on the development of a single-band effective mass model (developed previously in [2]) that can then be expanded into a 4-band model by using the 4-band k.p Hamiltonian for rock-salt materials. This method essentially calculates the envolute functions for the 4-band k.p basis from the diagonalized wavefunctions (determined from the 1-band model). These envolutes are then fundamental for further calculations, such as intra-band absorption. Several aspects of the model are then studied. Firstly, the CQD bandgaps that not only show a good agreement with the empirical results — determined by Moreels et. al. [3] — but also add the effect of host bandgap to the modelling scenario. Then the authors determined the envolute functions that can be used for calculating the absorption properties of the CQDs. Following this method, the authors calculated the transition rates and studied how they are influenced by the different CQD properties, using it then to determine the absorption coefficient density for the QD@Host system. To then understand the overall absorption behaviour with the different CQD properties the authors used a stochastic optimization algorithm (Particle Swarm) that can maximize a specified Figure of Merit (FoM) in a predefined parameter domain. Subsequently, a Monte Carlo analysis was performed around the maximum value to understand how significant is the impact of the parameter on the overall QD absorption.

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Label-Free Multiparametric Analysis Using Photonic Crystal-Based Biosensors

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Abstract. Photonic crystals (PCs) as label-free multiparametric sensors have been demonstrated to be an effective alternative to widely used surface plasmon resonance (SPR) sensors for detection of biomolecule interactions in modern diagnostics and drug development [1, 2]. PCs are multilayer stacks of dielectrics with a periodic modulation of their refraction indices in the optical wavelength range [3]. PC-based sensors are characterized by a longer surface wave propagation resulting in better sensitivity compared to SPR-based ones [3]. Surface modification is an important stage in the engineering of biosensors that directly affects the efficacy of the analysis of biomolecule interaction. SPR-based sensors are usually coated with gold or silver; therefore, this procedure requires the use of thiol chemistry. Their surface cannot be completely regenerated, which limits their use and increases the cost of analysis. In contrast, the PC surface is chemically stable, can be fully regenerated, and allows using varying surface chemistries to depose the desired functional groups onto the sensor for immobilization of analyte-binding moieties and subsequent oriented coupling of biomolecules to assemble bioanalytical complexes. In this study, we describe an approach to surface chemical modification and oriented functionalization of PC sensors using capture molecules (immunoglobulin- and biotin-binding proteins). We also present the results of label-free detection of protein analytes performed using a microfluidic PC-based sensor detecting PC surface modes. The obtained data demonstrate the possibility of label-free analysis of interactions of model proteins and pave the way to further engineering of a multipurpose biosensing platform based on PCs.

Keywords: protein sensing, label-free detection, photonic crystal, surface mode imaging, multiplexed detection

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Study of the impact on the absorption of III-V semiconductor nanopillars coated with dielectric-metal shells

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Abstract. Nanopillar and nanowire III-V semiconductor photonic devices have garnered considerable attention in the past few years as possible key elements for enabling next-generation applications, such as nanowire array lasers, on-chip and intra-chip optical interconnects, surface plasmon photodetectors, optical to electrical nanowire converters, plasmonic-photonic meta-absorbers, metal cavity nanopillar light emitting diodes and metal cavity nanopillar photodetectors.

In this work we aim to provide a study on how the absorption spectrum of nanopillar III-V semiconductor devices is impacted by the devices' multiple structural parameters. Our baseline design comprises a layer stack GaAs/AlGaAs semiconductor nanopillar with a 400 nm diameter covered by 50 nm a metal (gold) shell with a 50 nm dielectric shell acting as an interface between semiconductor and metal. Using Lumerical's DEVICE simulation suite, our goal was to understand which parameters of the pillar bear more weight in the devices' absorption in the red and near-infrared (NIR) part of the spectrum (600-900 nm wavelengths) and respective changes in the absorption maxima and minima. In terms of variation of parameters, we first studied the impact in absence of dielectric and metal shells that surround the pillar. Then we assessed the impact of the nanopillar's diameter, the thickness of the dielectric shell and the impact of the material of the metal shell by substituting the gold in the original design by silver.

Several conclusions were drawn from this study, notably devices with smaller diameter showed that a suppression of absorption in the 700-750 nm region of the spectrum occurs. The overall absorption seems to also be very sensitive to the thickness of the dielectric that acts as an interface between the metal shell, as different maximums in the absorption spectrum appeared for different wavelengths as a function of the thickness. The studies presented here can have applications in the design of energy-efficient and compact nanopillar photodetectors.

Keywords: Nanopillar, FDTD, Photodetector, Photonics

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Synchronous and asynchronous 3D examination of the eye with a slit lamp

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Abstract. Slit lamp is an essential instrument in any eye clinic practice, being routinely used by eye care practitioners during the ocular examination. The observation system of the slit lamp is composed by a binocular loupe providing 3D images during the ocular evaluation, which helps the identification and quantification of the progression of pathological signs. However, the registration of the images provided by the Slit Lamp continues to be in 2D, losing the additional information provided by 3D images. In this work we propose the use of 3D cameras attached to the eyepieces of the Slit Lamp to provide 3D videos that can be visualized synchronously or asynchronously by the practitioner or other colleague with which the video is shared. We compared the use of two different 3D cameras, one with the objectives separated a fixed distance, and another one whose objectives can be moved independently. Benefits and drawbacks of each camera will be presented. The visualization of the videos was tested on two different mobile phones of different screen sizes placed at two different 3D spectacles. Comparison of the 3D visualization of the videos will be presented making emphasis on the difficulty of binocular fusion. We will discuss the suitability of recording the slit lamp exploration with a 3D camera for synchronous and asynchronous remote exploration, promoting immersive tele-ophthalmology.

Keywords: 3D exploration, Slit Lamp, Optometry, Ophthalmology

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Teaching Optometry: setup for understanding the subjective refraction protocol and patient answers

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Abstract. Subjective refraction is not easy. Sometimes it is referred as the art of refraction. Why? because the different steps involved in the subjective refraction exam generates different answers depending on the patient. Teachers provides a general framework with general rules indicating the student the appropriate moment of performing each step of the protocol. But students that follow exactly the protocol do not always arrive to the correct refractive error. This is because the protocol must be adjusted to the patient answers. But for doing this, students need to understand not only how to perform the protocol, but also to experience the different ways in which the optotypes can be seen depending on the kind and magnitude of the refractive error. As subjective refraction is guided by the subjective answers of the patient, examiners must be able to put on the shoes of the patient. And this can only be possible if they were able to see the optotypes with the same refraction errors as their patients. In this work we propose a new setup for practicing subjective refraction while experiencing the way in which patients see the optotypes. The setup comprises: one projector; one computer; one screen; a set of trial lenses; one holder for trial lenses. The projector is used to project on the screen the optotypes created in the computer with the corresponding size in accordance with the projection distance. Close to the objective of the projector, we placed the trial lens holder to hold the lenses used to create the spherocylindrical refractive error. Spherical error can also be generated with the objective of the projector. The distorted image, like the one that experience patients with the same refractive error, is projected on the screen. Then different trial lenses are interposed following the steps involved in the subjective refraction protocol. This setup allows the training of the refractive protocol and the visualization of the optotypes during each of the steps of subjective refraction. The projection on the screen allows the visualization of a complete class promoting the interchange of ideas and impressions on the identification of the optotypes. It allows also individual training. We think that the proposed setup will help the understanding of the protocol of subjective refraction and why the patients' answers are not as clear as desired during the examination.

Keywords: Subjective Refraction, Teaching, Optometry, Trial lenses

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A Pilot Outreach Program for Optics and Photonics: Develop the Advanced and PioneeringConcepts

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Abstract. Optical and laser engineering are not only prevalent in science fiction movies but find numerous technological applications ranging from additive manufacturing over machining of micro/nano-scale features to biomedical imaging or space telescopes applications. In a related context, science simplification lectures with diverse visualization techniques and OSA optics suitcase can be utilized to bring attention and inspire careers in future technologies [1].

The suggested work focuses on developing the outreach program to train the trainees (as photonic ambassadors) specifically in the field of photonics and optical applications which is the expanded programme for multidisciplinary outreach activities as shown in Figure 1 (a). The extended activities can support a wide range of students in Ireland, Europe, and the international prospects as well, which increases the possibility of promoting photonics technology careers in the future.

The paper will explain the guidelines and topics of the proposed practical workshop (INNOVATIVE WAYS TO PHOTONICS FUTURE "TRANSFER THE KNOWLEDGE") which can help trainees and give them some techniques for engaging targeted students and creating an interactive environment. The detailed characterization of the workshop structures and related pragmatic and sensible sessions will be illustrated in this work. Figure 1 (b) shows the systematic steps of the outline of the developed program.

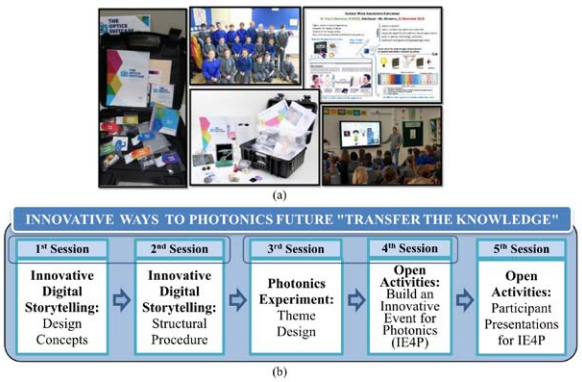

Figure 1. (a) Photographs of the optics suitcase and part of digital storytelling show-time in Carlow/Ireland [1], (b) Suggested workshop structure of training the trainees.

Keywords: Optical Demonstrations, Photonics Technology-Enhanced Learning, Interactive Group Education.

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Optical properties of low dimensional materials

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Abstract. We review here our recent work on optical properties of low dimensional materials. We start with discussion of lasing in semiconductor nanocrystals[1], follow with multi-exciton complexes in self-assembled[2] and graphene quantum dots[3], and finish with exciton fine structure[4] and broken symmetry phases in transition metal dichalcogenides[5].

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Superradiant optical shocks in arbitrarily diluted media

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Abstract. In its classical formulation, Cherenkov radiation occurs when a point-like particle travels faster than the phase velocity of electromagnetic waves in a medium. When such condition is fulfilled, the particle emits a cone of radiation that forms an optical shock at the Cherenkov angle. There are several optical media where this condition can be fulfilled. Yet, there are also others where Cherenkov emission is classically forbidden, namely vacuum and plasma. In contrast, we show that relativistic electron bunches can produce Cherenkov radiation in any medium, including vacuum. This interesting effect can be obtained by modulating a relativistic electron bunch with certain spatiotemporal modulations, which imprint a matter-wave perturbation travelling superluminally along the bunch. As in the classical Cherenkov effect, an optical shock forms at the Cherenkov angle defined by the matter-wave propagation velocity. We demonstrate that, at the optical shock location, the radiated intensity grows with the number of bunch particles squared. This is a key signature of superradiance. Yet, contrary to the longstanding tenet, according to which superradiance requires many light emitting particles per radiation wavelength, we demonstrate that superradiance can occur using an arbitrarily diluted medium, even when there is less than a particle per wavelength. We explore this concept in the context of a previously unexplored superradiant nonlinear Thomson scattering regime. Our findings can contribute towards a novel generation of advanced superradiant light sources, such as free electron lasers and plasma-based synchrotron light sources.

Keywords: Superradiance, relativistic beams, advanced light-sources, particle-in-cell simulations

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Reversible and non-reversible effects of silver nanoparticles on the photoluminescence properties of quantum emitters

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Abstract. Formation of weak plasmon-exciton coupling on nanoscale is a prospective way to overcome some limitations of quantum emitters (QEs) based on semiconductor nanocrystals. Realization of the coupling between plasmon resonance and absorptive transitions of QEs allow to increase the efficiency of photoexcitation of QE and thus to increase the photoluminescence (PL) intensity. In turn the coupling of plasmon resonance and radiative transition of QE is a prerequisite for the Purcell effect realization, increase of the radiative rate and enhancement of the PL quantum yield (QY). Previously we have shown that these effects may be realized and even combined for the stronger enhancement of both exciton and biexciton PL efficiencies and rates in semiconductor quantum dots (QDs) [1-3]. Moreover, our new experiments show that exciton and biexciton PL efficiencies in perovskite nanocrystals and CdSe/CdS QDs may be enhanced or decreased reversibly by real-time change in the structure of plasmon-exciton hybrid films. However for initially low-QY nanocrystals we observed irreversible increase in the PL efficiency even after the total elimination of plasmon-exciton interaction. We explained these effects by the plasmon-induced changes in rates of radiative and nonradiative transitions.

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Multi-wavelength optical phase unwrapping using low coherence Mirau interferometer

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Abstract. The phase ambiguity in conventional interferometers can be removed by using two or three different optical frequencies to generate a synthetic wavelength. The usefulness of synthetic wavelengths for removing phase ambiguities has been well documented [1-3], but the practical application of these techniques depends on the availability of compact, efficient, and reliable multiple-wavelength sources. In this work, we have implemented a micro-interferometer by using a Mirau interferential objective and the three-wavelength method to generate a synthetic wavelength and can achieve measurement of until 4350 nm step height. The phase ambiguity is removed using three light-emitting diodes (LEDs) emitting at three different wavelengths (Red, Green and Blue): $\lambda_1 = 458.7$ *nm*, $\lambda_2 = 512.8$ *nm* and $\lambda_3 = 637$ *nm*. Since LEDs have coherence lengths in micron range, speckle noise is greatly reduced. The phase-shifting algorithm called 8-Bell6 was applied to evaluate the phase map [4]. It is considered a correction due to the compensation of the cross talking between the red, green and blue channels (RGB). Measurements were made using, as a reference object, a thin-film aluminum step with a height of 1000 *nm*. The average height of this step, from our measurements, using three wavelengths interferometry was 970.97 *nm*. The relative error of the measurement is 2.9%. The effectiveness of multi-wavelength optical phase unwrapping using light sources of low coherence is demonstrated when it is evaluated the micro-topography of Red Blood Cells (RBC).

Keywords: Mirau objective, red blood cells, synthetic wavelength, phase-shifting algorithm, cross talking.

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White light interferometer for Fabry-Perot cavities sensors with absolute physical measurement

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Abstract. In this work an optical fiber interrogation system based on white light interferometry for Fabry-Perot (FP) cavities was developed. The system consists of two FP cavities in series. One FP interferometer, with nominal length of 191 µm, was interrogated by a Fabry Perot cavity with nominal length of 200 µm. The interrogation system was modulated with the aid of a PZT driven by a triangular signal at 5 Hz and varying amplitude, generated by a commercial signal generator. The output signal was collected, for each amplitude, by a photodetector and displayed on an oscilloscope. The signal displayed on the oscilloscope has the shape of a sinc. When the two cavities are balanced, i.e, there is no optical path difference between them, a maximum of the sinc is observed. The advantage of this system is that it can be used to estimate physical parameters (temperature, strain) with higher resolution than commercial optical interrogators.

Keywords: Fabry Perot Cavities, White Light Interferometry, Optical Interrogators

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A Low-cost Portable Interrogator for Dynamic Monitoring of Wavelength-Based Sensors

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Abstract. Fiber optics systems have developed considerably in the last 40 years. As the technology matured, advantages in fields other than telecommunications were discovered. Some of these advantages are the ones found in fiber-optic sensors. They are small, lightweight, resistant to electromagnetic interference, capable of multiplexing, chemically stable, and highly sensitive — all while on passive operation. Therefore, in the present day, these sensors can be great alternatives for remote sensing needed in robotics, medicine, and the industry overall. However, despite the benefits they have when compared to conventional technologies, commercial interrogators capable of acquiring the needed data remain relatively expensive and do not offer much portability. As a result, the usability of this solution in several fields is limited, for instance, in rehabilitation robotics (prostheses, orthoses, exoskeletons) where the interrogator must be integrated with the device, wearable sensors or smart textiles, and in general, applications where the interrogation unit would be in constant movement and needs to be integrated with the sensors in the same structure. This paper addresses this issue and proposes a low-cost portable interrogator for dynamic monitoring of wavelength-based fiber-optic sensors such as fiber Bragg gratings (FBGs) and Fabry-Perrot interferometers (FPIs). The interrogator is based on a compact solution involving a broadband light source and the spectral convolution between the sensor and a tunable filter. The filtered signal is then acquired by a photodetector where the optical-electrical conversion happens. Additionally, a microcontroller performs three actions: (i) controls the filter tuning, (ii) acquires the photodetector signal, and (iii) sends the data to a single-board computer (SBC). Lastly, the SBC performs further signal processing and displays the sensor data on a graphical user interface. The choice for hardware and software development combined allows for a lost-cost solution that supports monitoring of four channels simultaneously, real-time operation, compatibility with Windows and Linux-based operating systems, dynamic inputs for signal processing, and portability (wireless communication with low latency). This is done by using a high-performance microcontroller, writing its firmware and using a real-time operating system for better resource management. For the single-board computer, a program with a graphical user interface was developed in Python to perform the necessary signal processing, support dynamic monitoring, and many other functions to improve user experience.

Keywords: Interrogators, fiber Bragg gratings, Fabry-Perrot Interferometers, embedded systems

Development of a Low-Cost Interrogation System Using a MEMS Fabry-Pérot Tunable Filter

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Abstract. The interrogation of optic fiber sensors usually relies in complex and costly equipment with low portability due to their size. Because of this, micro spectrometer devices, such as Micro-Electromechanical Systems (MEMS) with Fabry-Pérot tunable filters, are emerging as simpler and compact alternatives [1].

Fiber Bragg Gratings (FBGs) are structures formed by a periodic modulation of index of refraction of the fiber's core. Long Period Fiber Gratings (LPFGs) are special cases of FBGs with larger grating periods. These are formed in common and cheap telecommunication fiber. However, the interrogation methods usually involve the use of typical Optical Spectrum Analyzers (OSA) which are expensive and only suited to laboratory tests [2], or dedicated OSAs with limited spectral response ranges. Our group has already published a low-cost alternative capable of interrogating LPFGs using three thermally modulated fiber-coupled laser diodes [3].

In this work it is described the development of an interrogation system capable of infrared spectroscopy using a MEMS Fabry-Pérot Interferometer (MEMS-FPI) with a spectral response in the 1350nm to 1650nm range. Its performance is tested with the interrogation of LPFGs both as a refractive index sensor and as a temperature sensor. Deconvolution techniques such as Wiener filtering are used to reduce the impact of the tunable filter's impulse response in the measured signal. Results are comparable to those obtained using a typical OSA which shows the system's potential as a cheaper and more transportable alternative.

Keywords: Fabry-Pérot; Interrogation Techniques; Long Period Fiber Grating; Optical Fiber Sensors.

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Single-cycle laser pulses through nonlinear pulse compression

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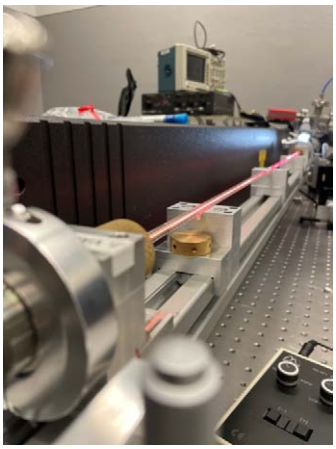

Abstract. Today most ultrashort lasers are capable of producing pulses in the order of dozens of femtoseconds, using mode-locked Ti:Sapphire oscillators. These ultrashort pulses are the tools of choice for exploring electron dynamics inside atoms, molecules and solids or in nanostructures. Shorter and more energetic pulses allow to explore electron dynamics inside atoms, molecules and solids or in nanostructures. This can be achieved with isolated attosecond pulses (IAPs) produced through few-cycle laser-driven high-harmonic generation (HHG), unlocking diagnostic tools like attosecond x-ray diffraction and spectroscopy with tabletop sources [1].

Our setup at the Voxel laboratory (GoLP/IPFN at Instituto Superior Técnico) consists of a Coherent Astrella laser (45 fs, 800 nm, 3.00mJ, 1kHz) whose output is focused onto a 250 µm inner diameter differentially pumped hollow core fiber, pressurized with Argon gas. The spectrally broadened output from the hollow core fiber is re-collimated before the beam is both compressed and measured in time by a d-scan system from Sphere Ultrafast Photonics [2]. Only a few mW are sampled for compression and diagnostics. The compressed beam is planned to be used for HHG in solids and gas.

In the Voxel laboratory at Instituto Superior Técnico we have achieved 3.81fs with minimal GDD and a transmission of 33%. The setup is still under optimization but already represents a powerful tool for table-top single cycle laser pulses in laboratories.

Keywords: nonlinear optics, hollow-core fibers, spectral broadening, D-Scan.

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Pulse broadening and compression of visible spectral range laser in a Herriott cell

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Abstract. Abstract. Spectral broadening and compression is a powerful technique to generate short pulses around 1 µm [1,2]. Extending this approach to different wavelengths would be highly beneficial. For instance, increasing demand for coherent and ultrafast laser sources in the 250–530 nm (UV to visible) spectral range is rising for industrial and scientific applications [3]. In this work, we propose shortening the pulses directly in green to not compromise the frequency doubling efficiency. We use a traditional BBO crystal for efficient second-harmonic generation at a moderate (>250 fs) pulse duration, from 1030 nm to 515 nm, followed by a spectral broadening and compression scheme in a Herriot-type cell (HC), using a bulk material as the nonlinear medium. The driver laser (Light Conversion PHAROS) delivers 15 W average power at 1 µm, emitting 250 fs pulses with a pulse energy of up to 200 µJ at a repetition rate of up to 1 MHz. After the conversion stage, the pulses are spectrally broadened and compressed in a multi-pass cell yielding sub-40 fs pulses with over 20 nm bandwidth around 515 nm. The efficiency of spectral broadening and compression exceeds 90 %. These results represent the first implementation of a multi-pass spectral broadening and compression in the green spectral regions and pave the way for similar experiments in UV.

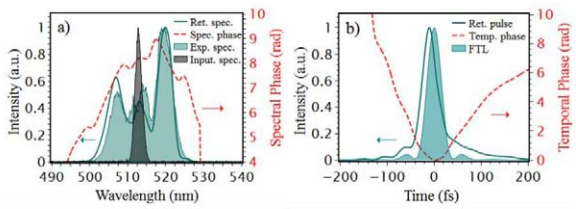

Fig. 1 a) M easured (shaded area) and FROG retrieved (solid line) output spectrum and spectral phase (dashed line) for the solid state broadening scheme at input energy of 15 µJ. b) FROG- retrieved temporal profile (solid line), temporal phase profile (dashed line), an d FTL reference (shaded area). The measured duration was 38 fs with an FTL of 35

Keywords: Nonlinear optics, spectral broadening, multi-pass cell.

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YCOB based ultrabroadband optical parametric amplification with a sub-picosecond pump source

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Abstract. Over the last decade there has been a growing interest in the applications enabled by high peak and high average power laser sources, in particular in the strong-field physics community. The progress in diode-pumped solid state sources coupled to nonlinear amplifiers based on optical parametric chirped pulse amplification (OPCPA) has enabled the development of state-of-the-art sources in the near- and mid-infrared spectral regions [1]. The OPCPA technique employs nonlinear crystals to mediate the energy transfer from a more readily available, long-pulse laser (the pump) into an ultrabroadband pulse (the signal), temporally stretched to match the pump duration, which can then be compressed to an ultrashort duration. The nature of parametric amplification allows overcoming the gain narrowing associated to inversion-based optical gain, while also allowing a tunable output. Driven by highly efficient and energetic diode-pumped, ytterbium-based sources, OPCPA has led to a new generation of advanced, high repetition rate ultrashort pulse systems [2]. We demonstrate the optical parametric amplification of broadband near-infrared laser pulses using a single yttrium calcium oxyborate (YCOB) crystal pumped in a noncollinear geometry by a sub-picosecond, milijoule-level source. The crystal uses an optimized orientation for phase matching outside of the principal planes, enabling ultrabroadband amplification in the range 750-950 nm. An amplified energy of 2 μJ is obtained, followed by compression to 25 fs.

Keywords: Ultrafast Lasers; Parametric Amplification; Nonlinear Optics; Materials.

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High contrast front-end for a petawatt laser system designed for electron acceleration and high intensity laser-matter applications towards advanced compact particle accelerators

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Abstract. Coherent light sources in spectral regions inaccessible to lasers have been an important issue for more than five decades. Despite tremendous progress in laser technology, substantial portions of the optical spectrum from UV to IR still remain inaccessible to conventional laser sources. This limitation arises from the limited gain bandwidth of the active medium, which defines the operating spectral region of the laser. This directly limits the application of such devices, while also placing a boundary on ultrashort pulse generation, which requires very broad bandwidths. In this context, coherent optical sources based on nonlinear conversion, with femtosecond/picosecond pulse duration and wide tunability, are rapidly emerging. They are extremely versatile and of considerable interest in a wide range of scientific and technological areas. We investigated the generation of ultrashort laser pulses in the near-infrared region between 750 and 1000 nm, which is of interest for current large-scale laser projects based on optical parametric amplification. We focus our attention on the design and development of efficient ultra-broadband Optical Parametric Amplification (OPA) stages in the picosecond regime and the relative temporal diagnostics. The developed operational systems are implemented at the Vulcan laser system at CLF devote to the upgrade of the laboratory with a fully Optical Parametric Petawatt laser system for laser-plasma interaction and pump-probe experiments. Furthermore, in this presentation, one of the most promising applications of such systems delivering ultrashort pulses is investigated. The technique presented is the Target Normal Sheath Acceleration (TNSA) which has been suggested for industrial, medical and physics research applications such as radiotherapy, isotopes production, fusion fast ignition schemes and proton imaging. A proper investigation of the experimental parameters influencing the TNSA process is needed to reach the most efficient operating conditions. The conducted experimental research is aimed at acquiring greater insight into the TNSA process, with a particular interest in the relation between the ultrafast electron beams, the established accelerating potential and the subsequent ion acceleration for different targets and laser parameters. The experimental campaign has been carried on in collaboration with the SPARC-LAB group at LNF-INFN.

Keywords: Ultrashort Lasers systems, OPA, TNSA, electron acceleration, proton acceleration.

Engineering the pupil for wavefront masking

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Abstract. Correction of low and high order aberrations for image enhancement has been performed using static elements, mainly for low order aberrations, and tuneable elements, like spatial light modulators or deformable mirrors, for correcting low and high order aberrations. The corrective element is shaped to counteract each of the aberrations presented by the system, following a compensatory framework. If the wavefront error changes, the corrective element has to change. Correction of ocular high order aberrations by static elements, as for example contact lenses, failed mainly due to misalignments which make impossible the compensation of the aberrations. There is another way of facing image enhancement in systems with aberrations, "wavefront masking". The idea is to include in the system an aberration that makes the optical transfer function of the system invariant to changes in the aberrations. This is the base of the technique named Wavefront Coding. In this work we will present this idea and explore its use in visual optics. We will show how it can be used to obtain high resolution images of the retina for improving ocular diagnosis. Besides we will show examples of the use of this idea for improving vision quality of patients suffering different refractive errors, and presbyopia. Moreover, we explored the performance on eyes with high amounts of high order aberrations as those presenting corneal ectasia. We will show different numerical simulations using Fourier Optics. For improving retinal images, we will show the degraded and enhanced images under different ocular aberrations. In the case of visual optics, we will simulate the vision of an eye under different pupil sizes and optotypes at different working distances, in presence of different ocular aberrations.

Keywords: Wavefront Coding, Jacobi Fourier Polynomials, Presbyopia

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What is the impact of accommodative insufficiency on the optical quality of the eye?

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Abstract. The aim of this study was to analyse the changes of high-order aberrations with accommodation and its impact in the ocular optical quality in subjects with accommodative insufficiency. For that purpose, data from eleven subjects with accommodative insufficiency were analysed, and compared to data from a control group of thirteen subjects without any accommodative dysfunction. The most significant changes occurred in primary and secondary spherical aberrations and vertical and horizontal comas. The changes of these aberrations with accommodation were different in subjects with and without accommodative insufficiency and were higher in the group of subjects with accommodative insufficiency compared to the control group, causing greater deterioration of the retinal image quality.

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Low cost adherent lenses for presbyopia

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Abstract. In this work we propose a very simple method for manufacturing self-adhesive lenses for presbyopia that can be attached to monocular ophthalmic lenses. The lenses are fabricated by soft embossing, using as a mould the posterior base curve of ophthalmic lenses of different prescriptions, and trial lenses typically used during the subjective refraction process. Our method is the simplest of the ones found in the literature. Besides, previous works do not analyse the aberrations of the manufactured lenses, and do not show the performance of the lenses attached to the ophthalmic lenses, questions that we analyse in here. The elastomeric lenses were made of PolydimethilSiloxano, a transparent and flexible material. After their fabrication, we measured their power with a frontofocometer and their aberrations with a Hartmann-Shack wavefront sensor. We tested the performance of the lenses after being placed on spherical and spherocylindrical ophthalmic lenses, with the Hartmann-Shack wavefront sensor. The results showed that the manufactured lenses do not present astigmatism or high order aberrations, being their optical quality very high. We also tested the optical performance of the lenses. We built an artificial eye with a camera and a 24.5 mm lens with an aperture of 4 mm, to mimic the eye. The artificial eye was corrected at far vision with an ophthalmic lens of -1.75 D. We took pictures of the optotype at far and at 50 cm. Then we placed one of the manufactured adherent lenses with 2 D of power at the front surface of the ophthalmic lens. We found that the adherent lenses allow for the perfect visualization of the optotype at near, showing the suitability of the adherent lenses to be used for presbyopia correction. The proposed lenses can be useful for those users that prefer to have a removable add for reading instead of changing the spectacles or using bifocals or progressive lenses.

Keywords: PDMS, presbyopia, Zernike, Adherent lens

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Assessment of central and peripheral accommodative lag by aberrometry

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Abstract. Accommodation lag is important factor for normal vision. Higher lag of accommodation may cause various ocular symptoms particularly during near tasks. In this study, the aim was to assess the lag of accommodation in the peripheral retina and compared it with the central accommodative lag with aberrometer. This was a cross-sectional study conducted in the University of Minho. Fifty-three young subjects with normal visual acuity and without any active ocular disease or past ocular surgery were included in this study. Aberrations in the central and peripheral field of view up to 30º off axis form the centre in horizontal and vertical meridian in 10º steps were measured with Hartmann-Shack aberrometer with stimulation of accommodation by -2.50D lens. Accommodative stimulus and accommodative response were calculated with defocus and hence accommodative lag was obtained. Accommodative lag in the centre and periphery was compared. Repeated measure of ANOVA showed that there was overall significant difference in lag of accommodation in various eccentricities ($F(8.912, 454.514) = 2.372$, $p = 0.013$). Pairwise test showed that lag in the centre was similar with lag on other peripheral field of view ($p > 0.05$). However, accommodative lag at 10º nasal field was significantly lower than the lag at 20º temporal, 20º nasal, 30º temporal and 30º nasal ($p < 0.05$). Similarly, lag at 10º superior fixation was lower than lag at 20º temporal, 20º nasal, 30º temporal and 30º nasal fixations ($p < 0.05$). We found higher lag of accommodation in horizontal off-axis fixations in comparison to that of vertical off-axis fixations ($p < 0.05$). Lag of accommodation was positive correlated with vertical coma and primary spherical aberrations but negative correlated with secondary spherical aberrations ($p < 0.05$). Thus, Hartmann-Shack aberrometer was successfully used to assess accommodative lag in the peripheral field of view up to 60º visual field. Peripheral lag of accommodation depends up on eccentricity. Lag was found higher in horizontal off-axis fixation than at vertical fixations. Coma and spherical aberration had association with lag.

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Comparison between central corneal thickness, anterior chamber depth and axial length values with and without contact lenses

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Abstract. Purpose: To compare the values of central corneal thickness (CCT), the anterior chamber depth (ACD) and the axial length (AL) on measurements performed with and without contact lenses (CL) in healthy subjects with two different devices (Visionix 120+ and EchoScan US-800). Material and methods: 20 volunteer participants (6 men and 14 women, 24.8 ± 2.73 years) were recruited. In a single visit, participants underwent autorefraction, biometry, topography and pachymetry with the naked eye (without CL). Then, biometry and pachymetry were repeated twice wearing two different CL (Somofilcon A and Nesofilcon A) of -3.00D lens power fitted in random order. Data were compared using t-tests for related samples. Results: CCT values wearing CL were significantly higher than those obtained with the naked eye (Paired t-test; both $p \leq 0.001$). On the other hand, no significant differences were found between the ACD or AL values with the naked eye versus any of the CL studied (Paired t-test, all $p \geq 0.111$). The ACD values comparing Visionix120+ to EchoScan US-800 measurements were significantly different with both the naked eye and with any CL (Paired t-test; all $p \leq 0.001$). Conclusion: CCT measurements cannot be performed while wearing CL. In contrast, ACD and AL measurements were not affected by the use of any CL. In addition, it was observed that ACD results from both devices are not interchangeable neither when measured with the naked eye nor using any CL.

Keywords: Central corneal thickness, Anterior chamber depth, Axial length, Visionix120+, EchoScan US-800

Subaquatic laser induced plasma-assisted ablation for channels and wells fabrication on glass substrates

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Abstract. The year 2022 has been declared as the International Year of Glass by the United Nations General Council [1] due to the important role played by the glass in different researching and industrial fields. There are many different techniques for machining and processing glass depending on their characteristics and the results to be obtained. Among all these techniques, laser glass processing stands out due to its simplicity, flexibility, low contamination, and so on. To our knowledge, the precise manufacturing of glass with rectangular cross section, steep edges (vertically) and great depth is still a challenge specially using nanosecond lasers. In this work we present a technique called Subaquatic indirect Laser Induced Plasma-Assisted Ablation (SLIPAA) for glass processing that reduces the thermal effects generated using nanosecond laser. Moreover, it facilitates the ejection of material from the laser-plasma interaction zone. In this technique, a laser beam is focused on a metal foil after passing through a glass and a layer of water. The laser source used is a Nd:YVO_4 laser operating at its fundamental wavelength, 1064 nm, with a pulse duration of 20 ns combined with a galvanometer system and a flat field lens that grants a homogeneous energy distribution on an area of 12 x 12 cm^2 on the target. When the laser is focused on the metallic target, a plasma located between the glass substrate and the target is generated and confined by the water layer. The mechanical shock waves [2], generated by the focused laser, combined with the ablation plume and the cavitation bubbles allow the ablation on the rear face of the glass. With this technique and selecting the proper processing parameters (fluence, repetition rate and scanning speed) it is possible to fabricate rectangular shaped channels and wells with a variety of dimensions and straight edges of excellent quality. The dependence of the fabricated structures shape on the processing parameters and the key points for complex structures manufacturing on glass using this technique will be discussed.

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Optimization of pulsed laser deposition process of superconducting $YBa_2Cu_3O_{7-\delta}$ films

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Abstract. Pulsed laser deposition (PLD) employing a scanning laser beam was used to deposit $YBa_2Cu_3O_{7-\delta}$ thin films on $SrTiO_3$ (STO) single-crystal substrates. Factor that affects the quality of the thin films including deposition temperature (T_s), in-situ annealing oxygen pressure (O_{ap}) and cooling time (C_t) were examined by AC susceptibility, magnetisation loops and transport measurements using a Quantum Design Magnetic property measurement system (MPMS) respectively to investigate its influence on the characteristics of the superconducting thin films. The effect of the thin film's microstructure was observed by Scanning electron microscopy (SEM), Atomic force microscopy (AFM) and X-ray diffractions (XRD). The critical temperature (T_c) decreased when the T_s rose from 780 to 820 °C. Film grown at T_s of 780 °C showed the smoothest surface with root mean square (RMS) ~ 2.40 nm. The RMS increased with increasing T_s. The T_c increased with O_{ap} and C_t to the optimum value of 91 K and then decreased. The granular and porous microstructure of the films was progressively observed with increasing O_{ap}. The orientation of the thin films grown on the single crystal as observed by XRD was totally along the (001) plane. The maximum current density (J_c) of 2.8 $MAcm^{-2}$ at self-field and 0.8 $MAcm^{-2}$ at 1 Tesla was achieved at 77.3 K. An optimum annealing oxygen pressure O_{ap} of 450 Torr was found to generate a peak J_c at 5 K and 77.3 K. It was found that thin film with a superconducting transition temperature of 91 K can be obtained at T_s of 780 °C and O_{ap} 450 Torr.

Keywords: Deposition temperature; *in situ*-annealing oxygen pressure; Superconducting; $YBa_2Cu_3O_{7-\delta}$; pulsed laser deposition.

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Optical, structural, morphological and chemical properties of doped TiO_2 nanoparticles with $FeCl_3$

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Abstract. Titanium dioxide (TiO_2) is a widely used semiconductor for photocatalysis. This captures only a small fraction of sunlight (only about 3%) in the ultraviolet (UV) region thus limiting its efficiency and photocatalytic ability. The large-scale application of TiO_2 nanoparticles has been restricted as it requires an ultraviolet excitation source to achieve a high photocatalytic activity. Incorporating chemical elements into the TiO_2 lattice can tune its band gap, resulting in an edge-shifted red absorption to reduce energies, improving photocatalytic performance in the visible region of the electromagnetic spectrum. In this research, TiO_2 semiconductor nanoparticles were subjected to a doping process using iron chloride ($FeCl_3$) powder to activate photocatalysis under visible light and consequently improve pollutant capture. To study the effectiveness of the doping process, the main ratios (3:1), (1:1), (1:1.622), (1:3) and (1:4.5) of TiO_2:$FeCl_3$ were evaluated by measuring the band gap using Diffuse Reflectance Spectroscopy (DRS). Subsequently, X-ray diffraction (XRD) was used to identify the crystalline phase of each material, as well as Fourier-Transform Infrared Spectroscopy (FTIR) to analyse the chemical composition of the doped materials, and Scanning Electron Microscopy (SEM) to investigate the homogenization and dispersion of the samples. The main results of this research show that doping TiO_2 with $FeCl_3$ shifted the absorption edge to longer wavelength values, changing the optical properties of the material and decreasing the band gap (Eg) of TiO_2 compared to the undoped TiO_2 (reference). There are no relevant differences between the XRD pattern of the samples with TiO_2-$FeCl_3$ and TiO_2 nanoparticles (reference). The fraction of the anatase phase in doped TiO_2 nanoparticles has the same magnitude as the reference TiO_2. Consequently, there is no significant influence on anatase-to-rutile transformation (ART). Regarding FTIR, the Fe-doping process alters the TiO_2 reference spectrum, especially increasing the intensity of hydroxyl bonds and peaks, indicating the Ti-O-Fe bond vibration.

Keywords: band gap energy, semiconductor nanoparticles, diffuse reflectance, nano-TiO_2, photocatalysis

Thermochromism applied to Transportation Engineering: asphalt roads and paints

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Abstract. Thermochromic materials change reversibly their optical response with temperature. They have many possible applications in aerospace, military, textiles, and construction. In the road engineering field, thermochromism studies are still incipient, addressing the temperature variation and energy absorption control on pavements to increase their durability. This study explores the application of thermochromism to road engineering from two perspectives. The first one is about the development of functionalized road markings (FRM) working as thermochromic sensors to alert the presence of ice on the road and, in this way, to improve road safety. The second one concerns the functionalization of asphalt pavements for reversible color change at high temperatures to reduce energy absorption in the form of heat and, in this way, mitigate Urban Heat Islands (UHI) effect. For the development of the FRM, thermocapsules with temperature transition (TT) commonly commercialized were added by volume incorporation into acrylic ink, then applied to an AC10 asphalt mixture, submitted to high and low temperatures, and finally visually characterized to attest to the thermochromic behavior. For the functionalization of the asphalt pavement aiming for UHI reduction, thermochromic solutions (TS) containing thermocapsules, dye, and resin were superficially sprayed at an AC10, and performed the Quick Ultraviolet Accelerated Weathering Test (QUV) followed by Colorimetry Analysis. The color coordinates L*, a* and, b* were measured as defined by the *Comissione Internationale de l' Éclairage* (CIE), as well as ΔE*. The results show that it is possible to functionalize road marks to work as a thermochromic sensor. Also, this property can be improved by synthesizing or using thermocapsules with TT closer to the water melting point. The results also indicate that the asphalt pavement functionalization with surface spraying of TS points out to higher luminosity results in terms of color coordinate, which is intended for the mitigation of heat energy absorption, consequently, mitigating the UHI.

Photocatalytic degradation of Malachite green using magnetic zinc and magnesium ferrite nanoparticles functionalized with silver under visible light irradiation

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Abstract. Water pollution is one of the biggest environmental challenges. Anthropogenic pollutants (e.g. pesticides, pharmaceuticals, industrial dyes, Per and Polyfluoroalkyl substances) are each day more and more present in water systems. Due to the inefficiency of conventional wastewater treatment plants to degrade them, the recalcitrant compounds, or their products, end up in rivers, lakes, oceans, and other water bodies [1]. Semiconductor photocatalysis is considered an efficient alternative/complement to conventional methods. This process initiates by semiconductor photon absorption and results in the formation of reactive species that will interact with the pollutant degrading it. The use of different nanomaterials as semiconductors have been widely explored, with special focus on the study of their activity under less energetic wavelengths, as in the visible light spectrum [2]. This work focus on the development of magnetic and photoactive zinc and magnesium mixed ferrites ($Zn_{0.5}Mg_{0.5}Fe_2O_4$), synthesized by two different methods, sol-gel and solvothermal. Due to a high recombination rate of electrons with holes, an intrinsic feature of ferrites, further functionalization is necessary to enhance charge separation. Noble metal surface deposition can promote separation of electrons/holes, promoting the photocatalytic activity [3]. To address the efficiency of the developed nanomaterials, an homemade irradiation set up was used, and the dye malachite green was tested as model pollutant. *Vibrio ficsheri* assays were also performed to evaluate the toxicity of the solution resulting from the irradiation experiments.

Keywords: Photocatalysis; Water pollutants; Semiconductors; Visible light;

Acknowledgements: This work was supported by the Portuguese Foundation for Science and Technology (FCT) in the framework of the Strategic Funding of CF-UM-UP (UID/04650/2020), UIDB/04469/2020 unit and COMPETE 2020 (POCI-01-0145-FEDER-006684). R.J.C. Fernandes acknowledges FCT for a PhD grant 2021.08418.BD. Ana Rita Silva holds an FCT grant SFRH/BD/131905/2017 and COVID/BD/15951/2021.

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Ultrafast spectroscopy of biomolecules in the ultraviolet range

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Abstract. Many molecules involved in biological processes absorb strongly in the ultraviolet (UV) spectral range. A notable example are DNA bases, which have strong absorption bands in this range but present remarkable photo-stability. These chromophores indeed relax in ultrafast time scales (tens of femtoseconds) after UV photo-excitation, preventing photochemical reactions that could end up on a photo-damage of the molecule [1]. In those ultrafast processes, conical intersections (CI) play a crucial role but tracking them is extremely challenging as it calls for ultrashort pulses in the UV range [2]. We have recently demonstrated sub-20 fs pulses in the UV by a scheme based on frequency up-conversion in nonlinear crystals. By combining these pulses with broadband supercontinuum generation driving by the fundamental or its second-harmonic we have set-up a transient UV spectroscopy setup with unprecedented temporal resolution of 20 fs [3]. We have exploited this setup to track the relaxation mechanisms in solvated pyrimidine nucleosides [4]. In particular, we trace the passage of the wave-packet through a CI in uridine and 5-methyluridine. In spite of their similarity (their chemical structure differs only in a methyl group), 5-methyluridine takes an order of magnitude longer Our results, supported by simulations from first principles based on mixed quantum mechanics /molecular mechanics (QM/MM), allow us to identify ring puckering as the dominant deactivation channel and rationalize the difference in decay times with larger inertia of the methyl group in 5-methyluridine with respect to hydrogen in uridine.

Keywords: ultrafast spectroscopy, femtosecond lasers, molecular dynamics, ultrafast optics

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Assessment of lipid formulations to develop multi-stimuli-responsive solid magnetoliposomes using fluorescence-based methodologies

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Abstract. The clinical success of liposomes in pharmaceutical sciences has driven the development of new multifunctional approaches for controlled drug delivery. Magnetoliposomes are hybrid lipid-nanoparticle complexes whose interest is based on the ability for magnetic targeting, controlled cargo release induction, thermal therapy potentiation, and theranostics capability. This work is focused on the assessment of lipid formulations to design solid magnetoliposomes (SMLs) as multi-stimuli-responsive vesicles for controlled release of doxorubicin (DOX) in pathological areas under the influence of thermal, magnetic, and pH stimuli [1]. The intrinsic fluorescence of DOX can be used as a facilitating tool for DOX-loaded SMLs characterization. Thus, the fluorescence spectroscopy technique was fundamental to evaluating the effect of lipid formulations on SMLs' properties, such as its encapsulation efficiency. The DOX localization in the lipid bilayer with pH variation was assessed by the simultaneous analysis of its fluorescence intensity variation with the steady-state fluorescence anisotropy (r). The interaction degree between the lipid vesicles and human serum albumin (HSA) allowed to conclude about the stability of formulations under physiological conditions. For that, the fluorescence quenching effect of HSA Trp214 residue, resulting from changes in the conformation of the HSA after interaction with vesicles, was monitored. The results confirm the fundamental role of PEG in enhancing the stealth properties of SMLs. Finally, DOX release kinetics assays were performed in mimetic environments of physiological conditions (37 °C, pH = 7.4) and therapeutic conditions (42 °C, pH = 5.5). The results reinforce the potential of SMLs as stimuli-responsive nanosystems for cancer targeting and therapy.

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Highly selective, compact and efficient vertical in-coupling for interferometric optical biosensors

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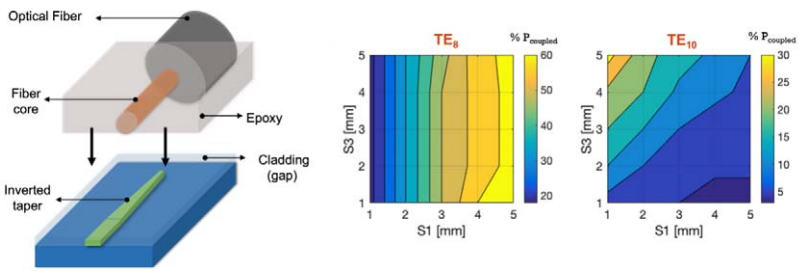
Abstract. One of the challenges in using integrated optical biosensors is their ability to operate in environments outside laboratories. This occurs mainly because suitable source coupling components are not considered at the design stage. In this work, a highly selective, compact and efficient in-coupling method is proposed with the aim to develop a genuine Point-of-care (POC) platform. The proposed configuration consists of a single-mode fiber core placed in parallel and centred above an inverted non-linear taper, which can also be seen as a pigtail input stage. These components are separated by the cladding of the taper that acts as a gap. In this setup, light is coupled from the fiber to the taper, which then becomes the core of a multimode waveguide. The coupled modes depend on the position of the fiber and the geometry of the taper. For interferometric biosensors, the power distribution between the modes is very important because each one reacts differently to the sample placed on the optical transducer. Therefore, the selectivity of the coupling stage affects the detection process. In the model presented in this work, the input is set as the fundamental TE mode of the fiber. Since it is centred, only the even modes are excited in the taper. The width of the taper varies from 2 µm to 3 µm, in order to select only high-order modes, due to their large evanescent tails lead to highly sensitive biosensors. The non-linear format optimizes the design by dividing the entire taper into a cascade of linear sections. Those in which the coupling of the desired modes occurs are prioritized by increasing their lengths, thus making the transition smoother. To select other modes or change the power distribution between them, one may just simply change the width of the taper and the length of the prioritized sections. In this work, a fiber-to-taper configuration of 8 mm length is presented, which couples 48% and 17% of the input power to TE_8 and TE_{10} modes, respectively.



Keywords: Optical fiber, non-linear taper, multimode waveguide, optical biosensor.

Acknowledgements: Brazilian agencies CAPES, FAPESP and CNPq.

Development of an Escherichia coli optical biosensor with computational validation

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Abstract. The biosensor consists of an optical sensing system and an optoelectronic data acquisition system. The sensor's optical system consists of a biochemically functionalized polymer optical fiber (POF-Plastic Optical Fiber) based on Field Evanescent technology. The Evanescent Field technique has been widely adopted in sensing and in this project it was obtained by bending the fiber in a "U" shape, aiming to increase the sensitivity of the biosensor, through the contact of the curved sensor part with the sample. biological. A data acquisition system was developed through an optoelectronic project aiming to increase the sensitivity when compared to a commercial equipment acquisition system.

This work presents a biosensor for the detection of Escherichia coli based on an evanescent field with a polymer optical fiber linked to the analog signal acquisition system through an optoelectronic system developed.

The interaction investigation of antibodies and antigens in Escherichia coli for computational methods was carried out in order to obtain information about the action of the antibody and in future steps apply in validation of the diagnostic method.

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Design and simulation of 3D printed freeform optics elements

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Abstract. On this work we will present the planned scenarios for the design and simulation of 3D printed freeform optics (FFO) elements, under the scope of the project ”Additive Manufacturing for the next generation of freeform optical components”. The design and simulation of 3D printed FFO elements will start with the simulation implementation (numerical models' construction) for some FFO elements, including freeform prisms, toroid lens, acylinder lens, anamorphs, and Alvarez lens. The main goal is the development and implementation of theoretical and numerical models to simulate and design the FFO elements. In a first approach the computational work is being developed using commercial Comsol Multiphysics. The optical characteristics and performance of the FFO will depend on their shape and roughness, which in turn depends on part in the resolution of the 3D printer, as well as on the refractive index of the production material - resin. Firstly, according to the typical printer resolution, the effect of geometric deviations and the surface roughness will be considered in the simulation and in the performance of the FFO elements. Secondly, resins with different refractive indexes will be considered in the design of the FFO elements, along with the mandatory performance assessment. From these two simulation steps, we aim to define an optimized refractive index range for each target application taking into account the limitation of the printer. Lastly, the effect of antireflective coatings will also be considered in the performance assessment of the FFO elements. The obtained results will provide guidelines for the design of 3D printed FFO elements produced by 3D printing, aiming its potential application in technological fields such as: aerospace, automotive, illumination and biomedical engineering.

Keywords: 3D printing, freeform optics, numerical methods, simulation

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Amorphous Silicon Photonic Integrated Circuit for beam steering in Lidar applications

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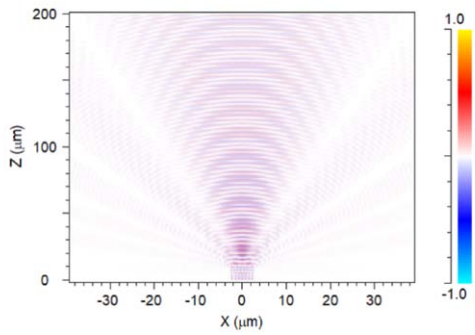
Abstract. Different configurations of LIDAR systems have been proposed during the recent years to face the variety of requirements that can be established, depending on the application framework.

Among others, the reduction of mobile mechanical parts and the overall miniaturization of the system can be claimed to improve robustness to harsh environment condition and reduction of the overall power consumption. An optical phased array configuration built on structure developed in a silicon photonic integrated circuit technology, may be able provide a solution to fit these requirements.

Nevertheless, there is some drawback and some fabrication complexity that can be limiting the direct application for automotive solution in a low-cost configuration. At the same time, other application fields, like for example biomedical under skin imaging systems, can be proposed as a possible playground for a silicon photonics Lidar Time-of-Flight working in the near infrared range of wavelengths. In this work, it is presented the design and the simulation of an amorphous silicon phased array working at a wavelength of 1550 nm. Potential and limitation of this approach will be outlined.



Light Directionality of an a-Si:H Optical Phased Array with seven parallel waveguides.

Keywords: Lidar, Amorphous Silicon, Optical Phased Array.

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Ocular accommodation and wavefront aberration in university students

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Abstract. Ocular wavefront aberrations (WA) mainly result from a balance between the cornea and the crystalline lens optical aberrations. It is known that ocular WA play a role in the accommodative response and that they change when accommodation is stimulated. University students are expected to spend significant time performing near vision tasks, leading to an important accommodative effort that can impact the ocular WA. Therefore, it is important to evaluate this impact on the university students during their time at the university.

This study aims to evaluate the impact of the near vision tasks in the vision system by assessing the changes in WA induced by ocular accommodation in university students during the three years of their academic path.

Fifty-four undergraduate students were recruited from the first to the final year of their courses (74% female; 26% male), with a mean age of 20.85 ± 2.94 years. A Hartmann-Shack wavefront aberrometer WAM700+, (Essilor Instruments USA) was used to measure the ocular WA for far and near vision. After the measurements, the ocular aberration values were exported in the form of Zernike coefficients up to the sixth order, and the root-mean-square (RMS) was computed for LOA, HOA Total aberrations.

The changes in Z (2, 0), LOA RMS and total RMS were significantly increased between the first year and third year (P-value <0.05). Moreover, the changes in spherical aberration induced by accommodation also increased over the three years, being statistically significant between the first and the last year (p = 0.02). The results suggested that during the three years at the university, the accommodative response suffered an increase impacting the primary spherical aberration for near vision.

Keywords: Ocular accommodation; Ocular optical quality; University students;

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Effect of accommodation on coma at central and peripheral retina

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Abstract. Coma is one of the most common ocular higher order aberrations and highly affects the quality of image. It is assumed that corneal aberrations are balanced by internal (lenticular) aberrations so that retinal image quality may not have great impact. However, during accommodation, the shape, position, and curvature of the crystalline lens changes which might disrupt this balance between internal and corneal aberration. This study aimed to investigate the effect of accommodation on primary coma (C_3^{-1} and C_3^1) and secondary coma (C_5^{-1} and C_5^1) in relaxed and accommodated eyes. Zernike coefficients were measured in 53 subjects with Hartmann-Shack aberrometer both at the central and peripheral retina up to 30º off-axis in horizontal and vertical meridians. The process was repeated with 2.50 D accommodation stimulus and comas were compared with and without accommodation. Root-mean-square of total coma was also assessed. With accommodation, vertical comas changed to more negative value and horizontal comas changed to more positive values in most of the off-axis positions. In contrary, the secondary vertical comas became less negative and secondary horizontal comas became more negative with accommodation in most of the off-axis fixations. Thus, the results showed that accommodation affects coma which depends up on position of the fixation.

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Influence of absorptive tinted filter lenses on contrast sensitivity in healthy participants under three different environmental conditions

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Abstract. Purpose: The present study aimed to analyse the influence of absorptive tinted filter lenses on Contras Sensitivity (CS) in healthy participants under three different environmental conditions. Methods: 10 Healthy qualified volunteers who fulfilled the inclusion/exclusion criteria were recruited: refractive spherical error between +2.00 and -4.00D, refractive cylindrical error less than 1.00 D, Best Corrected Visual Acuity (BCVA) ≥ 1.0 and Low Vision Quality of Life (LVQOF) score ≥ 50. Participants were scheduled for three-session under different environmental conditions where CS was measured with a Pelli-Robson chart with and without five (ML Filters 450, 500, 511, 527 and 550) absorptive tinted filters lenses: 1) indoor, 2) outdoor on a sunny day, 3) outdoor on a rainy day. The filters were always introduced in the same order, from the higher absorption filter (ML Filter 550) to the lower (ML Filter 450). Results between filters and environmental conditions were compared. Results: There was a statistical difference in the CS values obtained with and without a filter in the measurements performed in all environmental conditions (Friedman test: all $p < 0.001$) with no differences in the pairwise analysis between filters (Wilcoxon test; all ≥ 0.009). There was no statistically difference in the CS values between environmental conditions without filters or with any of the filters (Friedman test: all $p \geq 0.097$). Conclusions: The present study found that coloured filter lenses between 450 and 550 nm wavelength absorption had minimal impact on CS in healthy participants.

Keywords: contrast sensitivity, absorptive tinted filter. Low-vision.

Meibomian gland loss area and its relationship with eyelid margin hyperemia and MG orifice plugging

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Abstract. Purpose: The aim of the present study was to state a relationship between the meibomian gland loss area (MGLA), eyelid hyperemia and meibomian gland (MG) orifices plugging in a sample of university students. Material and methods: A total of 74 participants were recruited. Meibography images were obtained with the OCULUS® Keratograph 5M and MGLA was calculated using the ImageJ software; also, MGLA was categorized following the Meiboscale into 4 groups: group 1 (<25%), group 2 (25-50%), groups 3 (50-75%), and group 4 (>75%). An exhaustive slit lamp examination of both eyelids was performed. Eyelid margin hyperemia and MG orifices plugging of each eyelid were categorized following Arita et. al grading scales. Results: A significant statistical relationship was found between MG orifices plugging and MGLA for both eyelids (Fisher's exact test; both $p < 0.019$). Also, correlations were obtained between lower MGLA and lower MG orifices plugging (Cramer-V = 0.583, $p \leq 0.001$); and between upper MGLA and upper eyelid margin hyperemia (Cramer-V = 0.418, $p = 0.023$), and upper MG orifices plugging (Cramer-V = 0.413, Fisher's exact test: $p = 0.042$). Conclusion: MGLA varies depending on MG orifices plugging provoking the subsequent eyelid margin hyperemia.

Keywords: Meibomian Glands, Orifices Plugging, Meibography, Eyelid Margin Hyperemia

Differences in the values of Anaglyphs, vectograms and cheiroscopes on participants with low, normal, and high AC/A ratio

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Abstract. Purpose: Anaglyphs, Vectograms and Cheiroscopes are visual therapy materials based on red/green, polarized, or black/white targes that used similar but slightly different images for each eye to train fusion and vergence skills. This study aimed to analyse the differences in the results obtained on those devices on participants with low, normal, or high AC/A ratios. Material and methods: three groups of volunteer participants were recruited based on their recent clinical history among patients attending the Optometry Clinic of the centre: 15 participants with low AC/A, 15 participants with normal AC/A and 15 participants with High AC/A ratios. None of them was under any type of medication, have an ocular or systemic disease, or were performing any kind of visual training plan that could affect the study. In two sessions one week apart, following manufacturer's instructions, the participants performed in a random order three visual therapy device-based training: one red/green Fixed Demand Anaglyph [FDA], one Variable Demand Polarized Vectogram [VDPV], and the based on the Wheatstone W [WW]. Participants were instructed to indicate the maximum value base-out (BO) where both image fusion and clarity was lost. Results between both sessions were compared with an analysis of differences. Results: There was found higher BO vergences results with the three devices regarding the second to the first session in the Low and Normal AC/A groups (t-test for paired samples, all $p \leq 0.006$), but none in the High AC/A group (t-test for paired samples, all $p \geq 0.154$). Conclusion: There is an enhancement of BO vergences in Low and normal AC/A participants but not in high AC/A participants by performing visual training with Anaglyphs, Vectograms and Cheiroscopes devices.

Keywords: AC/A ratio, Fixed Demand Anaglyph, Variable Demand Polarized Vectogram, Wheatstone W

Comparison of three methods for measuring far and near vision heterophoria in free space

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Abstract. Purpose: The aim of the present study was to evaluate the agreement between three methods to measure far and near vision horizontal heterophoria in free space. Material and methods: A sample of 40 healthy young subjects was recruited for the present study. Participants attended a single session where far and near vision phoria were measured with three different devices (Cover Test, Modified Thorington test and OptoTab SERIES) under the same conditions of environmental lighting, primary viewing point and best refractive correction. Two examiners conducted the tests in random order to avoid variables like fatigue or practice. The results of the three methods were compared by Friedmann and Wilcoxon test. Results: Significant differences were found between the three methods in far vision measurements (Friedmann test; $p < 0.001$), whereas no between Cover Test and OptoTab POLAR when differences between pairs were checked (Wilcoxon test; $p = 0.735$). No significant differences were found between the three methods in near vision measurements (Friedmann test; $p = 0.504$). Correlations were weak between methods for far vision phoria, but good between methods for near vision phoria, particularly between the Cover Test and the Modified Thorington test ($r = 0.852$; $p < 0.001$) Conclusion: The three devices are interchangeable for near vision measurements while this condition is only true for Cover Test and OptoTab POLAR on far vision.

Keywords: heterophoria, Cover Test, Modified Thorington test, OptoTab SERIES

Analysis of the Interferential Lipid Pattern change through 4 and 6 years in Dry Eye Disease patients

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Abstract. Purpose: Dry Eye Disease (DED) is a chronic disease with a high prevalence among the global population and an increasing public health problem. No large number of studies describes the natural course of the disease. The aim of the present study was to analyse the evolution of the interference Lipid Layer Pattern (LLP) in a 4- and 6-year period on untreated DED patients. Material and methods: The sample was formed by 80 untreated DED patients divided in two groups (40 patients each). Patients were examined in two sessions: the first session was the basal, and the second session was performed in two periods (4 or 6-years since the basal session). Patients attending to the second session in the 4-years period formed Group 1, thus patients that attend in the 6-years period formed Group 2. The LLP was evaluated with the Tearscope-plus in both sessions. The LLP was classified following 3 different scales: the Guillon´s Scheme, Guillon´s Scheme with intermediate patterns and the Colour Scheme. Results: values were significantly lower for Group 1 in session 2 in all the scales: the Guillon's scheme (p=0.007), the Guillon´s Scheme with intermediate patterns (p=0.009) and the Colour Scheme (p=0.018). The values for Group 2 were significantly lower in session 2 in all the scales: in the Guillon´s Scheme (p=0.008), the Guillon´s Scheme with intermediate pattern (p=0.003) and the Colour Scheme (p=0.003). Conclusion: In untreated DED patients after 4 and 6 years, the LLP turns thinner showing a worsening of the disease during its progression.

Keywords: Dry eye disease, Tearscope, Tear film, Lipid layer pattern.

Hyperspectral Colorimetry of in-vivo dental structures

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Abstract. Accurate determination of tooth color is necessary to reproduce natural appearance of teeth in dental restorations. Hyperspectral imaging can provide point-by-point reliable reproduction of the colorimetric properties of the tooth surface. The aim of this work is to use a hyperspectral capture method to develop a mapping system for the analysis and colorimetric characterization of in-vivo teeth.

Material and Methods. Hyperspectral captures (Specim IQ, 400-1000 nm, 3nm spectral-resolution, 512x512px spatial-resolution) of in-vivo upper central (UCI) and lateral incisors (ULI) belonging to 15 subjects (45º/0º illumination/measuring geometry; D65 LED programmable light source) were performed. CIE L*a*b* chromatic coordinates were calculated for incisal *(I)*, middle *(M)* and cervical *(C)* third of each tooth. ΔE^*_{ab} and ΔE_{00} total color differences were computed between different teeth and teeth areas and compared with corresponding perceptibility (PT) and acceptability thresholds (AT).

Results. Very small color differences were found between UCIs or UCLs of the same patient. UCIs exhibited higher L* and lower b* and a* values compared with UCLs, indicating a brighter and less chromatic appearance. Mean ΔE^*_{ab} and ΔE_{00} between UCI and UCL exceeded corresponding PT and AT (ΔE^*_{ab}=7.29-7.79; ΔE_{00}=6.37-6.81). Large chromatic variations between *I*, *M* and C areas of the same tooth were found. For UCIs, L* coordinate increased from *C* to *M*. UCLs had a similar behaviour, with a slight decrease of L* for the *I* third, due to different anatomy. There was a continuous decrease from *C* to *I* third of a* and b* values. Color differences between tooth areas exceed both PT and AT (ΔE^*_{ab}=7.12-10.06 and ΔE_{00}=5.17-8.59).

Conclusion. The use of a hyperspectral camera has proven to be a reliable and effective method for color mapping of in-vivo natural teeth, allowing a complete and integrated evaluation of different teeth or different areas of the same tooth.

Keywords: Hyperspectral Imaging, Color, Dentistry, Optical Properties.

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Reservoir computing with nonlinear optical media

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Abstract. Reservoir computing is a versatile approach for implementing physically Recurrent Neural networks which take advantage of a reservoir, consisting of a set of interconnected neurons with temporal dynamics, whose weights and biases are fixed and do not need to be optimized [1]. Instead, the training takes place only at the output layer towards a specific task. One important requirement for these systems to work is nonlinearity, which in optical setups is usually obtained via the saturation of the detection device.

In this work, we explore a distinct approach using a photorefractive crystal as the source of the nonlinearity in the reservoir. Furthermore, by leveraging on the time response of the photorefractive media, one can also have the temporal interaction required for such architecture. If we space out in time the propagation of different states, the temporal interaction is lost, and the system can work as an extreme learning machine. This corresponds to a physical implementation of a Feed-Forward Neural Network with a single hidden layer and fixed random weights and biases [2]. Some preliminary results are presented and discussed.

Keywords: Extreme learning machines, Reservoir computing, Photorefracive media, Nonlinear optical media

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Detection of Acetic Acid Using a Balloon-type Optical Fibre Sensor

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Abstract. Food security and safety are an issue of growing concern to our society. Acetic acid is a compound that is often used as a food preservative and additive, but it is also produced during food processing and constitutes an important marker of food quality. Traditional methods of analysis such as chromatography, spectroscopy, or immunology assays, while accurate, sensitive, and selective, are also costly and time-consuming. Optical fibre sensors have emerged as a promising and versatile alternative for the detection of food contaminants, with several advantages over traditional methods, providing fast and sensitive responses, while remaining relatively small and inexpensive. In this work, we propose a balloon-shaped optical fibre sensor, consisting of a section of capillary tube spliced between two sections of single-mode fibre, for the simultaneous measurement of refractive index and temperature. The sensor was characterised in regard to its response to the refractive index, using thirteen aqueous solutions of increasing concentrations of acetic acid in the range of 0 to 60% (v/v), and to its response to temperature in the range between 22.7 and 48.0 °C. A sensitivity of 5 pm/ºC was attained for temperature. Measurements were performed at 1594.8 nm, providing a maximum sensitivity of 181.2 nm/RIU for the refractive index variations, with a resolution as low as 1.35 x 10^{-5} RIU.

Keywords: Balloon-shaped sensor, refractive index sensing, temperature sensing, acetic acid.

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Autonomous Optical Tweezers: from automatic trapping to single particle analysis

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Abstract. Optical trapping (OT) is a versatile and non-invasive technique for single particle manipulation. As such, it can be widely applied in the domains of particle identification and classification and thus used as a tool for monitoring physical and chemical processes. This creates an opportunity for integrating the method seamlessly into optofluidic chips, provided it can be automatized. Yet, even though OT is well established in multiple scientific domains, a full stack approach to its integration into other technological devices is still lacking. This calls for solutions in tasks such as automatic trapping and signal analysis.

In this poster presentation, we describe the implementation of an algorithm seeking autonomous particle location and trapping. The methodology is based upon image-processing, allowing for particle location using real time image segmentation. A local thresholding algorithm is applied, followed by morphological techniques for closing shapes and excluding non-bounded regions – after which only the particles remain on the image. Once the centroid is identified, the stage is translated accordingly by piezo-electric actuators, followed by the laser activation. In this way, trapping is achieved, and one may proceed to analyze the forward scattered optical signal, after which a new particle inside the actuators range may be automatically trapped.

This development, when compared with existent solutions involving holographic optical tweezers, allows for similar capabilities without using a spatial light modulator, thus dramatically reducing the setup costs of autonomous OT solutions. Therefore, when combined with particle classification techniques, this method is well suited for integration into possible optofluidic chips for autonomous sensing and monitoring of biochemical samples.

Keywords: Optical Tweezers, Optical Trapping, Signal Processing, Machine Learning

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Absorption and scattering coefficients in the 240-780nm range of daily disposable contact lenses

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Abstract. The constant growth in prescription of daily disposable (DD) Ultraviolet (UV)-blocking soft contact lenses (SCL) requires an in-depth study and understanding of their optical properties. The Inverse-Adding-Doubling (IAD) method, allow fast and accurate measurements of a large variety of optical properties. The main objective of the present work is to make a comparative evaluation of the absorption (μ_a) and scattering (μ_s) coefficients of different types of UV-absorbing DD SCLs.

Material and Methods. Four different UV-blocking DD SCLs (BVP -0.5D; n=3) were studied: Somofilcon A (CC; CooperVision); Etafilcon A (AM; Johnson&Johnson); Ocufilcon and Filcon V3 (SH and SS; Servilens). Absorption and scattering coefficients within 240 - 780nm range were derived from the spectral diffuse transmittance and reflectance measurements using the IAD method set-up (two coupled integrating spheres (60mm diameter), Xenon UV-VIS-NIR light source, two fiber-coupled identical spectrometers).

Results. For the 240-380nm range, high μ_a (peak between 350-360nm) and high μ_s values were found for all DD SCLs. The highest μa values were found for AM, followed by CC, SS and SH all with similar values but considerably lower than AM. AM lenses were also the most light dispersing, followed closely by CC, while SS and SH exhibited similar μ_s values but considerably lower than AM and CC. For the visible range, μ_a and μ_s values for all DD SCLs were low (with a slight increase of μs for wavelengths > 550nm), therefore not affecting their optical quality and performance

Conclusion. Although the amount of absorbed or scattered light differed, all tested DD SCLs comply with claimed UV-blocking, as they exhibited high absorption and scattering in the UV-range. For the visible range, all lenses efficiently transmit light, as shown by low μ_a and μ_s values. Among tested DD SCLs, Etafilcon A were the best performing, from an optical point of view.

Keywords: Absorption coefficient, Scattering coefficient, Inverse Adding Doubling, Contact lenses, UV

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Guiding losses estimation in hydrogel-based waveguides

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Abstract. The use of waveguides based on hydrogels for clinical therapy is arousing great interest in the field of medicine and optogenetics, as they allow the distribution of light several centimeters deep in human tissues, without causing damage to the patient [1,2].

A key parameter to determine its applicability is the attenuation experienced by the optical power along the waveguide. The well-established cut-off method, in which the output power is measured for progressively shorter waveguide lengths, has a number of drawbacks: it is destructive, requires longer samples and requires a certain time to prepare the sample between measurements.

In this work, an alternative method of measuring the attenuation in hydrogel waveguides through the recording of the power laterally diffused by the sample, which can be considered proportional to the guided power, is studied. Samples with CN monomers dissolved in water were used, having reached an equilibrium state. Three lasers centered at 450 nm, 532 nm and 633 nm were used to excite the hydrogel-based waveguides. A computer-controlled Canon EOS 1000D camera was used, allowing independent detection in the R, G and B channels. For each sample, pictures were taken seeking maximum contrast without reaching saturation.

First, attenuation values measured by means of both methods were compared and a difference of less than a 5% was obtained. Then, knowing the response curve of the CCD of the camera, from the recorded data the relative exposure was extracted and by fitting its longitudinal evolution to an exponential decay the attenuation coefficients were determined for the three channels. Finally, by using the absorbance spectrum and Rayleigh law, the losses contributions (absorption, scattering and guiding) can be uncoupled and coefficients for each of the contributions can be obtained. CN+H_2O (eq)-based waveguide guiding losses are estimated to be below 0.1 dB/cm.

Keywords: hydrogel-based waveguides, attenuation, guiding loss

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Noise analysis in self-interference incoherent digital holography

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Abstract. Self-interference incoherent digital holography (SIDH) has been intensively developed over the last 15 years for 3D imaging [1]. In SIDH, each point of the 3D object under spatially incoherent illumination emits a spherical wave which is split into two mutually coherent spherical waves with different radii that interfere on the optical sensor plane. The sensor records incoherent summation of the holograms created by all objects points. For inline SIDH, at least three phase-shifted incoherent holograms are recorded to build a complex valued hologram for reconstruction without the zero-order and the twin image.

Regardless of the way the SIDH system is implemented (splitting based on usage of SLM, interferometer or geometric phase lens), it is characterized by a high noise level and granular-like reconstructions. Despite the significance of the noise issue, the in-depth noise analysis in these systems is still missing, although analytical evaluation of using a broadband source and of the sensor sampling impact has been made and approaches for noise reduction by averaging have been reported. In the present work, we analyze the noise impact by numerical modelling of recording and reconstruction in a SIDH system. Angular spectrum approach is applied for modelling light propagation between the optical elements in the system. Additive detection noise is generated independently for four phase-shifted holograms according to the known noise models appropriate for CCD/CMOS cameras. Simulation includes monochromatic and broadband illumination. Noise behaviour at reconstruction of a single point source, different number of separate point sources and plane objects is studied and compared to experimental data.

Keywords: digital holography, incoherent, self-interference, modelling

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Thermoelectric imaging using photothermal radiometry of carriers, photoluminescence mapping in aged samples of GaAs:Sn

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Abstract. In the present work, the results of images obtained by non-destructive and non-contact spectroscopic techniques are reported for the evaluation of photothermal radiometry of carriers (RFP) in the frequency domain, a rapid photoluminescence mapping system (RPM2000), in aged samples of GaAs: Sn. The techniques were applied at room temperature, for the optical characterization of aged GaAs semiconductor samples, doped with different concentrations of tin (Sn) impurities. These samples have been studied in order to establish their thermoelectronic and photoluminescent homogeneity, taking into account aging under ambient conditions. It was found that aging caused a defect associated with a band other than and that this defect depends on the type and concentration of the impurities.

Keywords: Resonant tunnelling diode, optoelectronic oscillator, laser diode, injection locking

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Methods of optical fibre probes machining for holographic micro-endoscopy

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Abstract. With the use of state of the art light microscopy methods, we can image the tissue with sub-cellular resolutions down to 1.5 mm. Beyond this reach, the light must be delivered to the target region by optical relay elements inserted into the tissue – the fibre endoscopes. [2,3] With fibre micro-endoscopes, we can reach depth down to 5 mm (mostly the bottom of a living mouse brain) with negligible tissue disruption and keep the resolution equal to 1 micrometre, still sufficient for in vivo microscopy. [3] We designed a custom-made device for optical fibre tips machining. The presented poster will focus on optical fibre probe manufacturing (stripping, etching, polishing, splicing and coating) and on their impact on imaging quality and performance [1].

Keywords: optical fibre, micro-endoscopy, etching, polishing, splicing.

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Integrating Laser induced breakdown spectroscopy and photogrammetry towards 3D element mapping

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Abstract. Laser-Induced Breakdown Spectroscopy (LIBS) is a well-established analytical technique based on the spectroscopic analysis of the radiation emitted by an induced plasma created after laser pulse ablation of a sample. Being localized at the focal spot, the technique allows timely surface and volumetric elemental mapping of the sample with micrometer precision collected at high acquisition rates. After the acquisition process, versatile visualization tools are of paramount importance for the interpretation of the results. Nevertheless, while solutions for 2D distributions[1] are available commercially and can be easily implemented with standard programming libraries, 3D solutions are still lacking.

In this work, we explore the combination of photogrammetry and LIBS techniques for the creation of a 3D model of the spectral map of the sample. Using a dedicated photogrammetry setup and software, we reconstruct a 3D model of the mineral sample before analyzing it, establishing a process pipeline that results in the creation of a 3D playground to interactively interpret the results. In particular, we make use of Paraview software, which integrates production algorithms and computing performance in a unified solution for scientific purposes.

Our results demonstrate that combining these two techniques can give us a valuable resource for better qualitative analysis, providing a three-dimensional model that can be further analyzed interactively. These findings open the door to a new range of possibilities, from quality control technology involving alloys and mechanical parts to interactive teaching environments for geo and biosciences, just to name a few examples.

Keywords: Laser induced breakdown spectroscopy, Photogrammetry, Minerals

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Listening plasmas in Laser Induced Breakdown spectroscopy

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Abstract. While the most important source of information in Laser-breakdown induced spectroscopy (LIBS) is the plasma emission itself, the by-products of the process like the emitted sound may also correlate with characteristics of the experiment, opening a window of opportunity for multimodal sensing. In this context, one of the most interesting examples in LIBS is the use of microphones to capture the sound of shock waves. Empirical analysis suggests that the sound captured by a microphone may contain information on the plasma properties such as volume, density, and even temperature, which in the second-order can be related to the sample characteristics such as its composition, humidity, and hardness[1]. Yet the relation between physical parameters and shock wave characteristics can be sometimes complex and hard to deconvolve, thus needing a careful analysis for each case study.

In this work, we report on the possibility of relating plasma properties with the sound from the shock waves in multiple materials, from metals to minerals. First, by analyzing the behavior of shock wave sound from homogeneous reference metallic targets, we investigate the relation between plasma properties and sound signal, demonstrating that distinct materials and plasma characteristics correspond to distinct plasma sound fingerprints. Furthermore, it also demonstrated a correlation between plasma variability and the collected sound. Finally, additional preliminary results demonstrate that sound can be used to identify minerals in geological samples at some extent. In conclusion, the findings presented suggest that microphones are accessible sources of information in LIBS systems, that can be used for rapid diagnosis of plasma and sample properties while paving for other technological applications such as identifying hardware malfunctions in autonomous systems.

Keywords: Laser induced breakdown spectroscopy, Shock waves, Minerals

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Multimodal approach to mineral identification: merging Laser induced breakdown spectroscopy with hyperspectral imaging

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Abstract. The capability to perform localized analysis combined with high rate of acquisition makes Laser Induced Breakdown Spectroscopy (LIBS) one of the most interesting tools for mapping elements in solid and heterogeneous samples. For these reasons, it is rapidly becoming a go-to tool for fast qualitative analysis of the presence and absence of major, minor, and even trace elements, providing interesting insights into a multitude of fields from geology to heritage conservation.

While it is often a standalone technique, LIBS can also work as a tandem solution, combined with other techniques such as UV-VIS-NIR, Raman spectroscopy, or hyperspectral imaging. Concerning the latter, hyperspectral imaging hardware is capturing significant attention for industrial applications and remote sensing by providing novel information from the analysis of the irradiance at invisible regions of the electromagnetic spectrum, allowing it to rapidly discriminate materials in a non-invasive and remote fashion.

In this work, we try to identify possible synergies that arise from merging the analysis from the two techniques and comparing it with the performance of standalone solutions. Having investigated the multimodal approach for a case study involving the identification of lithium minerals, our preliminary results demonstrate that while both solutions can provide reasonable results for qualitative mineral identification, they feature advantages and disadvantages that shall be taken into further consideration. Nevertheless, when working in collaboration, the results enclosed suggest that an integrated tandem solution can be an interesting tool for material analysis for research and industrial applications, combining the best of both instruments.

Keywords: Laser induced breakdown spectroscopy, Hyperspectral imaging, Minerals

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Drying Patterns of Cerebrospinal Fluid as Indicator for Alzheimer's Disease by a Machine Learning Framework

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Abstract. Cerebrospinal fluid (CSF) contains specific biomarkers of Alzheimer's disease (AD) that include amyloid beta peptides and tau proteins. Here we present for the first time possible evidence that the formation of the constituents of CSF during drying is related with AD. We use machine learning to examine optical microscope images of dried CSF patterns from patients with AD and healthy controls to create a diagnostic model. CSF samples were obtained by a lumbar puncture done by clinical doctors. The liquid is filtered by ultracentrifugation (filter Amicon® ultra-0.5) to enrich protein concentration. A 5 µL drop of each CSF sample was deposited by careful pipetting onto a quartz substrate; samples were dried in air for 20 min; dried samples were analyzed by a Zeiss microscope with a 63x objective. A total of 22 samples from volunteers were studied, of which several were clinically diagnosed with AD. From each patient/sample several images were acquired, such that 166 images were available for image analysis. Fig. 1a shows an example of the patterns formed within a dried drop of CSF with the typical coffee ring effect. The center of the drop (areas 3, 4) contains less proteins, forming thin fern-like patterns, and moving radially away from the center, the macromolecules accumulate in a denser fern-like pattern (area 2). The rim of the drop (area 1) forms a dense ring-shaped film. Although such patterns have been previously observed in drying patterns of protein mixtures, this is the first time relating such features to AD. Fig. 1a (right) highlights typical structural differences between healthy and AD-diagnosed patients. To analyze the images, the histogram of oriented gradients (HOG) is used as a feature descriptor. Each image is mapped into its HOG features space, and principal component analysis (PCA) is applied for dimensionality reduction. Fig. 1b visualizes the separation of healthy and AD groups by the 1st and 2nd principal component (PC). By a quadratic discriminator, AD is predicted with a sensitivity of 82%; the area under the ROC curve (receiver operating characteristics) is 0.75; the figures of merit corroborate the quality of our model, which is still based on low statistics. These promising preliminary results show great potential for new rapid and low-cost diagnostic pathways in the detection of AD.

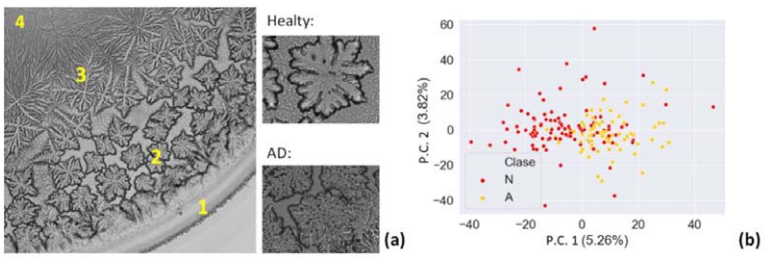

Fig. 1: (a) Microscopy image of dried CSF sample; the small images represent typical patterns from healthy and AD subjects. (b) PCA analysis from images of healthy (N) and AD (A) subjects.

Low-Cost Ultrafine Motion Control System Design for Nano Positioning and Beam Steering

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Abstract. The effects of human operation limit the precision of many optical adjustments. In practice, the lateral forces applied to a component during an adjustment often have an excessive effect, making alignments lengthy and inaccurate. Also, many optical experiments are extremely sensitive to environmental factors. Solution for the above problem is highly expensive and is inaccessible to scientific community due to financial implication.

Developed system is highly precise and low cost. System have better than 12-nm resolution with minimal backlash, and can exert a 5-lb (22-N) force. Moreover, they have exceptional long-term stability and the ability to hold their position with no power applied.

Step Controlled motorized Kinematic mirror mount: A motor driven mirror that can be controlled remotely and can be configured through software for varying operational parameters at an accuracy of **1.2±0.2** µrad.

Auto beam steering/alignment system with QPD feedback: AAS system is based on a control unit that receives signals from detectors (quadrant photo-diode) of beam position and direction, and consequently issues commands for motorized optical elements (e.g., adjustable mirrors/ stage) in order to maintain proper alignment of the beam in millisecond latency.

Above System comprises of DC Micro motor with gear reduction ration of **298:1** with hall effect encoder for accurate positioning is used to precisely control the position with an accuracy of up to **12nm** with **100TPI** screw. **1000x** programmable micro-step resolution for ultra-smooth positioning. Communication is based on **MODBUS protocol** enabling it to control up to 247 actuators using a single point of connection.

Able to attain **8000 steps** in one revolution of motor, which is when coupled with **100TPI** screw giving positional accuracy of **12 nm** approximately and **1.2±0.2** µrad angular accuracy with a minimal cost, 20times less than other similar equipment.

Keywords: Quadrant Photodiode, Kinematic mount, Actuator, Linear Actuator, Beam Steering, Laser.

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Color interferometry using the fractional Fourier transform

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Abstract. We present a mathematical modelling and an experimental work in order to implement a color interferometer using the fractional Fourier Transform (FrFT). The optical setup is based on a Lohmann's first-type system, trifurcated optical fiber and three lasers with wavelengths in the red, green and blue bands of the visible light spectrum. We implement the Young's interference experiment with circular apertures at the input plane of the optical setup and this plane is illuminated with the three lasers and the trifurcated optical fiber. Then, an FrFT is performed by using a Lohmann's first-type optical system and we show that the resulting diffraction pattern depends on the fractional order of the FrFT, the wavelengths of illumination and the separation distance of the circular apertures.

Keywords: Lohmann's first-type optical system, Young's interferogram and fractional Fourier Transform (FrFT).

Real color fractional Fourier transform holograms using fiber optics

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Abstract. A new experimental setup to obtain the complex distribution in amplitude and phase of a real color object is proposed and implemented. This holographic configuration is based on the fractional Fourier transform (FrFT) techniques and it uses a trifurcated optical fiber interferometer. Three focused lasers beams with different wavelengths in the red, green and blue bands of the visible light spectrum are passed through the optical system and we obtain two holographic images: one obtained from the reflections on the surface of the object (the hologram) and other from the transmitted reference beam. The holographic images are recorded by a CCD camera and processed using an iterative computer algorithm based on the FrFT. We show that the obtained holographic image quality is better than those generated by traditional methods.

Keywords: Fractional Fourier transform, color holography, optical fiber interferometer.

Towards real-time identification of trapped particles with UMAP-based classifiers

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Abstract. Optical trapping provides a way to isolate, manipulate, and probe a wide range of microscopic particles. Moreover, as particle dynamics are strongly affected by their shape and composition, optical tweezers can also be used to identify and classify particles, paving the way for multiple applications such as intelligent microfluidic devices for personalized medicine purposes, or integrated sensing for bioengineering.

In this work, we explore the possibility of using properties of the forward scattered radiation of the optical trapping beam to analyze properties of the trapped specimen and deploy an autonomous classification algorithm. For this purpose, we process the signal in the Fourier domain and apply a dimensionality reduction technique using UMAP algorithms, before using the reduced number of features to feed standard machine learning algorithms such as K-nearest neighbors or random forests. Using a stratified 5-fold cross-validation procedure, our results show that the implemented classification strategy allows the identification of particle material with accuracies above 90%, demonstrating the potential of using signal processing techniques to probe properties of optical trapped particles based on the forward scattered light. Furthermore, preliminary results of an autonomous implementation in a standard experimental optical tweezers setup show similar differentiation capabilities for real-time applications, thus opening some opportunities towards technological applications such as intelligent microfluidic devices and solutions for biochemical and biophysical sensing.

Keywords: Optical Tweezers, Optical Trapping, Signal Processing, Machine Learning

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Raman based DTS using a 1064 nm pump

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Abstract. Distributed temperature optical fiber sensors (DTSs) are intrinsic optical fiber sensors that can provide temperature measurements continuously along a fiber. Usually, DTSs rely in Raman based optical-time-domain-reflectometry (OTDR) technologies, in which the temperature can be obtained from the ratio between the Stokes (S) and anti-Stokes (AS) bands' powers. The AS band power is more sensitive to temperature than the S band's, in the linear regime, these bands arise from molecular vibrations of silica, providing a 13.2 THz frequency shift relatively to the pump source. The use of already installed singlemode fiber-based telecommunication networks as sensor networks together with data transmission has attracted a great interest recently, as reported in [1], [2]. Such systems can be used for multiple purposes, such as for detecting vehicle speed, road conditions and environment temperature. However, in these trials, data transmission channels were allocated for sensing purposes, decreasing the data transmission capacity. A possible solution to maintain the network capacity is to use a pump wavelength for sensing away from the transmission windows. To evaluate the viability of such systems, we developed a model based on [3], which estimates the Raman S and AS powers. A 1064 nm pump source, with a pulse width of 10 ns, corresponding to a spatial resolution of 1 m, and different peak powers, were considered. For this pump source, the S and AS bands are expected to be centered in the 1115 nm and 1015 nm, respectively. Different fiber lengths and various conditions of temperature for the fiber are evaluated.

Keywords: Distributed Optical Fiber Sensor, Raman backscattering, Optical time domain reflectometry

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Robust calibration models for the mining industry: from spectral similarity to multimodal analysis

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Abstract. Dealing with the chemical matrix of a sample is a complex challenge and one of the biggest hurdles for performing quantitative with laser-induced breakdown spectroscopy. In particular, the problem is of paramount importance for geology applications, where the heterogeneous nature of rocks allied to the multitude of constituent minerals often leads to inconsistent results for technological applications such as ore grading in mining operations.

We explore in this work the use of clustered regression calibration algorithms, that first perform an unsupervised clustering operation in the space of training samples before deploying local linear calibration models for the specific cluster. Furthermore, we investigate three distinct clustering strategies, two of them involving dimensionality reduction techniques (i)PCA and ii) UMAP), and an additional technique involving multimodal data analysis using UV-VIS spectra.

Focusing on a case study of lithium prospection in three distinct exploration drills, the results suggest that deploying local models allows to mitigate the effect of the mineral matrix and improve the performance over a wide range of concentrations. Also, the results generalize well for exploration drills on distinct rock veins in the same exploration area, which suggests that multi-level regression can be an interesting alternative. To finalize, and putting on a broader perspective, the results can inspire the development of algorithms based on this approach that can be reliable in while robust for technological applications.

Keywords: Laser induced breakdown spectroscopy, Lithium mining

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Nonlinear encryption for multiple images based on a joint transform correlator and the Gyrator transform

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Abstract. A novel nonlinear encryption system based on a joint transform correlator (JTC) and the Gyrator transform (GT) to encrypt multiple images in grayscale is proposed. The multispectral or color images are considered as a special case taking each color component as a grayscale image. All multiple grayscale images to encrypt are placed in the input plane of the JTC without overlapping. We introduce two random phase mask (RPM) keys for each image to encrypt at the input plane of the JTC-based encryption system. The total number of the RPM keys is given by the double of the total number of the grayscale images to be encrypted. The use of several RPMs as keys improves the security of the encrypted image. The joint Gyrator power distribution (JGPD) is the intensity of the GT of the input plane of the JTC. We obtain only one real-valued encrypted image for all multiple grayscale images to encrypt by introducing nonlinear modifications on the JGPD. The security keys are given by the RPMs and the rotation angle of the GT. The decryption system is implemented by two successive GTs applied to the encrypted image and the security keys given by the RPMs and considering the rotation angle of the GT. Numerical simulations are computed with the purpose of demonstrating the validity and performance of the novel encryption-decryption system.

Keywords: Optical multiple images encryption-decryption system, joint transform correlator (JTC), Gyrator transform, multispectral images, nonlinear image processing.

Double image encryption system using a nonlinear joint transform correlator in the Fourier domain

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Abstract. In this work, we present a new encryption and decryption system for two images based on a nonlinear joint transform correlator (JTC) in the Fourier domain (FD) along with four random phase masks (RPMs). The two images to be encrypted can be related to each other, but they can also be independent. The encryption system is based on the double random phase encoding (DRPE), which is implemented by using a nonlinear JTC in the FD. The input plane of the JTC has four non-overlapping data distributions placed side-by-side with no blank spaces between them. The four data distributions are phase-only functions defined by the two images to encrypt and four RPMs. The joint power spectrum (JPS) is produced by the intensity of the Fourier transform of the input plane of the JTC. This JPS is modified by two non-linear operations in order to obtain a real-valued encrypted image. The security keys of the encryption system are represented by the four RPMs, which are all necessary for a proper decryption. The decryption system is implemented using a 4*f*-processor along with the encrypted image and the security keys given by the four RPMs. Finally, the feasibility and performance of the proposed double image encryption and decryption system based on a nonlinear JTC is validated through computational simulations.

Keywords: Double image encryption, joint transform correlator (JTC), Fourier domain.

Convolution, correlation and generalized shift operations based on the Fresnel transform

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Abstract. The Fresnel transform (FrT) is commonly used to describe the free-space propagation of optical waves. In this work, we present new definitions for the convolution, correlation and generalized shift operations based on the FrT. The generalized shift operation is defined by using simultaneous space and phase shifts. The new convolution and correlation operations defined in terms of the FrT can be considered as a generalization of the usual convolution and correlation operations. The sampling theorem for distributions whose resulting FrT has finite support is formulated by using the new convolution operation introduced in this work and a new definition of the Dirac comb function. These new definitions and results could be applied to describe, design and implement optical processing systems related to the FrT. Finally, we present some centred optical systems used in holographic and optical information processing systems that can be described or modelled by the new definitions of the operations proposed in this paper.

Keywords: Fresnel transform, shift operation, convolution, correlation, optical systems.

Electricity generation from solar irradiation using the Seebeck effect

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Abstract. Different mechanisms have been developed to generate electricity from solar irradiation, such as photovoltaic cells and optical reflection or transmission concentrators that focus solar irradiation into a thermal working fluid. The Stirling dish is an optical reflection concentrator of solar irradiation that heats a thermal fluid contained in a receiver represented by a Stirling engine. In this work, we present a design of technological adaptation for the Stirling dish in order to focus the thermal energy coming from the sun by reflection in several pairs of two twisted wires composed by different materials and connected serially. The proposed technological adaptation consists of replacing the receiver of the Stirling dish system by a serial array of two different twisted conductive materials (wires) with the purpose of producing the phenomenon known as the Seebeck effect to generate electricity from the thermal energy obtained by using the solar irradiation. The selected conductive materials correspond to those with the higher electrical potential difference reported in the literature.

Keywords: Stirling dish, energy conversion, Seebeck effect, thermosolar energy.

Multiplexed holographic lenses applied to solar concentrators and passive solar trackers

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Abstract. Nowadays, there are different technologies for the conversion of thermosolar energy with multiple purposes, such as: parabolic trough collector, concentrating solar power plant, Stirling dish collector and linear Fresnel systems. These solar collector systems have some drawbacks, as they need a tracking system to follow the relative position of the sun and their mechanical support structures need to be continually maintained, which results in increased costs for the transformation of the solar energy. In this work, we propose to use volume holography as an alternative application in thermosolar concentrator technology. In order to overcome the mentioned drawbacks of the traditional thermosolar concentrators, several multiplexed holographic lenses can be recorded in a volume holographic optical element. These multiplexed holographic lenses behave like a fixed solar tracker of the light coming from the sun in different relative positions at different times of the day. Therefore, the sunlight is always focused on the same point, where a receiver is located for the transformation of this solar energy. Finally, we present numerical simulations of the design of multiplexed holographic lenses using a volume holographic optical element, with their respective performance for solar energy concentration.

Keywords: Holographic thermosolar concentrator, thermosolar concentrating technology, volume holographic.

GUI-Based Phase Retrieval Algorithm for the Reconstruction of the Longitudinal Component of Electromagnetic Beams

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Abstract. In this work we present a guided user interface (GUI) that facilitates the reconstruction of the longitudinal component of a highly focused electromagnetic beam, as has already been shown in a recent publication [1]. The GUI is based on a phase retrieval algorithm [2, 3], which instead of trying to resolve the energy content of the longitudinal component near the focal plane of a highly focusing optical system, it reconstructs the phase of the transversal components probed through a magnifying optical system. To complement the reconstruction and avoid possible local minima, we have included an acceleration parameter on the algorithm [4]. The GUI guides the user input all the key parameters needed for the reconstruction, such as the pixel size, the magnification of the probing system and the number of iterations. Moreover, the GUI also visually represents the effect of some of the parameters on the recorded field. Amongst others, the Fourier Transform of the irradiance, which helps determine the size of the Entrance Pupil of the focusing optical system, and the local phase difference between x and y components. Once the phase is retrieved, the user can check the validity of the reconstruction through an included propagation and visualization algorithm. Finally, the user can save the retrieved phases and the configuration used to retrieve them through a drop-down menu or a combination of keys.

Keywords: Focal fields, Fourier Optics, Polarization, Phase Retrieval

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Percentage estimate of the coffee seeds germination using processing of dynamic speckle images

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Abstract. Determination of germination capacity is a major concern for coffee growers. The slow seed germination and the use of traditional methods of estimation (sowing samples of a population) lead to the investment of long-time intervals, generally one to two months. In addition, transport and storage conditions, and the high sensitivity of seeds to humidity and temperature affect their germination capacity. In the present work, the analysis of the time evolution of the speckle diagram of coffee beans is performed in order to establish the presence of live embryos in seeds in short time intervals (minutes). The implemented system consists of a cell phone CMOS camera for the acquisition and transmission of the 720x480 images, a computer for the management, reception and processing of the images, a wireless local area network, a He-Ne 633 nm laser with 10 mW optical power as coherent light source, an optical diffuser and an aluminium surface for the placement of the seeds. The study shows satisfactory results in determining how many and which seeds germinate out from a given total. The use of the proposed system reduces the time to estimate the germination percentage from months to minutes. In addition, this research opens the door to future projects for the classification of coffee seeds by mechanical systems, and to projects for the prediction of crop productivity.

Keywords: Speckle, image processing, coffee seeds germination.

Optical generation of surface plasmons in graphene with femtosecond laser pulses

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Abstract: Although surface plasmons (SPs) in graphene are coupled intrinsically to *p*-polarised electromagnetic waves and form surface plasmon-polaritons [1], their generation entirely by optical means is difficult because of the large wavevector and small frequency (in the THz range) characteristic of these excitations. One of the ways to bypass this difficulty is to use two optical beams with a sufficiently small frequency difference and use a geometry where their wavevector sum up via an interaction mediated by graphene electrons.

We are aware of very few previous experimental works [2, 3] that succeed in an all-optical generation of SPs by exploiting graphene's nonlinear response with two optical beams. This nonlinear response is believed to be caused by a quadratic light-matter interaction, described by a second-order conductivity. This function was calculated in several works [4, 5]. However, these predictions do not agree between them and strongly deviate from the experimental data of Ref. [2], where the 2-nd order conductivity was estimated by measuring the differential reflectivity of the beam probe. In this work we present a new calculation of the second order conductivity that, in spite of giving a better description of the experimental results, it also fails to explain it correctly. Also, we use our conductivity to calculate the differential reflectivity in [2] and compare with the previous experimental results and possibly with those of our experiments, currently in progress.

Keywords: graphene, surface plasmons, pulsed optical pump, fentonsecond laser

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Au-ZnO thin films: Influence of gold concentration and annealing on the microstructure and plasmonic response

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Abstract. Nanoplasmonic thin films, composed of Au nanoparticles dispersed in a ZnO matrix were produced for Localized Surface Plasmon Resonance (LSPR) applications. The thin films were deposited by reactive magnetron sputtering, with different gold concentrations, followed by post-deposition annealing to promote the nanoparticles' morphological evolution, crucial for LSPR bands. Four sets of thin films were prepared, containing Au atomic concentrations of 0, 9.3, 12.4 and 18.4 at.%. The Au nanoparticles were formed in a nearly stoichiometric and polycrystalline ZnO matrix, and observed in different stages of their growth (size and shape) depending on the annealing temperature. As both annealing temperature and gold concentration were raised, large and irregular nanoparticles were formed, due to coalescence processes. Well-defined LSPR bands appeared in the films with Au concentrations of 9.3 and 12.4 at.%, but only at higher annealing temperatures (400 and 600 °C), with resonance peaks in the range from 570 nm to 615 nm. The increase of the annealing temperature also improved the LSPR properties of the Au-ZnO thin films, namely a two-fold increment of the refractive index sensitivity, showing promising responses to be tested in plasmonic applications.

Keywords: Thin films; Magnetron sputtering; Au nanoparticles; ZnO matrix; Localized Surface Plasmon Resonance

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Diffractive optical element fabrication at chalcogenide thin film surface

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Abstract. Focused electron beam used to interact with chalcogenide thin film substrate. Result of interaction presented as controlled relief formation on substrate surface after etching in alkaline amine solution. By managing focused electron beam parameters, diffractive optical elements and hidden image effect by means of digital hologram have been recorded. As the result reflected laser beam of the thin film substrate, in the near field, represents hidden image that been recorded along the hologram at the background. The possibilities of practical usage of this substrate as the material for the production of holograms and diffractive optical elements discussed in this study.

Keywords: diffractive optical elements, thin films, focused electron beam

Hand grip strength using an FP sensor embedded in 3D printed cantilever

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Abstract. A 3D printed cantilever with two embedded fibre Fabry-Perot sensors is proposed for hand grip strength measurement. The FP sensors rely on a hollow core fibre (270 µm in length, 75 µm of inner diameter) spliced between two single mode fibres thus requiring only the use of a commercial fusion splicer for the fabrication of the sensors. The cantilever structure was printed in ABS polymer, which, due to its resistance to bending, makes it ideal for this type of tests. The sensing structure was tested in 22 healthy right-handed and 22 left-handed adults to measure the hand grip strength by means of an anti-stress ball. In an initial phase of the work, the calibration of the sensors was carried out. The lateral load measurements were performed by placing the FP sensors embedded in the 3D printed cantilever in a flat platform, so that the stress was applied evenly throughout the structure. Cylindrical weights of ~250 g were sequentially positioned on top of the structure, translating into a lateral load ranging from 0.0 N to ~13.0 N. All the experiments were performed several times and by considering both the increase and decrease of lateral load. The FP sensors were characterized and sensitivities of 0.076 ± 0.003 nm/N and -0.057 ± 0.005 nm/N were attained. There was good reproducibility of the results, evidencing the reversibility of the structure. The resolution of ~-0.0179 N was estimated considering the reading resolution of 1pm. The final objective of this study was to demonstrate the feasibility of FP interferometry in measuring hand-grip strength, and by comparison with studies published in the literature, that the dominant hand of right-handed/left-handed individuals has more strength [1].

Keywords: Optical Fibre sensor; Fabry-Perot interferometer; Anti-Stress ball; Strength; Dominant hand.

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White light interferometer for Fabry-Perot cavities sensors with absolute physical measurement

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Abstract. In this work an optical fiber interrogation system based on white light interferometry for Fabry-Perot (FP) cavities was developed. The system consists of two FP cavities in series. One FP interferometer, with nominal length of 191 µm, was interrogated by a Fabry Perot cavity with nominal length of 200 µm. The interrogation system was modulated with the aid of a PZT driven by a triangular signal at 5 Hz and varying amplitude, generated by a commercial signal generator. The output signal was collected, for each amplitude, by a photodetector and displayed on an oscilloscope. The signal displayed on the oscilloscope has the shape of a sinc. When the two cavities are balanced, i.e, there is no optical path difference between them, a maximum of the sinc is observed. The advantage of this system is that it can be used to estimate physical parameters (temperature, strain) with higher resolution than commercial optical interrogators.

Keywords: Fabry Perot Cavities, White Light Interferometry, Optical Interrogators

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Fabry-Perot cavity based on silica tube with steel for Physical parameters measurements

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Abstract. In this work, a Fabry-Perot cavity (FP) based on silica tube fused between two single mode fibres for physical parameters measurements is proposed. The FP cavity consisted of a 400 µm-length silica-cavity inserted into a stainless-steel tube with ~60 mm in length. The FP cavity was characterized in temperature and strain. The temperature was measured within a range of [25, 80] ºC to which the FP sensor response presented a low sensitive of 1.3 pm/K. Furthermore, for strain measurements it revealed a sensitivity of (30.11± 0.31) pm/με. This type of FP cavity inserted into a stainless-steel tube was compared with a conventional all-fibre FP cavity with a strain sensitivity of (31.24 ± 0.10) pm/με and presenting also a very low temperature sensitivity. Finally, this sensing head design presents robustness and compact size when compared with the all-fibre FP configuration. By combining these two distinct FP configurations, one enables a strain-temperature discrimination sensor. The proposed FP sensor using stainless-stell can be useful for engineering applications where the environment requires robust sensors.

Keywords: Fabry-Perot cavity, interferometer, optical fiber

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Simulation and development of a prototype for high precision surface metrology

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Abstract. Optical techniques are used in many applications in the metrology field, namely for high accuracy surface profiling. Although there are many techniques available, a specific measurement methodology must be correctly chosen according to the specifications of the range of measurement, field and surface characteristics. In this work we simulate and develop a small prototype capable of measuring surfaces of circa 10 by 10 cm with an uncertainty of 20 μm in all directions, using the astigmatic method as baseline. The aim of this paper is then to show a dedicated and optimized optical setup that allow the surface characterization of a sample surface.

Keywords: astigmatic method, surface profiling, topology

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Development of plasmonic thin films for new biodetection approaches

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Abstract. Optical biosensors based on Localized Surface Plasmon Resonance (LSPR) are the future of biosensing detection methods. Plasmonic thin films, composed of noble nanoparticles dispersed in a dielectric matrix, exhibit peculiar optical properties based on the LSPR phenomenon, proving to be an outstanding tool in biodetection. The LSPR effect is based on the excitation of localized surface plasmons on the metallic nanoparticle's surface. Therefore, the main goal was to develop a sensitive and robust optical platform based on nanoplasmonic thin films composed of gold nanoparticles (Au) embedded in different dielectric matrices for biosensing application. After the plasmonic thin film deposition, through reactive DC magnetron sputtering and post-deposition treatments, a biorecognition layer was immobilized on the surface of Au-TiO_2 thin films providing target analyte specificity. Streptavidin and biotin-conjugated with horseradish peroxidase (HRP) were the receptor–analyte model chosen to prove the immobilization efficiency and to demonstrate the LSPR-based sensor potential. Firstly, streptavidin, the biorecognition layer, was immobilized, and the interaction between the aimed target, biotin-HRP, was confirmed by an LSPR wavelength shift. However, due to the low sensitivity of the plasmonic thin film, the LSPR response was not as expected. The sensing platform can be improved by increasing the Au-TiO_2 thin film sensitivity and functionalizing with an adhesion layer. The functionalization can promote an optimal orientation of the biorecognition elements, increasing the available biorecognition area and, thus, increasing the biointeration efficiency. Therefore, thiol crosslinker (DSP) functionalization was performed and successfully confirmed by an LSPR wavelength shift and AFM data. The immobilization of the biorecognition layer into the functionalized Au-TiO_2 thin films will be considered the following step in biosensor development. The main advantage of an LSPR-based sensor consists in the versatility of sensing ability since the main base of knowledge can be applied to other targets.

Keywords: LSPR sensing; Plasmonic Thin Film; Optical Biosensors; Nanotechnology

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Ionisation of camphor molecule doped in helium nanodroplets by EUV and soft X-ray photons

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Abstract. HHelium nanodroplets are widely considered as an ideal cold, weakly interacting host matrix for spectroscopic investigation of dopant species. However, intriguing relaxation processes occur between the dopant and the host He nanodroplet [1,2]. In this work, we present ionisation of camphor molecules doped He nanodroplet ionised by extreme UV (19 -26 eV) and soft X-ray (near C 1s edge of camphor molecule) synchrotron radiation. We employed velocity map imaging with photoelectron photoion coincidence (VMI-PEPICO) [1] to image electrons/ions generated from an ionisation event. Photoelectron energy spectra (PES) and mass spectra with 19 eV photon suggest cooling of molecular ion post ionisation. Penning transfer of excitation to dopant molecule is observed at 21.6 eV in presence of He nanodroplet. The Penning PES reveals a notable scattering of electrons in the droplets as reported earlier [2,3]. Indirect ionisation of the camphor molecule is unambiguously observed at 26 eV. A noticeable decrease in the energy of droplet correlated ionic fragments as compared to the fragments from effusive camphor molecule is observed, as seen previously [4,5]. A similar decrease of fragment kinetic energy is observed at C 1s edge.

Keywords: Camphor molecule, Doped He nanodroplet, Photoelectron spectra, Ion energy spectra

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Effect of bandwidth on Two Plasmon decay instability

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Abstract. Laser plasma interaction is one stop source of high energy electrons, ions, electromagnetic radiation ranging from THz to X-rays. Such bright particle beam and small source size has potential applications in wide range of contexts, from medical physics to defence and many other industries. To make the source viable for many applications production of high energy electrons with high repetition rate of laser is necessary. The recent developments from our group have shown that structural modification of target enhances two plasmon decay instability and boosts electron acceleration to MeV energies even at intensity of 10^{16} W/cm^2. In this work, we present the effect of bandwidth on the emission of electrons studied by manipulating the chirp of the laser pulse for its potential use with MHz lasers which have a shorter bandwidth.

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Electron spectrum and angular distribution from aerosol jet collimated by an aerodynamic lens

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Abstract. Electrons at relativistic temperatures are typically generated with laser intensity of 10^{18} W/cm^2. However, electrons of temperature at 200 keV and 1 MeV and photons of energies up to 6 MeV have been observed at non-relativistic intensities (~10^{16} W/cm^2) for single micro-droplet target of size 15μm [1] and from boric acid solid particles of size ranging from 100 nm to 1μm [2]. To bridge the gap in understanding of the physics in 1μm – 10μm particle size interaction with the laser, an aerosol generator was considered as the particle source and an aerodynamic lens to collimate the aerosol jet to increase the particle intensity. Simulation of aerodynamic lens was carried out on SimScale and the lens was fabricated according to the design. The size and velocity distribution of the jet were calculated by analysing the images of the droplets imaged with nanosecond laser pulses. In this work, we present the data from the aerosol size distribution, the electron spectrum and angular distribution obtained from the aerosol interaction with a femtosecond laser at an intensity of ~10^{16} W/cm^2.

Keywords: Aerodynamic lens, high energy electrons, laser-matter interaction, particle imaging with laser, Simscale simulation.

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Relativistic electron acceleration at non-relativistic intensities using sub-lambda targets

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Abstract: Intense laser plasma interactions have traditionally been seen as a source of accelerated charged particles and radiation and involves a transfer of energy from a laser pulse to particles. This transfer of energy from EM wave to the plasma and subsequently to individual particles have been attributed to various mechanisms and their scaling laws are well documented. At intensities of 10^{16}W/cm^2, one can ideally expect electron temperatures of 50keV. Recent studies conducted at our lab have shown that at similar intensities, with certain structural modifications of the target, one can get a temperature enhancement of 20 times, with maximum electron energies reaching up to 6MeV. The structural modification is brought about by carefully designing the low intensity pre-pulse that precedes the main pulse. The emissions were studied both experimentally and through simulations to reveal the exact mechanism leading to this enhancement. Parametric Instabilities triggered by the modifications were ascertained to be the chief cause of this energy enhancement. The emitted electrons had a very distinct directionality and was released in bright ultrashort bunches, thus making this technique a promising contender for various applications – both scientific and commercial. The emission ranges that were only possible with low repetition rate multi-terawatt laser systems could now be realized using a high rep-rate sub-terawatt university class laser. The above experiments were conducted using particles that were several multiples of the laser input wavelength in size, thus ensuring the occurrence of the concerned structural modification. The change in the density profile was largely expected to have a stringent dependence on the initial target structure, but experiments have proved the contrary. In later studies it was observed that even with smaller targets (some of them smaller than the wavelength of light) similar temperature enhancements could be seen in the electron emission spectra, thus offering an incentive for further exploration of such systems.

Keywords: laser plasma interaction, two plasmon decay, ultrafast intense laser, nano-particles, relativistic electron.

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Peripheral optics in the eye: from myopia to cataracts

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Abstract. The optical quality of the images formed by the eye in the retina imposes a physical limit to our vision. For decades, the eye's optics has been mainly studied on axis, typically at the fovea where the eye has its maximum spatial resolution. However, beyond the fovea, the quality of the eye in the periphery of the retina presents special characteristics. In the last years, there has been a renewed interest in this area fueled by two important applications. On the one hand, it was suggested that optical errors in the periphery could trigger the development of myopia in children. On the other hand, it was discovered that the crystalline lens have a protective effect for the peripheral optics that was missed after cataract surgery when intraocular lenses were implanted. In this talk, I will revise the state of the art of this area with special emphasis in the results of my lab including the design and clinical result of a new intraocular lens to improve peripheral optics in pseudophakic patients.

Some recent advances in color science

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Abstract. We will discuss some of main topics in two recent publications on color from the International Commission on Illumination (CIE): CIE 015:2018 [1] and CIE 248:2022 [2]. Regarding CIE 015:2018, it is the 4th edition of most important CIE general publication on color science, generally known as 'CIE 15' publication. Among main novelties of CIE 015:2018 with respect to its previous edition, dated 2004, we can mention the introduction of the next four topics: 1) cone-fundamental-based colorimetric observers; 2) new CIE illuminants (indoor daylight illuminants, smoothed daylight illuminants, illuminant E, LED illuminants); 3) CIE colour appearance model CIECAM02; 4) CIE 2017 color fidelity index. As a consequence of the active research on color appearance during the past few years, CIE 248:2018 proposed the CIECAM16 color appearance model for related colors and CIE 1931 standard colorimetric observer. In general, color appearance models provide a viewing-condition-specific method for the transformation of the tristimulus values X, Y, Z, to or from perceptual attribute correlates. CIECAM16 replaces CIECAM02 and may be useful for color management systems or used in the imaging industries. CIECAM16 is simpler and maintains the CIECAM02 predictions of experimental visual data. Finally, we will discuss advances on two issues related to color within the currently proposed CIE Research Strategy [3]: 1) A roadmap toward a new CIE colorimetry based on cone fundamentals, currently studied by CIE Technical Committee 1-98; 2) Color differences in tri-dimensional object colors and spatio-chromatic complexity, currently studied by CIE Technical Committees 8-17 and 8-14, respectively. In overall, we can conclude stating that color science is an active inter- and multi-disciplinary research field where optics continues playing a key role.

Keywords: colorimetry, color appearance, color difference, color rendering, cone fundamental.

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Color prediction of monolithic and layered dental resin composites of varying thicknesses

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Abstract. **Objectives:** Resin composite is the material of choice for direct anterior restorations. Newer composites are offered with different translucency levels, usually referred as dentin and enamel shades which are layered to mimic the optical properties of the teeth. The main objective of this study was to develop a regression predictive method for color estimation of monolithic and layered dental resin-based composites of varying thicknesses.
Material and method: Monolithic and bi-layer pellets of 2M2, 3M2 and 4M2 shades of VITAPAN Excell were used in this study. The monolithic samples were manufactured at 5 different thicknesses within 0.5–2.5 mm range while 14 bi-layered samples were manufactured by combining different clinically relevant thicknesses of dentine and corresponding enamel shades. A non-contact spectroradiometer (PR 670, Photo Research) with CIE 45o/0o geometry was used to measure the spectral reflectance of all samples over a standard black background. Second degree polynomial regression was used to estimate the CIE L*a*b* color coordinates. CIEDE2000 total color difference (ΔE_{00}) was used as performance tool, by comparative assessment with 50:50% acceptability (AT) and perceptibly (PT) thresholds for dentistry.
Results: For color prediction of monolithic samples, mean color difference among predicted and measured (real) color was ΔE_{00} = 1.24, with 80% of the color differences (ΔE_{00}) lower than AT and 46.6% lower than PT. In the case of the bi-layered samples, the mean color difference among predicted and measured (real) color was ΔE_{00}= 0.87, with 86.6% of the ΔE_{00} lower than AT and 53.3% lower than PT.
Conclusions: The proposed predictive method allowed color estimation of monolithic and layered dental resin-based composites of varying thicknesses with a high degree of accuracy. These results open the way for custom design and manufacture of dental resin composites and could be a useful tool for the clinical success of dental restorations.

Keywords: predictive method, color coordinates, color thresholds, spectroradiometry, dental materials.

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Effect of thickness and printing angle on color of 3D printing dental restorative polymer-based materials

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Objective: Digital technology has leaded to a breakthrough in restorative dentistry. This allowed development of a large variety of 3D printed materials with different applications in dentistry. This study explores the effect of thickness and printing angle on the color of recent 3D printed dental restorative polymer-based materials.

Materials and Methods: Specimens of 0.5, 1.0, 1.5 and 2.0mm thick (n=3) corresponding to A1, A2 and A3 shades of Freeprint® Temp (DETAX GmbH, Germany) were manufactured using a DLP printer (Asiga Max UV 385) with a 62microns pixel resolution and 0º and 90º printing angles. CIE L*a*b* color coordinates of all samples were calculated form spectral reflectance measurements over a black background using a spectroradiometer PR-670, CIE D65 illuminant and the CIE 45°/0° geometry. CIEDE2000 color difference (ΔE_{00}) between samples with different thicknesses and printing angles, for all shades, were evaluated by comparative analysis with corresponding 50:50% perceptibility (PT) and acceptability (AT) thresholds.

Results: L*, a* and b* coordinates increase with thickness of the sample, with ΔE_{00} greater than AT (1.8 units) for all shades. When different printing angles were used for manufacturing, the color differences found for each shade were $\Delta E_{00\,(0^o\text{-}90^o)}$ A1= 2.6, 1.0, 2.5, 1.4; $\Delta E_{00\,(0^o\text{-}90^o)}$ A2= 0.7, 0.6, 1.0, 3.0 and $\Delta E_{00\,(0^o\text{-}90^o)}$ A3= 0.9, 0.4, 1.2, 2.1 for 2.0, 1.5,1.0 and 0.5mm thick samples, respectively. Except for A1 and for 0.5mm thick samples, PT<ΔE_{00}>AT were registered. Thus, in general, color change due to difference in printing angle is visually perceptible and depends on the thickness and shade of the sample.

Conclusions: Color of 3D printed dental polymer-based materials is influenced by its thickness and the used printing angle. Such behavior must be considered by dental technicians to achieve an appropriate dental restoration.

Keywords: 3D printing, Color, Dental restorative polymer.

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Standardization of Diffractive Optical Surfaces

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Abstract. Although optical elements with diffractive features exit since many years, fabrication processes for these are still not as common as those for corresponding purely refractive optical elements. This is mainly due to primarily non-mechanical fabrication processes such as lithographic and replication techniques, arising the necessity to develop new manufacturing, testing and handling skills of the technicians. Moreover, up to ten times more parameters are required to characterize and tolerance the complex discontinuous nanometric surface geometries. Starting from a general analysis of the current situation in optical industry, the following issues will be addressed: First, general types of corresponding material-, coating-, manufacturing- and drawing-standards will be discussed. Here, a special focus is on standardization issues of fabrication and testing including the related dimensioning and tolerancing. Second, in order to confine the term "diffractive feature" a classification of diffractive optical surfaces will be developed. Finally, this paper gives an introduction to the newly published ISO-standard ISO 10110-16 including application examples.

Keywords: Diffractive optical surfaces, standardization of optical features, ISO 10110-16

Optical design for Sport Optics

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Abstract. T&I department at Leica Camera AG works mainly in three different fields: technology development, product development and product industrialization. To launch a product into the market with some required features, quality and cost, the three steps above must be very well synchronized.

As an example, the process could start from an idea of market needs, followed by a benchmark on technology available for that end. The product development starts whenever all the technologies needed are within an high Technology Readiness Level (TRL).

The development of a rangefinding binocular has to consider analogic binocular, laser rangefinding and augmented reality technologies synchronized all together. For the first, geometrical optics is considered to minimize aberrations, the second photonic components as Laser diodes and Avalanche photo diodes (APD) should be optimized positioned to do the measurements and finally a display with user relevant information must be projected into the visual path of the binocular.

To deliver the newly developed product to the market, an industrialization stage must be taken into account. At this stage a MonteCarlo analysis using production and adjustment tolerances for the process is done in collaboration with the process engineers.

Keywords: Optical Design, Range Finding

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Photon bubble turbulence in cold atomic gases: astrophysics in the lab.

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Abstract. Cold atomic gases, produced with state-of-the-art laser cooling techniques, are excellent platforms to simulate astrophysics phenomena, as photons and atomic species interact in a self-consistent matter, just like in stars. In the particular case of near-resonant laser cooling, the light transport inside the atomic cloud is diffusive, and the photon residence time can increase up to five order of magnitude in respect to its free-space (off-resonant) value. For particular conditions, the diffusive light interacting with the cold atomic gas may trigger some sort of photon bubbling turbulence, in analogy to what happens at the interior of some stars. We experimentally report on the observation of photon bubble turbulence in cold Rubidium gases, and discuss the excellent agreement with the theoretical model for the photon bubbling instability.

Keywords: photon bubble turbulence, quantum simulation, astrophysics, dynamical instability

Experimental turbulent states with paraxial fluids of light in photorefractive media

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Abstract. The analogy between a quantum fluid and light propagating in nonlinear optical materials allows researchers to investigate quantum-like complex dynamics in faithful two-dimensional, more predictable, and affordable experimental setups [1]. Turbulence is a good example of a complex and not fully comprehended behavior that can be explored and studied in a controllable manner using these fluids of light [2]. In this work, we take advantage of these similarities and explore the formation of turbulent regimes in a fluid of light disturbed by an all-optical defect with a photorefractive crystal as a nonlinear medium. These states are created by working above the superfluid regime, where the emission of vortex pairs, a hallmark of turbulence dynamics, occurs. Using a holographic technique, we can reconstruct the complex representation of the field (amplitude and phase) and examine the presence of energy cascades in the incompressible component of the kinetic energy. These energy cascades are a signature of turbulent states [3], and in this work, we show how to study them in a controllable manner. The experimental results are compared with numerical simulations, revealing similar dynamics with the experimental analogue simulator.

Keywords: Fluids of light, Turbulence, Optical Analogues, Photorefracive media, GPGPU supercomputing

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Expansion Dynamic and Characterization of Stagnation Layer in Laterally Colliding Plasmas: Dependence of Observation Bandwidth and Plasma Plume Separation

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Abstract. The colliding laser-produced plasma (CLPP) has a wide range of applications in various contexts, that might start with astrophysical applications or pulsed laser deposition or Laser-induced breakdown spectroscopy, which is a powerful analytical technique for elemental analysis and material identification.

In CLPP experiments, the stagnation layer might form at the interface region when two dense laser-induced plasmas collide [1], and the degree of stagnation can be diagnosed by the collisionality parameter that is used to determine what kind of interaction will take place, i.e., soft or hard stagnation [2].

Our experimental present the results of the temporal, spatial and semi-spectrally imaging of colliding plasmas of aluminium and silicon targets. The analysis is focused on describing the velocity of the expanding plasma front for the interaction zone. The aim of the work presented here is to further advance and study colliding plasma techniques, as well as other methods to realize and control species density and expansion, with a view to a deep understanding of these complex mechanisms and optimising emission in the visible wavelength range.

All investigation sequences were based on a similar experimental setup, where two different focusing lenses were used with an effective focal length (EFL) of approx. 100mm or 125mm to achieve seed separation around 1.66mm or 125mm, respectively. Time-resolved emission imaging was employed to track the stagnation layer's size and shape, which might act as a signature of hard versus soft stagnation.

The study provides a considerable amount of detailed data related to the expansion velocity of the interaction zone which extends the understanding of the behaviour of particular species within colliding laser-produced plasmas.

Keywords: Laser-induced plasma, LIBS, Colliding plasma systems, Stagnation layer, Emission imaging.

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On the total estimation of the electromagnetic field in the focal area with no interaction with the media

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Abstract. The potential offered by highly focused fields has been demonstrated in last years. The design of these beams to provide them with the properties required in each situation continues to be a challenge, where it is essential to take into account the distribution of polarization and phase along the beam. In addition, it is also crucial to bear in mind not only the transverse components of the field, but also the longitudinal one. Moreover, this component parallel to the beam propagation direction often plays the most relevant role. However, experimentally detecting the complex amplitudes of the three components of the electromagnetic field to foresee the properties of the beam is not a simple task. Although what refers to the transverse components can be studied simply by taking polarimetric images in a conventional way, as soon as we deal with a three-dimensional field, knowing the longitudinal component becomes mandatory. In this talk, we review several techniques to detect experimentally the contribution of the longitudinal component. These methods usually require specially designed optical elements to extract light from the focal zone in an invasive manner or they have a very limited signal-to-noise ratio [1-3]. In addition, we discuss a new approach to estimate the entire electromagnetic field using the transversal Stokes images recorded on different transverse planes near the focus [4]. In this way, we computationally retrieve the phase of each component and finally we infer the longitudinal component by means of the Gauss's law.

Keywords: Optical Physics, Polarization, Fields in the focal area.

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Contribution to the improvement of the correlation filter method modal analysis with a spatial light modulator

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Abstract. It has been proved that it is possible to obtain the full information of the optical field at a waveguide output end employing the correlation filter method (CFM), just by measuring the modal amplitudes and relative phases of the structure modes [1]. Achieving a full modal decomposition of light is of great interest for some applications (i.e. mode division multiplexing, mode converters, large mode area designs, etc.) and it also allows us to study the transmission properties of waveguides, of particular importance due to the physical insight that can be obtained (i.e. beam quality, mode coupling, angular momentum, etc.).

While implementing this mode analysis setup, there are different factors that can influence and worsen its performance (i.e. system alignment, filter adjustment, a priori mode computation, laser instabilities, etc.). In this work we propose a set of procedures that can help us reduce the instabilities and imprecisions of the mode analysis performance. We have tested all of them with a conventional SMF-28 fiber excited at 632 nm which presents six LP propagation modes. In order to implement the correlation filters we have used a phase-only spatial light modulator (SLM), encoding the complex amplitude by using the double phase method (DPM) [2]. First of all we have studied the influence of the mode normalization in the DPM inherent noise term, concluding that it can be avoided by means of an appropriate normalization. Then, we have used the symmetries of the LP modes in an effort to improve the SLM transversal alignment (through both LP_{11}^{e} and LP_{11}^{o} modes) and the system magnification (through the LP_{02} mode). These symmetries, which can be found in different set of modes, help us to smoothly correct the adjustment, thus improving the modal analysis results. Finally, we propose a more robust method to measure the phase difference between modes, by performing more than just two measurements (as it is common) and acquiring the phase through a function fit. This method allows us to particularly reduce both the laser and fiber position instabilities. Finally, we show the experimental performance of the modal analysis procedure by comparing two measured intensity distributions with their reconstruction departing from the modal analysis results.

Keywords: filter correlation method, mode analysis, spatial light modulator, double phase method.

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Design concepts of a new imaging system for a high-intensity XUV source beam by colour centres excitation in lithium fluoride crystals

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Abstract. Stable colour centre production in lithium fluoride (LiF) crystals can employ as a high-spatial-resolution imaging tool for extreme ultraviolet (XUV) irradiation, as well as the possibility for images of the unfocused beam and the beam focused by a multi-layer mirror.

The LiF crystal sensitivity has sufficient to impress high-contrast photo-luminescent patterns with XUV single-pulse irradiation on an area up to 40mm^2. The suggested imaging technique, using LiF as a detector, can contribute to reducing the lack of sufficient knowledge for XUV beam characterization and profile featurization which can open a very wide range of XUV metrology and tomography applications.

The experimental results explain the concepts of detection of high-intensity source at13.5nm using a YAG:Ce scintillator crystal embedded with a CMOS camera, additionally using LiF as a 2D high-resolution detector, as shown in Figure (1), and the work shows investigations outcomes and improvement procedure and analysis.

The results demonstrate the potential of LiF crystals as a sub-micrometre resolution two-dimensional imaging tool for XUV irradiation applications. Moreover, The research study explains the optimization sequences of the new imaging technique that will play an important role to predict the achievable spot size, geometry, beam profile and intensity distribution, as well as the characterization complexity of XUV source features.

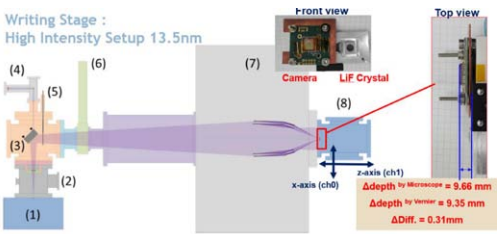

Figure (1): Scheme of the experimental setup with source (1), 6-way-cross connector (2), multilayer mirror (3), reference diode (4), removable collector blocker (5) (not visible in the photograph), gate valve (6), collector chamber (7) and sample chamber (8).

Keywords: colour centre production, instrumentation for new light sources, imaging system and digitization processing.

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Rubber vulcanization method for FBG pressure sensors

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Abstract. Vulcanization is a widely used process in industries for diaphragms fabrication, allowing the optimization of rubber properties, providing higher tensile, resistance to expansion, and higher elasticity. Sensors based on fibre Bragg gratings (FBGs) have been applied to measure several parameters. One approach for measure parameters such as liquid level, pressure, and vibration is to embed the FBG in a diaphragm. In this paper, we present the experimental analysis of the vulcanization of nitrile rubbers for the construction of diaphragms used in pressure sensors based on FBGs. The vulcanization process comprises the use of two rubbers of the same thickness, which received a mixture containing solvents, resins, catalysts, and sulphur, together, in the presence of heat and pressure, formed a bonded. Tests using diaphragms with different rubber thicknesses (0.5 mm, 1.0 mm, and 1.5 mm), vulcanization temperatures (125°C, 150°C, and 200°C), and vulcanization times (2.5 min and 5.0 min) were performed to analyse the chemical degradation caused by the rupture of the elastomer cross-links. Degradation analysis was performed using digital macrography of the diaphragm surfaces in which ten images were taken at different positions. Subsequently, the stiffness of the diaphragms was analysed by tensile tests. By inspection, the parameters of temperature and time which resulted in the lowest rubber degradation were selected to embed the FBG in the diaphragm. Thereafter, the FBG signal was analysed during the vulcanization process. Also, an analysis of the diaphragms' sensitivity in a metallic structure was also carried out by measuring the Bragg wavelength variation during a compression test. Results of the visual inspection (via software) show that diaphragms vulcanized at 125°C showed smaller areas of degradation regardless of the time (2.5 minutes or 5.0 minutes). Diaphragms with 0.5 mm rubbers showed an area degradation mean of 17.5%, whereas 1.0 mm rubbers showed a 14.5% area degradation mean, and 1.5 mm rubbers showed an 11.0% area degradation mean. In addition, there is a higher standard deviation of the degraded area for temperatures of 150°C and 200°C, showing an inconsistency of vulcanization for these temperatures. Moreover, the greater thickness (higher the density of cross-links), the smaller the degraded area for the same temperature and vulcanization time. Tensile test results using the diaphragms vulcanized at 125°C presented stiffness of 29.59 N/mm, 41.95 N/mm, and 72.01 N/mm, whereas the diaphragms vulcanized at 150°C presented 39.69 N/mm, 48.25 N/mm and 78.29 N/mm stiffness. Thus, for the same thickness in the rubber, the higher vulcanization temperature results in a higher stiffness of the material, where stiffness is directly related to the reduction of cross-links due to the degraded area of the high temperature. Results of the sensitivity test using diaphragms vulcanized at 125°C showed a pressure sensitivity of 11.67 kPa/mm and wavelength sensitivity of 456.1 pm/mm for 0.5 mm rubber thicknesses, 18.04 kPa/mm pressure sensitivity, and 112.3 pm/mm wavelength sensitivity for 1.0 mm rubber thickness and 31.55 kPa/mm pressure sensitivity and 913.8 pm/mm wavelength sensitivity for 1.5 mm rubber thickness. It concludes that the 0.5 mm rubber vulcanized diaphragm obtained higher sensitivity when comparing pressure and wavelength.

Keywords: (Fibre Bragg Gratings, Diaphragm, Vulcanization, Rubber)

A FBG based sensor for horizontal displacement measurements of a small scale tailing dam model.

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Abstract. The Brazilian mining disasters in the state of Minas Gerais has motivated the development of several studies aimed at increasing the safety of tailings dam [1]. The present work consists in the development of a novel sensor based on FBGs to measure the horizontal displacements of an iron ore tailings dam scale model, built to simulate liquefaction triggers. The sensor was built with a slender acrylic bar with 1 m of length, 15 mm of width and 3 mm of thickness. The FBGs were manufactured using a Nd:YAG laser, and characterized in strain and temperature in the Instrumentation and Photonics Laboratory of COPPE/UFRJ. The strain variations measured by the FBGs were converted into horizontal displacements through the Euler-Bernouli Beam theory [2]. The sensor was interrogated using an interrogator Micron Optics si155 with a resolution of 1 pm. Two strings with five FGBs spaced at 200 mm were glued to the opposite faces of the bar in order to perform temperature self-compensation [3]. The simulation results show that the sensor has a resolution of 0.01 mm for the measurement range from 0 to 150 mm. The five deformation points obtained with the sensor will be interpolated in order to obtain a two-dimensional profile. These results will be compared with accelerometer measurements and cameras that will monitor ground displacements using the Digital Image correlation (DIC) technique. The dam model will be built in a test box with dimensions of (4 x 1 x 1) m where the sensor will be installed in order to measure the model deformations. The sensor developed in this work will generate data that will help to understand the behaviour of tailings dams subjected to triggers that can cause the phenomenon of rupture by liquefaction.

Keywords: FBG, Tailing Dams, Soil displacement measurement

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Fatigue crack growth monitoring using Electronic Speckle Pattern Interferometry

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Abstract. In this work, an Electronic Speckle Pattern Interferometry system is deployed in order to monitor the growth and closure of a previously generated fatigue crack, through an innovation in discontinuity analysis, during the unwrapping process; while also measuring the in-plane displacements of the specimen in analysis. In parallel, a DIC system is also employed, performing the same analysis as ESPI, as a redundant method to confirm the results. For this purpose, Middle Tension (MT) specimens, fabricated with an initial notch, were subjected to fatigue cyclic loading, originating a crack on the flanks of said notch. At the end of the loading, the cracks are measured through the use of a travelling microscope, obtaining a reference value for the crack length. For the analysis, the specimens are mounted on a portable tensile machine, setup on an optical table, and subjected to static loading. Due to the ESPI system's nature, the analysis is always performed between an interval of force values. For each set of force values, a full analysis is performed, obtaining the crack length on both flanks of the initial notch, measuring the in-place displacement, and also calculating the strain field. As such, it is possible to monitor the crack length with the increasing load values, enabling the study of the crack closure phenomenon for low loads, and the opening curve of said crack. At the maximum load value, which corresponds to the maximum value for the fatigue cyclic loading, the crack length also corresponds to the reference value, obtained from the traveling microscope methodology. Additionally, the results obtained from DIC are in agreement with the analysis performed with the ESPI system.

Keywords: ESPI, Interferometry, Fatigue crack, Monitoring

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Innovative hybrid optical sensing design to simultaneously discriminate pressure and temperature.

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Abstract. In this work, hybrid optical fiber sensors based on Fabry-Perot (FP) interferometers and fiber Bragg grating (FBG) sensors were developed to simultaneously measure two external parameters, pressure, and temperature. The proposed sensor consists of a photosensitive Single-Mode Fiber (SMF), where the FBG is recorded, spliced to a small section of a Hollow-Core Fiber (HCF) (~200 m). After that, the HCF tip is submerged in a UV-photosensitive polymer, creating two cavities: one composed by air in the HCF, and the other with the polymer. These two cavities will create three light interferences, allowing the observation of two FP responses in the spectral response. Two liquid polymers with different viscosities and refractive index (RI) were used to create the hybrid sensor. After the curing process, the sensors were calibrated to both parameters in the ranges of 0.0 to 4.0 bar (steps of 0.2 bar), and 20.0 to 30.0 °C (steps of 2.0 °C), respectively. By tracking the spectral responses, and the peaks shifts of the FPs, it achieved high sensitivities for the sensor with UV-photosensitive polymer with lower viscosity (RI = 1.46) of around 0.6 nm/ºC and 20.0 nm/bar. On the other side, the higher viscosity polymer (RI = 1.39) achieved a different spectral response: around -0.15 nm/bar and -0.15 nm/ºC for the FP. On both sensors, the FBGs achieved nearly 9.0 pm/ºC and 6.0 to 12.0 pm/bar. With these results, the sensor with the cavity from the lowest viscosity polymer presents higher pressure and temperature sensitivity values and it was simpler to make, due to the smaller curing time. In this way, the simultaneously discrimination of pressure and temperature could be achieved by using the matrixial method with the FP and FBG sensitivities. The developed sensor has potential to be used inside batteries to measure and decouple both parameters.

Keywords: Hybrid optical fiber sensors; UV-photosensitive polymer; Dual parameter discrimination; Pressure; Temperature.

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A Fiber Bragg Grating based Accelerometer for Monitoring the Vibration of an Industrial Engine Prototype: A Preliminary Study

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Abstract. Optical fibers are most commonly known as a component of communication systems that provide broader modulation bandwidth than electrical mediums. In addition to this wellknown application, they have also been intensively explored for electro-optical sensing. Regarding industrial applications, optical fiber sensors (OFS) have shown potential to overcome some drawbacks of electronic solutions due to the fiber's intrinsic characteristics. An important parameter to continuously monitor in industrial control plants is the vibration of engines, since this information is essential for fault detection and predictive maintenance. Therefore, this paper describes an optical accelerometer based on a fiber Bragg grating (FBG) and a cantilever structure for monitoring the vibration of an industrial engine prototype whose maximum operating speed is 6000 rpm (100 rps). The optical accelerometer uses an uniform FBG inscribed in a standard single mode fiber (SMF) and centred at 1550 nm. The FBG is attached to an 1-axis bronze cantilever that is coupled to the motor's gearbox to identify its vibration along the z-axis and connectorized to an optical interrogator with a sampling rate of 1 kHz. To validate the proposed system, an electronic accelerometer (IMU sensor GY-80) whose sampling rate is approximately 320 Hz was also attached to the gearbox. In addition, to compare the vibration signal signature in different parts of the motor, the bearings were also monitored via an electronic accelerometer. Experimental tests were performed adjusting the motor's rotation speed during normal operation to 15, 20, 25, 30, 35, 40, 45 and 50 rps. At each frequency, data was collected by means of a computer and processed offline. Experiments have shown that the cantilever's fundamental frequency is 220.1 Hz, which is in accordance with the simulated result. The optical fiber sensor was able to correctly identify the operation speeds of 20, 25, 35, 40, 45 and 50 rps with a maximum error of 0.011 Hz. The mean signal-to-noise ratio (SNR) of the signals provided by the optical fiber sensor was 25.8% higher than the mean SNR of the GY-80 signals. The experiments have pointed out that the vibration signals have different characteristics when measured at the bearings and at the gearbox, indicating the feasibility of multi-signals analysis for fault detection.

Keywords: FBG, Cantilever, Accelerometer, Vibration Monitoring, Optical Fiber Sensor

Azobenzene based on-fiber waveplates for polarization control

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Abstract. Currently, all optical fibre polarization control devices make use of massive devices for polarization control, which often forces the light to leave the optical fibre into the air with lenses and wave plates, requiring the need for tricky alignment and high re-coupling losses. On the other hand, more modular solutions using dedicated high-birefringence fibres of the spun Hi-Bi fibre type are limited in terms of high cost and non-trivial application. In this work it is proposed novel fibre optic devices capable of controlling the polarization state based on azobenzene films. The underlying idea is to make use of the isomerization properties around the N=N bond of the azobenzene compounds; from the fact that this photoisomerization can be induced by light, resulting in changes in conformation and molecular spatial orientation, susceptible of inducing a net birefringence in the medium where these compounds are dispersed. In this work describes the dynamics of birefringence creation in azobenzene thin films in terms of film preparation conditions and conditions as solution concentration and thermal treatment and writing lasers parameters as power and polarization state. Birefringence close to 10^{-2} were shown to be reachable which allows to assemble half or quarter have plates in a few tens of micron of film thicknesses. A discussion will be provided on the real capabilities of azobenzene devices to write birefringence and change the polarization state of a propagating wave, in reliable devices and infer about real applications in which they can be applied.

Keywords: Azobenzenes, Birrefringence, Writable Waveplates, Polarization Control

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Optimal filtering of measured Mueller matrices using full Poincaré polarimetry

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Abstract. Non-uniformly totally polarized beams contain many independent states of polarization [1]. In particular, the so-called full Poincaré beams (FPBs) present all possible states of polarization across their transverse section [2]. FPB's have been proposed for Mueller matrix polarimetry [3]. The states of polarization before and after the sample are measured by means of a polarization state analyzer consisting of a quarter wave phase plate and a linear polarizer that are positioned before a CCD camera in six different configurations [4]. For this approach, a critical point is the inaccuracy of the intensity measurement at each pixel of the CCD camera. Due to small misalignments of the optical measuring elements and the sample, displacements of the images captured by the CCD camera can occur and will introduce additional errors in the determination of the Mueller matrix. For a Mueller matrix to be physically realizable, i.e., to correspond to a real sample, it must satisfy a number of constraints [5]. This set of conditions can be cast in the form of a coherency matrix **H** associated with a Mueller matrix **M** [5]. The four eigenvalues of the Hermitian matrix **H** must be nonnegative. An optimal filtering [5] can be done to eliminate any negative value of the eigenvalues in **H** before reconstructing a new Mueller matrix **M**. This optimal filtering has been tested with several Mueller matrices measured by full Poincaré polarimetry and it has been found that the filtering procedure leads to an overall error of the 16 elements of **M** that is lower than the error found before optimal filtering.

Keywords: Polarimetry, Polarization, Full Poincaré beams, Mueller matrix, Optimal filtering

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Estimation of Zernike polynomials for a highly focused electromagnetic field using polarimetric mapping images and neural networks

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Abstract. In this communication, we present a method to estimate the aberrated wavefront at the focal plane of a vectorial diffraction system. In contrast to the phase, the polarization state of optical fields is simply measurable. In this regard, we introduce an alternative approach for determining the aberration of the wavefront using polarimetric information. The method is based on training a convolutional neural network using a large set of polarimetric mapping images obtained by simulating the propagation of aberrated wavefronts through a high-NA microscope objective; then, the coefficients of the Zernike polynomials could be recovered after interrogating the trained network. On the one hand, our approach aims to eliminate the necessity of phase retrieval for wavefront sensing applications, provided the beam used is known. On the other hand, the approach might be applied for calibrating the complex optical system suffering from aberrations. As proof of concept, we use a radially polarized Gaussian-like beam multiplied by a phase term that describes the wavefront aberration. The training dataset is produced by using Zernike polynomials with random coefficients. Two thousand random combinations of polynomial coefficients are simulated. For each one, the Stokes parameters are calculated to introduce a polarimetric mapping image as the input of a neural network model designed and trained for predicting the polynomial coefficients. The accuracy of the neural network model is tested by predicting an unseen dataset (test dataset) with a high success rate.

Keywords: Wavefront sensing, Polarimetric images, Convolutional neural networks, highly focused beams

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The development of test station to characterize the capabilities of emission of LiDAR

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Abstract. Light Detection and Ranging (LiDAR) technology offers an efficient way of generating high-accuracy spatial data for a wide range of mapping and surveying applications. It has gradually being integrated as a sensor in autonomous vehicle applications, and it might become the most important technology in this field of application in the near future. Automotive industry quality and safety requirements are rigorous. Thus, these kinds of devices have to be tested in a way to ensure the quality that meets automotive original equipment manufacturer standards. The performance of the light source and beam propagation characteristics through free space are also important for a more accurate evaluation of the returned signal and the control of these parameters during the development of LiDAR systems is also critical, and can have a strong impact on its success.

To address this question, a prototype test station capable of characterising the beam quality and propagation parameters of a LiDAR system laser was developed. The main techniques of the station that enables the measurement of the different parameters are described. Among those parameters, the evaluation of the system eye safety class, wavelength peak and full width at half-maximum (FWHM), pulse duration and pulse energy, pulse repetition rate, horizontal and vertical angular resolution, the field of view and the beam propagation factor (M^2), this latter one allowing the determination of beam waist size, position and divergence. For a demonstration of the performance of this test station, a commercial spinning LiDAR, a Velodyne VLP-16 emitting at a wavelength of 913 nm, was used. The measurement of the beam propagation characteristics was performed successfully with the LIDAR working in normal operational conditions

Keywords: LiDAR, beam propagation factor M^2, beam divergence, eye safety, Field of View

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Implementation of a Scheimpflug Lidar for Assessment of Native Aerofauna in Tropical Forests in Ecuador

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Abstract. Ecuador has a great diversity of bats: in a single habitat, more than 50 species of bats can be present.[1] Insectivorous bats eat large quantities of nocturnal insects, thus contributing to the environmental balance and to regulate pests, which in turn, saves on pesticide expenditures.[2] Entomological lidars are optical tools for the non-invasive, continuous, and extensive monitoring of insects. They are better than conventional methods such as sweep nets or traps. We implemented a lidar, based on the Scheimpflug principle, as a new technique for the detection, counting, and classifying the insects in Ecuadorian ecosystems. The counting rate reaches several hundred thousand observations per day, allowing for detailed statistics [3], while operating at a kHz sampling rate. With this rate, targets can be classified according to their oscillatory properties (wing flapping). [3] Fig. 1(a) and 1(b), show the exposure time of one animal in front of the optical sensor and its position about the sensing termination point. Fig. 1(c) shows the three statistical measures used to set the detection threshold. Fig. 1(d), the total oscillating signal is shown in blue, and in red the contribution of the slow body. The most harmonics for the oscillatory signal are presented in Figure 1(e) in the power spectrum. For the first time, targets were detected through dense fog with this technology with high sensitivity in the frequency domain. With this instrument, Ecuador becomes part of a world network on remote optical sensing.

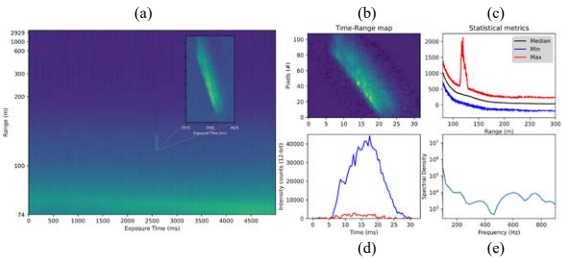

Figure 1. (a) (b) Time-range maps of an observation (La Maná). (c) Maximum, median and minimum for each range for the time window in (a). (d) The time series from the time-range maps. (e) The power spectra of the time series shown above.

Keywords: Entomological lidar; Remote sensing; Scheimpflug; Biodiversity; Measurement in Fog

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Neural network computing with large-area lasers

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Abstract. High-performance computing hardware is crucial for advanced neural network (NN) computing schemes [1]. Photonics promises strong advantages in terms of parallelism, yet until now scalable and integrable concepts are scarce and partially rely on exotic substrates [2]. Here, we implement a fully parallel photonic reservoir computer based on the spatially distributed modes of an efficient and fast large-area vertical-cavity surface-emitting laser (LA-VCSEL) [3].

As photonic neuron substrate we use the complex multimode field of an injection locked LA-VCSEL of ~50 µm diameter emitting around 920 nm. Our LA-VCSEL was fabricated via standard commercial technology and follows a minimalistic design principle boosting its small-signal modulation bandwidths beyond 20 GHz. Noteworthy, all the photonic NN connections to- and from- the LA-VCSEL are implemented in hardware: the injected information is Boolean encoded on a digital micro-mirror device (DMD). Intra-cavity fields and carrier diffusion intrinsic to LA-VCSELs recurrently couple the >300 photonic neurons, and trainable readout weights are encoded on a second DMD and photo-detected to directly provide the computational result. We online train the readout weights to perform n-bit header recognition, XOR and digital-to-analog conversion tasks.

We operate our recurrent photonic NN in its steady state with bandwidths of several 100s inferences per second, only limited by the communications with external hardware. Further, we analyze the optimal system parameters and relevant computational metrics for neural network computing [4]. Finally, we discuss the application of our approach to a photonics

Keywords: Neuromorphic computing, Semiconductor lasers, Photonic neural networks.

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Photonic Neuromorphic Computing with Vertical Cavity Surface Emitting Lasers

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Abstract. Photonic approaches emulating the powerful computational capabilities of the brain are receiving increasing research interest for radically new paradigms in ultrafast information processing and Artificial Intelligence (AI). In this talk, I will review our research on neuromorphic photonic systems built with artificial optical neurons based upon Vertical-Cavity Surface Emitting Lasers (VCSELs). These are ubiquitous light-emitting optical devices found in mobile phones, supermarket barcode scanners, automotive sensors, optical transceivers in data centres, etc. Hence, there is great potential in adding intelligence and novel processing capabilities in key-enabling VCSELs for a wide range of novel technological developments.

Our research has shown that a rich variety of neuronal computational features (e.g. spiking activation/inhibition) can be reproduced optically in VCSELs at ultrafast sub-nanosecond speeds (up to 9 orders of magnitude faster than the millisecond timescales in cortical neurons) [1-3]. During the talk I will describe how we capitalise on the ultrafast neural-like behaviours elicited in VCSELs to develop novel photonic spike-based processing systems for use in strategic applications (e.g. pattern recognition, image processing) and neuronal circuit emulation at ultrafast speeds [1-3].

This talk will also introduce our recent work on laser-based, Recurrent and Spiking Neural Networks (RNNs and SNNs) for novel VCSEL-based photonic Reservoir Computing (RC) systems, yielding excellent performance across complex computing tasks at ultrafast rates [4].

Finally, this talk will review our recent work on neuromorphic systems merging in the same platform VCSELs with key-enabling Resonant Tunnelling Diodes (RTDs), for novel ultrafast, low power spiking optoelectronic artificial neuronal models, towards future chip-scale SNN implementations of light-enabled brain-inspired computing and AI hardware [5].

Keywords: Neuromorphic Photonics, Vertical-Cavity Surface Emitting Lasers (VCSELs), Resonant Tunnelling Diodes (RTDs), Photonic Neurons, Photonic Reservoir Computing.

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Dynamic speckle imaging with SVD compression

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Abstract. Dynamic speckle imaging (DSI) produces a 2D map of activity through statistical processing of speckle patterns formed on the surface of industrial or biological objects under laser illumination. The map gives areas of different speed of processes ongoing in the objects. DSI is highly sensitive to micro-changes of the object topography in time at the expense of strong fluctuations of the map entries. For a high-quality map, storage and processing of a large number of images is required. Raw data compression becomes mandatory for monitoring a process in time when many maps are built. The raw data are 8-bit encoded images of correlated in time speckle patterns. They represent widely spread within the dynamic range of the optical sensor symmetric/asymmetric intensity distributions with a signal-dependent variance. The latter entails normalized processing for non-uniform illumination. Compression must keep intact information about the speed of intensity changes.

We propose compression of the raw DSI data by applying singular value decomposition (SVD). A specific feature of speckle images for DSI is lack of a structure with areas of close intensity values. Thus, the gain from the direct SVD application to the recorded images is rather modest because a comparatively great number of non-zero singular values should be kept for an activity map comparable in quality to the ground truth map from bitmap images. For higher compression, we proposed SVD to be applied to the 2D arrays containing the differences between the successive images. The arrays exhibit some structure due to the spatial distribution of the speed of the ongoing processes. High quality of the activity map is achieved for much smaller number of non-zero singular values and compression substantially increases. The proposed method is feasible for non-uniform illumination if the differences are normalized. The method is verified by using synthetic and experimental data.

Keywords: dynamic speckle, compression, SVD

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Data Augmentation in 3D Object Detection for self-driving vehicles: the role of original and augmented training samples

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Abstract. Safe self-driving vehicles require precise 3D Object Identification. LiDAR sensors are key in accomplishing such a task, as LiDARs produce high-definition point clouds. Such point clouds are then processed by 3D Object Detection models to finally detect objects.

Most Object Detection models require massive amounts of data to be trained. Gathering and processing this data is an expensive and time-consuming task, which is why the information taken from each sample must be fully harnessed. Such can be done through Data Augmentation.

Data Augmentation contributes significantly for improving performance, being at least as relevant as the advances in the Object Detection models themselves.

A few studies have been reported regarding the effectiveness of Data Augmentation. However, the role played by original and augmented samples has been neglected. This work reports the first-ever detailed quantification of the impact that the inclusion of original and augmented samples in a dataset has in 3D Object Detection in the context of autonomous driving. The obtained results show that although a good augmentation strategy is crucial to the model's performance, it is only as good as the quality of the original samples allows it to be.

Keywords: LiDAR sensors, computer vision, data augmentation, point cloud, autonomous driving

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Intrinsic temperature-compensated fibre optic current/ magnetic sensor

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Abstract. The fibre optic current sensor demonstrated here uses the intrinsic temperature and wavelength dependence of the Verdet constant of a terbium gallium garnet (TGG) magneto-optic material and the two micro-optic linear polarizers attached, to simultaneously extract the values of temperature and the optical Faraday rotation (induced by the presence of the magnetic field due an electric current on a conductor) without any extra optical component attached to the optical sensor head. The simultaneous measurement is achieved by illuminating the sensor head with a broadband optical source and by careful signal processing of the originated channelled-spectrum, compensate the sensor's temperature dependence.

Keywords: fibre optic, sensor, magneto-optic, TGG, multiplexing

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Considerations involving the determination of the band gap energy by diffuse reflectance spectroscopy

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Abstract. The band gap energy (E_g) of non-single-crystal semiconductors can be obtained from diffuse reflectance measurements. For this purpose, the classical theory proposed by Kubelka and Munk (K-M) and the so-called plot Tauc have been largely employed. In this work, the authors revisited the main aspects of the two-flux K-M model. For a sample with semi-infinite thickness, the ratio between the K-M absorption and scattering coefficients defines a function, named K-M function, $F(R)$, that depends only on the reflectance (R) of the sample. In addition, it is shown that in obtaining E_g the correct use of the $F(R)$ needs to take into account the nature of the electronic transition. On this matter, a recent case in which the E_g values are obtained inadequately, because E_g was obtained directly from the plot of $F(R)$ versus incident photon energy, is also discussed.

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Coupled two-cores integrated waveguides modal analysis

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Abstract. Multicore fibers are currently of great interest in optical communications due to their suitability for increasing the capacity of optical fibers and for the design of large mode area structures [1]. Writing techniques by means of strongly focused femtosecond pulsed lasers [2] facilitates the transfer of fiber-based technology to compact monolithic optical circuits. The characterization of these waveguides entails not only the difficulties of rare earth doped integrated waveguides characterization but also the issues associated with the multicore structure and with the fabrication process (i.e. ions migration, irregularities).

We present the modal analysis of coupled two-core integrated waveguides fabricated in an Er^{3+}/Yb^{3+} co-doped phospate glass by femtosecond laser writing. In order to do that, we implement the correlation filter method in a phase-only spatial light modulator (SLM). This method has been used several times in multimode fibers [3], but there is no report yet of its performance in multicore integrated waveguides. In this work, we first show that the special symmetry of the two-core waveguides with identical cores allows us to perform the modal analysis with a phase-only element, without the need of encoding any complex amplitude distribution. Then, we compare the theoretical modal weights with the measured ones as a function of the fiber excitation position and the waveguide core-to-core separation. The selection of the focal plane lens position to perform the modal analysis is critical, and both the asymmetries between cores and the gap between the two-core waveguide and the excitation fiber play a fundamental role on the modal behaviour. However, this phase-only modal analysis method allows us to reproduce the modal weights theoretical behaviour. The advantages of its use are clear: on one side, the SLM alignment is much simpler. On the other hand, there is no need to use any technique to implement complex amplitudes in a phase-only device. This considerably simplifies the experimental setup adjustment.

Keywords: multicore fiber, femtosecond laser writing, modal analysis, correlation filter method

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Analysis of power transfer between two multi-core fibers with long-period gratings

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Abstract. Multi-core fibers (MCFs) have been proposed to increase the capacity over an optical fiber by spatial division multiplexing. Some devices for MCF systems were developed, but they are still inefficient, sensitive and/or complex. Long-period gratings (LPGs) may play a role in the development of efficient in-line MCF components. LPGs are periodic perturbations of the optical fiber refractive index that promote the coupling between the core mode and a cladding mode at a resonant wavelength [1]. We have numerically demonstrated a single-mode fiber (SMF) to MCF coupler based on LPGs, which showed promising results [2]. The SMF cladding is reduced to increase the power transfer between the fibers. If the fibers are similar, i.e., an MCF replaces the SMF, the coupler will show high power transfer without any further changes. Furthermore, techniques to inscribe gratings in just one core of a 4-core fiber were already developed [3]. Here, we analyse the coupling between two MCFs using couple-mode theory [1] and the scheme of [2], with the input fiber as an MCF with an LPG inscribed in one core. First, the pump light is launched into the input core of the MCF and the optical power is transferred to the cladding due to the LPG inscribed in the core. The optical power in the cladding is then transferred to the other MCF cladding by evanescent field coupling. The optical power in the cladding of the output MCF is distributed by all its cores due to the identical LPGs inscribed in them. As the LPGs are wavelength selective, the other signals are not affected. We optimized the LPGs period, their lengths and offset distance to increase the power transfer at 1480 nm. We achieved a power transfer of 92% of the input power, distributed by all MCF cores, in 10.6 cm of length.

Keywords: Multi-core fibers, Long-period Gratings, Coupler

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Indoor guidance of Automated Guided Using Visible Light Communication

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Abstract. In recent years, devices with wireless communication capabilities have generated a growing interest in indoor navigation. Indoor localization and proximity detection is becoming increasingly attractive due to the emergence of the Internet of Things (IoT) and the inherent end-to-end connectivity of billions of devices. In a closed space, GPS has poor, unreliable performance, requiring alternative techniques and wireless technologies. In this paper, we propose the use of Visible Light Communication (VLC) to support guidance and communication for signaling in an indoor environment. Visible Light Communications (VLC) is a precursor of optical communication for large scale-integration with other conventional communication technologies, and a strong candidate for next generation of indoor interconnection and networking, in parallel with radio communications. Main characteristics of VLC include high capacity, unregulated spectrum, immunity to RF electromagnetic interference, spatial confinement, and low power consumption, making it an energy efficient green technology.

This research focuses mainly on the development of navigation VLC systems, transmission of control data information, and decoding techniques to support positioning and guidance of automated guided vehicles. The communication system uses RGB white LEDs as emitters and pinpin photodiodes with selective spectral sensitivity as receivers. Downlink communication is established between the infra-structure and the automated guided vehicles. The illumination infrastructure transmits operates in two different communication mode. In the standard mode it transmits the geographic position, which is delivered to every vehicle under the coverage of the lamp. In the request mode it additionally transmits instructions to the vehicle related to guidance directions or other instructions. The transduced signal measured by the receiver unit is a multiplexed signal, resultant from different optical excitations. The decoding strategy of the multiplexed signal is based on accurate calibration of the output signal and uses bit error control methods to reduce the BER of the system. In this paper, we will describe the coding schemes and decoding algorithms, as well as the characteristics of transmitters and receivers.

Cooperative Traffic Control using Visible Light Communication.

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Abstract. Monitoring the network traffic status of urban roads in real-time can provide rich and high-quality basic data and allow the assessment of traffic control effects. Information and communication technologies enable optoelectronic cooperative vehicular systems with bi-directional communication, where vehicles communicate with others vehicles, road infrastructures, traffic lights and vulnerable road users.

Our work focuses on the use of Visible Light Communication (VLC) as a support for transmission of information providing guidance to drivers, as well as specific information to them. Connected vehicles communicate with one another and with the infrastructure using street lights, street lamps, and traffic signals. Using V-VLC-ready connected cars, we propose a queue/request/response approach for managing an urban intersection. In this study, the connected vehicles receive information from the network (Infrastructure-to-Vehicle, I2V), interact with each other (Vehicle-to-Vehicle, V2V) and with the infrastructure (Vehicle-to-Infrastructure,V2I), using a request distance and pose estimation concept. In parallel, an Intersection Manager (IM) coordinates the crossroad and interacts with the vehicles (I2V) using the response distance and the pose estimation concepts. The vehicles' arrival is controlled and they are scheduled to cross intersections at predetermined times to minimize traffic delays. V2I2V communication provides real-time data on queues, requests, and messages distances, including queue, request, and message travel times that influence traffic channeling in various routes. The communication is performed through VLC using the street lamps and the traffic signalling, to broadcast the information. Data is encoded, modulated and converted into light signals emitted by the transmitters. Tetra-chromatic white sources are used, providing a different data channel for each chip. As receivers and decoders, optical sensors with light filtering properties, are used. To command the passage of vehicles safely queue/request/response mechanisms and temporal/space relative pose concepts are used. A communication scenario is stablished and a "mesh/cellular" hybrid network configuration proposed. As a PoC, a phasing of traffic flows is suggested. The results indicate that the V-VLC system increases safety by directly monitoring critical points such as queue formation and dissipation, relative speed thresholds, as well as inter-vehicle spacing. Based on the simulated/experimental results, the proposed VLC cooperative architecture appears to be appropriate for the intended applications.

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Visible Light Communication-based Indoor Navigation for Mobile Users in Large Buildings.

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Abstract. With the rapid increase in wireless mobile devices, the continuous increase of wireless data traffic has brought challenges to the continuous reduction of radio frequency (RF) spectrum, which has also driven the demand for alternative technologies. In order to solve the contradiction between the explosive growth of data and the consumption of spectrum resources, Visible Light Communication (VLC) has become the development direction of the next generation communication network with its huge spectrum resources, high security, low cost. Compared to conventional wireless communications, VLC has higher rates, lower power consumption, and less electromagnetic interferences. VLC is a data transmission technology that can easily be employed in indoor environments since it can use the existing LED lighting infrastructure with simple modifications. The main goal of this paper is a VLC based guidance system to be used by mobile users inside large buildings. The system is composed of several transmitters (ceiling luminaries) which send the map information, alerts and the path messages required to wayfinding. Tetra-chromatic white sources are used providing a different data channel for each chip. Data is encoded, modulated and converted into light signals. Mobile optical receivers, with VLC support, using joint transmission, collect the data at high frame rates, extract their location to perform positioning and, concomitantly, the transmitted data from each transmitter. An architecture based on a mesh cellular hybrid structure was used. The luminaires are equipped with one of two types of nodes: a "mesh" controller that connects with other nodes in its vicinity and can forward messages to other devices in the mesh, acting like routers nodes in the network and a "mesh/cellular" hybrid controller, that is also equipped with a modem, providing IP base connectivity to the central manager services. The luminaires, via VLC, deliver their geographic position and specific information to the users, making them available for whatever use they request. The communication protocol, coding/decoding techniques, and error control are examined. Bidirectional communication is implemented and the best route to navigate through venue calculated. We propose several guidance services and multi-person cooperative localization. The system informs the users, in real time, not only of the best route to the desired destination, through a route without clusters of users, but also of crowded places. By analysing the results, it became clear that the system not only provides self-location, but also the capability to determine the direction of travel and to interact with information received in order to optimize the route towards a static or dynamic destination.

Photonic tools for single cell analysis

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Abstract. The ability to select, separate, manipulate and monitor single cells is one of the keystones of modern biotechnology. Sensing at the single cell level can provide insights into its dynamics and heterogeneity, yielding information otherwise unattainable with traditional biological methods where average population behaviours are observed.

For this purpose, minimum invasive techniques are required and trapping and accurate manipulation without physical contact is an important requirement. Presently some of the most attractive solutions available rely on the use of optical trapping techniques using single beam optical tweezers. While many different approaches have been reported and successfully applied for in vitro, and even some in vivo assays, there are still many challenges to overcome before this can be considered a standard tool.

In this talk, the implementation of optical systems with single cell manipulation and sensing capabilities are presented. Different strategies, from the design and fabrication of fiber optical tweezers to the implementation of automation strategies, coupled with advanced statistical analysis, for cell classification and diagnostics, will be discussed.

Keywords: (optical fiber tweezers, single cell analysis, scattering)

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Generation of high-frequency photoacoustic pulses to enhance skin permeation of active molecules

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Abstract. Skin is a complex physical barrier which protects the body against pathogens, chemical agents and physical aggressions, and prevent unregulated loss of water and salts [1]. Its barrier effect is also effective among the drugs and cosmetics making their passive topical deliver very inefficient for molecules with high molecular weight (>500 Da) [2]. As solution, the research community is searching the for new methods to increase the transdermal delivery of active molecules in localized areas of the body, minimizing their invasive nature and increasing the compliance by patients or individuals [3].

In this work, we present a painless, non-invasive transdermal delivery technique based in the release of photoacoustic pulses on the skin, "piezoporation". During the procedure, a piezophotonic converter is placed over a specific spot of the skin, previously covered with a gel moisturizing. Gel is the base solvent for active molecules and provides the required acoustic coupling for an efficient transmission of the photoacoustic pulses to the skin. The piezophotonic converter is then lighted by 10 mJ-level, nanosecond, Q-switched laser generating high pressure amplitude, high-frequency ultrasound pulses capable to transiently destabilise the skin's barrier, allowing an efficient permeation of large active molecules.

In pre-clinical studies, we demonstrate "piezoporation" can be used to increase the diffusion of active substances into the skin compared with a passive topical application. We show, 5 minutes of "piozoporation" are enough to increase the deposition into the skin of an anti-aging and skin whitening agent, vitamin C analogue [4] and of a drug indicated in the treatment of alopexy, minoxidil, in 15 folds. The results are obtained after 1 and 3 hours of dermal exposure to the substances, respectively. In clinical studies, we also demonstrate this technique to be used to enhance facial and dermal filling together with a high concentrated hyaluronic acid gel with a molecular weight of 20 kDa [5].

Keywords: Transdermal delivery, Skin barrier, Photoacoustics, Piezophotonic materials, Pulsed lasers

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Multifunctional liposomes containing magnetic and gold nanoparticles for cancer therapy

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Abstract. Plasmonic magnetoliposomes are promising nanosystems for dual hyperthermia (magneto-photothermia) and local chemotherapy. The combination of magnetic and gold nanoparticles in a single nanosystem (multifunctional liposomes) enables greater efficiency, allowing to reach deep tumors and use hyperthermia as a therapeutic approach. In addition, it enables the targeting and controlled release of encapsulated drugs [1-3].

In this work, manganese ferrite nanoparticles and gold nanoparticles were prepared. The structural, magnetic and optical properties were measured by SEM, SQUID and UV/vis/NIR absorption, respectively. The gold nanoparticles were incorporated in the membrane of liposomes and the magnetic ones in the aqueous core of liposomes of Egg-PC or DPPC, resulting in multifunctional nanosystems. The transition temperature was evaluated by fluorescence anisotropy measurements and the heating capacity of the nanosystems were assessed under irradiation. The developed multifunctional liposomes are promising for combination between hyperthermia and chemotherapy, addressing a better cancer treatment with lower drug dosages and minor side effects.

Keywords: magnetic nanoparticles, plasmonic nanoparticles, multifunctional liposomes, photothermal effect, combination therapy.

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Detection of Alzheimer's by Machine Learning-assisted Vibrational Spectroscopy in Human Cerebrospinal Fluid

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Abstract. Nowadays, the diagnosis of Alzheimer's disease (AD) is a complex process that involves several clinical tests. Cerebrospinal Fluid (CSF) contains common AD-related biomarkers that include amyloid beta 1-42 (Aβ1-42) and tau proteins. In this work, we propose vibrational spectroscopy techniques supported by machine learning for the detection of ADrelated biomarkers in CSF by prediction models. Vibrational spectroscopy provides the entire biochemical composition of CSF and that way small but typical physiological changes related with AD can be ascertained. CSF samples were obtained by a lumbar puncture done by clinical doctors. The liquid is filtered using ultrafiltration in such a way that the protein concentration is enriched. A 5 µL drop of each CSF sample was deposited by careful pipetting onto a quartz substrate for Raman measurements, and 3 µL was poured onto an ATR (attenuated total reflectance) crystal for FTIR (Fourier-transform infrared) measurements. The samples were dried in air for 20 min. The dried sample is analyzed with a Witec Raman microscope at 532 nm and a Bruker FTIR-ATR system. A total of 22 samples from volunteers were studied, of which some were clinically diagnosed with AD. Of each patient several measurements were performed to capture the complete variability of each CSF sample. A dataset with 610 spectra, including Raman and FTIR, were analyzed within a machine learning framework. Fig. 1a shows the spectral differences between control and AD patients for both Raman and FTIR spectra. Applying principal component analysis (PCA) to a combined dataset including Raman and FTIR unveils a clear separation between the two classes (AD vs. healthy), as shown in Fig. 1b. We found that a logistic regression model can discriminate between healthy control and AD patients with a precision of 98%, when the input for the model combines data from both vibrational spectroscopy methods. Our approach shows high discriminative capabilities and constitutes a proof of concept for an alternative and accurate tool for the diagnosis of AD.

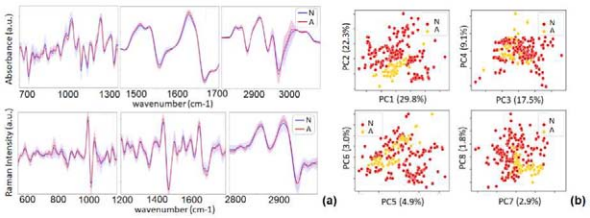

Fig. 1: (a) FTIR and Raman spectra from CSF samples of AD patients (A) and healthy control (N). (b) PCA analysis of the vibrational spectroscopy data.

Insect-Brain inspired Neuromorphic Nanophotonics

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Abstract. Combining highly efficient nanophotonic structures into artificial neural networks hold significant promise for superior hardware solutions [1]. However, we need well-defined circuit architectures and concepts, with limited size and clear functionality to develop and verify the novel concepts. Insects are capable of amazing autonomous feats well beyond current computers, such as navigating across hundreds of kilometres of unfamiliar terrain, with only a few drops of nectar as energy supply. One important module of the insect brain, conserved across species with vastly different lifestyles, is the central complex navigation circuit. This has been distilled to its fundamental neuroarchitecture and the function of a number of its components into a biologically constrained computational model [2].

We use this architecture to explore the potential of neuromorphic nanophotonic computing. We propose an artificial neural network in which the weighted connectivity between nodes is achieved by overlapping light signals inside a shared quasi 2D waveguide – a broadcasting concept. This decreases the circuit footprint by two orders of magnitude compared to existing optical solutions. The evaluation of optical signals is performed by neuron-like nodes constructed from highly efficient III–V nanowire optoelectronics [3]. This minimizes power consumption of the network. [4]. Detailed simulations of the central network parts, demonstrate feasibility and promise performance orders of magnitude beyond present hardware solutions [4].

We now expand these concepts in the European Innovation Council (EIC) project InsectNeuroNano. The vision is a novel on-chip hybrid nanostructure platform for energy-efficient, fast artificial neural networks and integrated sensor arrays. It is based on (i) neural circuit architectures found in insects [2] (ii) replacing physical interconnects by light (iii) using novel nanoscale components [3,4] and molecular dyes [5] to control and interpret signals with extreme energy efficiency. The novel neural components can be assembled into a wide spectrum of circuits and the technology platform can be integrated with standard silicon technology.

Keywords: Nanowires, III-V semiconductors, insect, neuromorphic, nanophotonic

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Dendritic-like computation using multimode optical fibers

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Abstract. Multi-mode and few-mode optical fibers are recently being considered for optical computing purposes. By exploiting the complex spatial and spatio-temporal transformation of the optical signals that propagate along these types of optical fibers, unconventional computing tasks such as learning of ultrafast pulses, image classification or image identification can be performed. Here we propose and numerically demonstrate the use of a few-mode fiber as an equivalent optical dendrite that mimics some of the operations performed by the dendrites of real neurons. Given that different spatial modes propagate along the fiber with different group velocities, we can consider that each group of spatial modes with equal group velocity act as a dendritic branch. In this manner, a few-mode fiber can operate as an ultra-fast spatio-temporal coincidence detector [1]. More precisely, we focus on the use of a few-mode, step-index fiber as a linear computing element that operates at 40 Gb/s data encoding rate, showing that the spatio-temporal information at the output of a few meters fiber can be efficiently used to solve header recognition tasks at the same rate of 40 Gb/s. Depending on the diameter of the few-mode fiber core, we can perform the recognition of headers with up to 6 bits, at a 1550nm wavelength operation. This becomes possible as the few-mode fiber introduces multiple delay paths and short-term memory that effectively operate as different dendritic branches, temporally mixing the input information. In the proposed scheme, the spatio-temporal information at the fiber end is photodetected and further post-processed with a simple supervised learning algorithm (logistic regression) to solve the corresponding tasks. The analogy between the optical hardware computing scheme and biological neurons could be advanced a step further by introducing nonlinearities and adaptive (plasticity) mechanisms in the input-to-output optical transformation. Since the adaptation mechanisms can operate at a slower time scale compared to the encoded information as in biological neurons, such mechanisms could be implemented by using optical elements like spatial light modulators or digital micromirror devices.

Keywords: few-mode optical fibers, neuro-inspired photonic computing, spatio-temporal coincidence detector.

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High-speed Silicon Photonic neuromorphic computing enabled by hardware-aware deep learning methods

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Abstract. The relentless growth in complexity and energy requirements of next generation AI workloads, combined with the inevitable stagnation of computing growth solely based on micro-electronic technology advancements, has shifted research interest in non-Von-Neuman architectures and novel technological platforms. In this context, neuromorphic photonics have arisen as a powerful technological candidate [1], capable of harnessing photonics low-power and high bandwidth credentials in neuromorphic hardware implementations. Demarcating, however, from lab-based demonstrations towards powerful Silicon Photonic (SiPho) integrated systems, necessitates advances in the underlying architecture and the deployment of deep learning (DL) training models capable of harnessing photonics' high-speed advantages even in noisy and nonlinear frequency response circuitry.

In this communication, we provide an overview of our progress in high-speed and high-accuracy SiPho coherent neuromorphic layouts, that synergize novel architectures with hardware-aware DL training models [2]. Our approach is built upon the unique properties of a coherent Crossbar layout, that breaks through the inherent modulation bandwidth insertion loss trade-off of previous implementations, allowing for the first time both high-speed data and weight update rates [3]. Through the deployment of two SiPho prototypes, we validate experimentally both the high-speed and high-accuracy advantages of hardware aware DL-models and demonstrate for the first-time GHz-scale input-data and weight imprinting. Accuracy improvements of up to 6% in the MNIST and CIFAR-10 classification tasks at 5 GMAC/sec/axon are reported when noiseaware training is enforced, while a neuromorphic photonic layout reaching 16 GHz update rates in the MNIST classification task is presented. Finally, we project the scalability of our architecture towards a 32×32 layout revealing lower than ~0.09 pJ/MAC at 50 GHz update rates.

Keywords: —neural networks, neuromorphic computing, neuromorphic photonics

Acknowledgements: This work was supported by the EC through H2020 PLASMONIAC (871391).

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Optical Computing with Extreme Learning Machines

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Abstract. Computing paradigms alternative to von Neumann architecture are now fueling renewed approaches to analogic processing, easing the path towards all-optical computing solutions. In particular, the reservoir computing framework is an emerging concept that greatly simplifies the transference of neuromorphic concepts to hardware implementations, leveraging solely on nonlinear dynamics which allow most physical systems to act as a computing platform.

In this communication, we explore how interferometric concepts can be exploited to perform computing tasks when using phase or modulation encoding techniques of an optical beam. First, we establish a theoretical framework based on the transmission matrix and connect it with extreme learning machines to understand the computing capacity of the systems in terms of regression and classification tasks. We then present experimental results obtained with two distinct setups: an optical system using i)amplitude encoding through a DMD and with a multimode optical fiber as the propagation media, and another with ii)phase encoding using an SLM and a nonlinear crystal as the reservoir layer. The results demonstrate that both systems can perform some classification and regression tasks, with specific advantages that will be discussed in detail. Furthermore, the results are consistent with the theoretical framework derived, which is an important step to support future research towards general-purpose all-optical hardware. To conclude, the findings enclosed have thus potential to drive future research toward novel technological applications, such as dedicated edge computing solutions integrated in optical sensing devices.

Keywords: Optical Computing, Extreme Learning Machine

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Ultrafast ptychography: from tabletop HHG to Free Electron Lasers

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Abstract. Breakthrough advances in ultrafast imaging have recently been enabled by the availability of bright, coherent, pulsed sources. In this talk, I will present a novel ultrafast microscopy approach to functional imaging, with resolution on Ångstrom-to-nanometer length and femtosecond time scales. The novelty of this method relies on combining soft X-ray sources with ptychography [1, 2], a technique for coherent diffractive imaging [3, 4] in which multiple diffraction patterns from overlapping fields of view are processed by iterative algorithms to recover amplitude and phase images of sample and beam, separately. I will provide an overview of recent demonstrations applied to the study of thermal transport [5] and plasmonics in nanostructures.

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Ultra-fast Laser-induced Molecular Dissociations on Plasmonic Nanoparticles Driven by Tailored Optical Fields: Mass Spectrometric Evaluations

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Abstract. Reactions on molecular adsorbates on nanoparticles are key players in nano-photocatalysis, atmospheric, and astrochemistry. They can be induced, enhanced, and controlled by field localization and enhancement on the nanoparticle surface. Being able to control near-field-mediated reactions would help in understanding surface photoactivity on nanosystems. Recently, with reaction nanoscopy, it was demonstrated that ion (proton) momenta from dissociation reactions induced by intense femtosecond pulses exhibit clear, distinguishable signatures for single silica nanospheres and their clusters. Later, with waveform-controlled tailored near fields from one and two-color laser pulses, an all-optical nanoscopic control of surface reaction yields was accomplished. Site-selective proton emission from dissociated adsorbate molecules on SiO2 nanoparticles was observed as a function of polarization and relative phase of the two-color pulses. The angularly resolved mapping between the surface reaction yields and the measured ion momentum demonstrates effective spatial control of molecular reactions on the surface with nanoscopic resolution. In another study, the role of the solvent in the surface composition of the nanoparticles has been investigated. These evaporate on millisecond time scales upon injection of the nanoparticles into the vacuum. The mass spectrometric study indicated that the generated ions originate predominantly from covalent bonds with the silica surface rather than from physisorbed solvent molecules. The experimental results have been modelled and reproduced qualitatively by classical trajectory Monte Carlo simulations. This work paves the way toward all-optical control of photocatalytic chemical reactions on nanoscale surfaces, including plasmonic particles.

Keywords: reaction nanoscopy, adsorbates dissociation, nanoparticle surfaces, optical emission control

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Hollow square core fiber sensor for physical parameters measurement

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Abstract. The measurement of physical parameters is important in many current applications, since they often rely on these measurands to operate with the due quality and the necessary safety. In this work, a simple and robust optical fiber sensor based on an antiresonant hollow square core fiber (HSCF) is proposed to measure simultaneously temperature, strain, and curvature. The proposed sensor was designed in a transmission configuration where a segment of HSCF, with a 10 mm length, was spliced between two single mode fibers. In this sensor, a cladding modal interference (CMI) and a Mach-Zehnder interference (MZI) are enhanced along with the antiresonance (AR) guidance. All the present mechanisms exhibit different responses towards the physical parameters. For the temperature, sensitivities of 32.8 pm/ºC, 18.9 pm/ºC, and 15.7 pm/ºC were respectively attained for the MZI, AR, and CMI. As for the strain, sensitivities of 0.45 pm/με, -0.93 pm/με, and -2.72 pm/με were acquired for the MZI, AR and CMI respectively. Meanwhile, for the curvature measurements, two regions of analysis were considered. In the first region (0 m^{-1} – 0.7 m^{-1}) sensitivities of 0.033 nm/m^{-1}, -0.27 nm/m^{-1}, and -2.21 nm/m^{-1} were achieved, whilst for the second region (0.7 m^{-1} – 1.5 m^{-1}) sensitivities of 0.067 nm/m^{-1}, -0.63 nm/m^{-1}, and -0.49 nm/m^{-1} were acquired for the MZI, AR and CMI, respectively.

Keywords: Antiresonance, Interferometers, Curvature, Strain, Temperature

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Silicon Nitride Interferometers for Optical Sensing with Multi-micron Dimensions

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Abstract. Increasing the size of the smallest features of Photonic Integrated Circuits (PICs) to multi-micron dimensions can be advantageous to avoid expensive and complex lithographic steps in the fabrication process. In applications where the small chip size is not a requirement, the design of devices with large dimensions is potential interesting to avoid the need for e-beam lithography. Another benefit is that making the dimensions larger reduces the effect of lithographic imperfections such as waveguide surface roughness. However the benefits do not come without limitations. Coupling the light in and out of the circuit is more challenging since diffraction gratings are not available when designing for such large dimensions. Circuit curves must have a larger radius of curvature and the existence of multimode propagation conditions can have detrimental impact in the performance of several devices, such as interferometers. In this study we perform simulation of the power transfer between a lensed multimode optical fiber and several multi-micron SiN waveguides, both in the strip and rib waveguide formats. Light coupling efficiency is analyzed as a function of alignment and distance variations using the FDTD and the Beam Propagation methods. We study the fraction of power carried in the fundamental waveguide modes. Moreover we use numerical simulations to study the performance of a Mach-Zehnder interferometer sensitive to refractive index variations in the top layer. Both the interferometer, splitters and combiners are design with multi-micron dimensions.

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Fiber Loop Mirror temperature sensor interrogated with different techniques

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Abstract. In this work two different techniques are used to interrogate a Fiber Loop Mirror temperature sensor. In the first method, for static measurements up to 1Hz, a FiberSensing for Optical Spectrum Analysis like traditional OSAs was used to acquire both the transmission and reflection spectra of the temperature sensor. Using this method, the measured sensitivity for a Hi-Bi fiber FLM sensor with a free spectral range of 8.8 nm is 309 pm/ºC. In the second approach, more suitable for dynamic measurements, the fiber loop mirror was cascaded with a Fabry-Perot cavity with variable length. A linear PZT drives a silver mirror that works as one of the interfaces of the FP. The applied triangular signal and optical output are acquired by a photodetector and analysed in an oscilloscope. The shape of the output signal is related to optical vernier effect, and after processing it one can accurately interrogate the temperature sensor. A sensitivity of 147 mV/ºC was attained. The two methods may be complementary but under different practical situations one may be more adequate than the other. White Light interferometry interrogation may be interesting of complex sensing networks of fiber optic interferometric sensors.

Keywords: white light interferometry, fiber loop mirror, temperature sensing, Fabry-Perot, signal demodulation

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Plasmonic and Thermal Properties of Nanostructured Systems Probed with Low-cost Optical Setups

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Abstract. The characterization of nanostructured systems can be a complex and demanding task, depending on the target properties of the nanostructures. Optical methods are a natural election as they are rather ubiquitous and of simpler implementation. Also they construction can be efficiency-cost-efficient. The size of the wavelength of the light involved in the measurement is normally critical to accomplish the goals, and can be a limiting factor, because typical nanometric dimensions are much smaller than UV-Vis and NIR wavelengths. Still, absorption, fluorescence or diffuse reflectance can shed light into properties such as plasmonic resonances, related to the material and the size of the nanostructures. Also specular reflective measurements with evanescent wave penetration of thin metal films permit probing nanometric and molecular systems, even in real time. We will discuss several setups implemented in our laboratory on a competitive-cost philosophy, based on easy to acquire and off the shelf elements, complemented with 3D printing and ready-made electronics. First we will introduce a thermal lens setup working on the frequency domain in transmission geometry for the determination of thermal diffusivity of solutions or nanoparticle suspensions. Second, we discuss a complementary instrument based on a Sagnac interferometer and a CMOS camera for imaging to evaluate convective heat transfer in such solutions or suspensions. Thirdly, a simple Surface Plasmon Resonance device in Kretschmann configuration in introduced, which is being used to study molecular detachment (evaporation) from porous nanoparticles in ambient and vacuum conditions. Finally, the application of a homemade multispectral scanner with repurposed and 3D printed parts to evaluate the plasmonic responses of butterflies form three distinct vertical layers in a rainy forest (canopy, overstory, and understory) middle height and in connection with thermogravimetric measurements and SEM images of the underlying micro and nanostructures.

Keywords: Photothermal lens, SPR, Multispectral, plasmonic nanoparticles, interferometry

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Highly Sensitive Plasmonic Sensors and Biosensors realized via Polymer Waveguides

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Abstract. Several developed low-cost, highly sensitive, and simple to realize and to use plasmonic sensor configurations are here presented. In particular, the proposed sensor configurations are based on unconventional platforms that efficiently excite the plasmonic phenomena in gold nanofilms, continuous on nanostructured, such as planar polymer waveguides, polymer optical fibers, and light-diffusing fibers (LDFs). The presented plasmonic sensor chips are monitored using a simple experimental setup based on a white light source and spectrometer. Moreover, the proposed platforms can be combined with chemical and biological receptors in several application fields. In these cases, we can obtain the selectivity for the substances of interest via the use of specific Molecular Recognition Elements (MREs) in contact with the plasmonic sensing surfaces, such as those based on molecularly imprinted polymers (MIPs), antibodies, aptamers, and nanoMIPs [1]. The substances measured with the proposed approach are pollutants, viruses, bacteria, toxic metals, pesticides, or other molecules of interest to detect in aqueous solutions. So, the advantages and disadvantages of each biochemical sensor system are presented in detail. More specifically, plasmonic extrinsic and intrinsic optical fiber sensor types will be reported in terms of plasmonic characteristics and key application fields. For instance, these selective plasmonic optical fiber sensor systems (intrinsic or extrinsic schemes) can be used for "Smart Cities" applications, as in water quality monitoring, through an IoT (Internet of Thing) approach, or, alternatively, they can be used onboard of simple robots, based on an autonomous guide, to follow increasing concentrations of pollutants in rivers or sea to identify the point of interest (the source), etc. Similarly, these plasmonic polymer-based biosensors can be used to realize interesting point-of-care tests for biomedical applications.

Keywords: Plasmonic sensors, Polymer waveguides, Biosensors, Polymer optical fibers, Nano-plasmonic sensors

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Improving plasmonic sensing with suspended core fibres and metallic nanostructured inclusions

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Abstract. Optical fibres with metallic nanostructured inclusions provide great versatility to tailor enhanced optical fibre sensors based on surface plasmons resonances. Through the control of both the geometry (fibre and inclusions) and the material optical properties of the micro and nanostructured components, it is possible to customize the plasmonic and fibre guided modes to optimize their respective interaction, improving the performance of these sensors [1].
The coupling of the optical modes with plasmonic modes depend essentially on the dispersion curves of the different type of modes and are stronger at wavelengths where these curves intersect. The optical properties of these modes near these intersection points define not only the spectral location and width of the plasmonic resonances, but also how these resonances respond to changes in the refractive index of an external analyte and ultimately, how these structures can be used as optical sensing platforms. From these general principles plasmonic sensors can be optimised. On one hand, metallic nanostructured inclusions, such as metallic films or filaments, at specific positions relatively to the core of the fibre permit to adjust the plasmonic resonances to certain wavelength ranges and create spectral telemetric channels. On the other hand, certain optical fibre geometries can further enhance the sensitivity of the plasmonic sensors to external refractive index changes [2-3].
In this work, we discuss the use of a suspended core fibre harnessing how this geometry facilitates the contact between the external analyte with the core fibre and the metallic nanostructured inclusions, permitting to optimise their optical-plasmonic interactions, resulting in changes in the spectral responses that are substantially more significant than in the conventional optical fibre plasmonic sensing configurations.

Keywords: Optical fibre plasmonic sensors, Refractive index sensor, Suspended core fibres, Metallic nanostructured inclusions.

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Strongly coupled plasmonic systems on optical fiber sensors

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Abstract. The recent development of hybrid nanostructures composed of metal nanoparticles (NP) and nanometric metallic films separated by a thin dielectric spacer presented a promising path towards highly performant near infrared (NIR) plasmonic sensing [1].
On such system, the surface charges created on the NPs are anti-symmetrically mirrored onto the thin film, creating a large electromagnetic (EM) field enhancement centred at the dielectric spacer. Thus, overcoming the extremely localized EM field enhancement only around the NPs surface, that hinders its refractive index (RI) sensitivity capabilities. The plasmonic characteristics of such strongly coupled system can be controlled by the NP surface area parallel the film, the NP shape, where sharper features cause band narrowing and both the NP and dielectric spacer complex permittivity. Those parameters can be used to tune the plasmonic band towards NIR with enhanced RI sensitivity [2]. However, illumination conditions are critical, requiring a careful implementation on optical fibres.
In this work, it was studied the coupling between Au nanospheres, with diameters of 20, 60 and 90 nm, to a 50 nm Au thin film, with a dielectric spacing controlled by the number of polyelectrolytes layers. The optical platform chosen was a multimode optical fiber and it was found that by changing the NP size from 20 nm to 90 nm a red shift of 500 nm, from 700 to 1200 nm, was achieved along RI sensitivities around 2500 nm/RIU, a 25-fold increment from single Au nanospheres.

Keywords: Optical Fiber Sensors, Surface Plasmon Resonance, Localized Surface Plasmon Resonance

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Room-Temperature Electroluminescence in RTDs: Towards a Universal Model

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Abstract. The first room-temperature electroluminescence in n-type resonant tunneling diodes (RTDs) was reported in 2017-2018 [1,2] in GaAs/Al0.6Ga0.4As double-barrier structures emitting around the GaAs band-edge wavelength of ~870 nm. In the same timeframe, GaN/AlN double barrier structures were found to emit near the GaN band-edge around 363 nm [3]. More recently, In0.53Ga0.47As/AlAs double-barrier structures were found to emit around the InGaAs band-edge wavelength of 1631 nm [4]. For the GaAs/AlGaAs devices, the emission was attributed to hole generation by impact ionization on the collector side, followed by e-h radiative recombination on the collector or possibly emitter sides. For the GaN/AlN devices, the emission was attributed to hole generation by interband (Zener) tunneling on the collector side followed by e-h recombination on the emitter side. For the In0.53Ga0.47As/AlAs devices, a detailed analysis suggested that both generation mechanisms are present, with impact ionization dominant at lower bias voltages, and interband tunneling comparable at the higher voltages [4]. In this paper, we apply the same analysis to the GaAs/AlGaAs and GaN/AlN structures, seeking a universal model of electroluminescence applicable to all types of RTDs and their vastly different material parameters. The overriding goal is to predict how high the internal quantum efficiency (IQE) can possibly be, particularly when RTDs are used in the promising application of unipolar-doped light emitting diodes (LEDs). A value of IQE = 6% has been obtained from InGaAs-RTD experimental results [4], but much higher values are possible.

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Dual-functioning emitter-receiver III-V unipolar and bipolar microLEDs for on-chip neuromorphic photonic circuits

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Abstract. Since the invention of semiconductor p-i-n LEDs and lasers, these components have been predominantly used as light sources for various applications. LEDs operating in reverse- bias mode can be used as photodetectors [1], and have been previously explored in applications for sensing and visible light communications [2,3]. The possibility of a single light source component to operate simultaneously and efficiently as an emitter and receiver under the same forward-bias conditions remains largely unexplored. Here we introduce two novel and miniaturized two-terminal n-i-n-type and p-i-n-type micropillar LED (μLED) devices based on III-V GaAs/AlGaAs semiconductor compound material with an embedded AlAs/GaAs/AlAs double barrier quantum well (DBQW) resonant tunneling diode [4], which can emit and detect light under the same forward-bias conditions. We have studied the static and dynamic characteristics of fabricated μLEDs to demonstrate their potential for receiving and emitting light-modulated signals. These devices operate under low-voltage (<2 V) and current (<1 mA for n-i-n and <5 mA for p-i-n) driving conditions enabling an energy-efficient emitting and detecting integrated unit. Such compact light-receiver component which would be able to emit, sense and process light-modulated signals could pave the way for important application for LIDAR systems, imaging systems, low jitter optical clocks and on-chip neuromorphic photonic elements.

Keywords: III-V semiconductors, microLEDs, photodetectors, on-chip neuromorphic photonic circuits

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Resonant Tunnelling Diode – Photodetectors for spiking neural networks

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Abstract. Spike-based neuromorphic devices promise to alleviate the energy greed of the artificial intelligence hardware by using spiking neural networks (SNNs), which employ neuron like units to process information through the timing of the spikes. These neuron-like devices only consume energy when active. Recent works have shown that resonant tunnelling diodes (RTDs) incorporating optoelectronic functionalities such as photodetection and light emission can play a major role on photonic SNNs. RTDs are devices that display an N-shaped current-voltage characteristics capable of providing negative differential conductance (NDC) over a range of the operating voltages. Specifically, RTD photodetectors (RTD-PDs) show promise due to their unique mixture of the structural simplicity while simultaneously providing highly complex non-linear behaviour.

The goal of this work is to present a systematic study of the how the thickness of the RTD-PD light absorption layers (100, 250, 500 nm) and the device size impacts on the performance of InGaAs RTD-PDs, namely on its responsivity and time response when operating in the second (1310 nm) and in the third (1550 nm) optical transmission windows. Our focus is on the overall characterization of the device optoelectronic response including the impact of the light absorption on the device static current-voltage characteristic, the responsivity and the photodetection bandwidth. For the static characterization, the devices I-V curves were measured under dark conditions and under illumination, giving insights on the light induced I-V tunability effect. The RTD-PD responsivity was compared to the response of a commercial photodetector. The characterization of the temporal response included its capacity to generate optical induced neuronal-like electrical spike, that is, when working as an opto-to-electrical spike converter. The experimental data obtained at each characterization phase is being used for the evaluation and refinement of a behavioural model for RTD-PD devices under construction.

Keywords: RTD-PDs, Optoelectronics, Photodetectors

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Towards spiking laser diodes on a III-V/Si nanophotonic platform for neuromorphic applications

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Abstract. The monolithic integration of resonant tunnelling diodes with metal-cladding cavity nanolasers opens up the opportunity for dense integration of low-power spiking optical devices. Moving towards nanoscale neuromorphic functionality raises design and fabrication challenges. Fabrication non-idealities play a crucial role in nanophotonic devices performance, for example: high series resistance and unoptimized surface passivation of nanopillar devices may lead to excessive Joule heating and early thermal roll-off (i.e. before reaching lasing threshold). Furthermore, to allow for high-speed spiking operation, design flexibility to adjust the electrical characteristics of devices is desirable. The InP-Membranes on Silicon (IMOS) platform provides the possibility for double-side processing, thereby allowing a significant design freedom. In this work, we discuss our progress towards nanoscale spiking lasers integrated on the IMOS platform.

Keywords: nanophotonic, nanolaser, neuromorphic computing

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Optical nanoantennas: from sensing to killing cancer

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Abstract. Nowadays, optical biosensing and photothermal (PTT) cancer treatments are currently highly active research topics. In the case of biosensing, there is an increasing demand of high sensitivity-enhanced, strong selective and low-cost devices [1]. And in PTT, its success strongly depends on the heating source i.e., the optically absorbing agent employed [2].

Metallic or high-refractive index dielectric nanostructures that show resonances when excited with light can act as optical nanoantennas, providing a versatile tool to control light beyond the conventional diffraction limit [3]. Depending on the type of nanoantennas, they can be appropriate for different applications such as ultrasensitive (bio-) sensing, surface enhanced spectroscopies or photothermal application.

In this talk, I will present the most recent contributions we have made in this topic. In the first part, I will pay special attention to novel designs of highly sensitive optical biosensors based on surface plasmons and optical chirality [4,5]. The second part will be devoted to new nanoheating prototypes able to enhance and deliver heat in a control manner [6-8].

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Au nanoparticles/semi-conductor thin film prepared by laser annealing and sol-gel

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Abstract. The development of alternative methods of integrating electronic devices has become a major issue in the context of the Internet of Things (IoT). Among these basic components, photodetectors are important devices for applications in health, sports or more generally sensors.

We propose a new method for preparing gold nanoparticles (Au NPs)/indium-zinc-oxide (IZO) nanocomposite thin films based on photothermal mechanisms with near-Infrared (NIR) laser-annealing, which allows integrating the nanomaterial on fragile substrates such as thin glass, plastic sheets, or 3D printed pieces. The Au NPs were first prepared by NIR laser dewetting of a thin Au layer. Then, the Au NPs were used to locally cure the semiconductor material and provide suitable electronic properties owing to their efficient thermoplasmonic effects under our NIR laser annealing conditions. Finally, the electronic properties of the Au NPs/IZO thin films were characterized in the dark and under light excitation. Good photoresponsivity at 410 nm (UV, > 10^0 A/W) was demonstrated, but interestingly, the presence of Au NPs significantly improved the detection ability to a longer wavelength range, such as to 515 nm (green, ~ 5×10^{-3} A/W), even extending to 630 nm (red, ~ 5×10^{-4} A/W), and 780 nm (NIR, ~ 10^{-4} A/W). In addition, with the critical evaluation of dynamic light detection and lifetime trace (> 22 days), the laser-annealed Au NPs/IZO photodetector (PD) demonstrated useful operating reliability and stability.

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Plasmonic/magnetic liposomes based on nanoparticles with multicore-shell architecture for chemo/thermotherapy

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Abstract. Multifunctional liposomes containing magnetic and plasmonic nanoparticles (magnetic/plasmonic liposomes) are promising nanosystems for cancer therapy. Their structural and physical properties enable a synergistic effect between dual hyperthermia (magneto-photothermia) and local chemotherapy, allowing overheating of cancer cells while increasing drug toxicity [1,2].

In this work, multicore magnetic nanoparticles (NPs) of manganese ferrite were prepared using carboxymethyl-dextran and melamine as agglutinating agents. The NPs prepared exhibit a flower-shape structure and good capabilities for magnetic hyperthermia. Magnetoliposome-like structures containing the multicore NPs exhibit sizes in the range 250 – 400 nm, being suitable for biomedical applications. A new antitumor thienopyridine derivative was loaded in these nanocarriers with a high encapsulation efficiency. The stability of the nanosystem was confirmed, pointing to suitable characteristics of the magnetoliposomes for dual cancer therapy (combined hyperthermia and chemotherapy).

Keywords: magnetic nanoparticles, plasmonic nanoparticles, multicore-shell nanostructures, magnetic hyperthermia, combination therapy

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Gas detection with high-resolution LSPR spectroscopy

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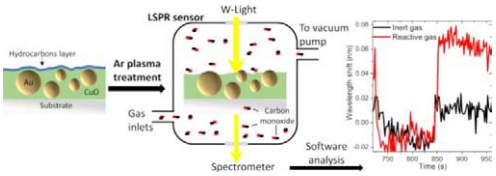
Abstract. Gas sensing, based on bulk refractive index (RI) changes, has been a challenging task for localized surface plasmon resonance (LSPR) spectroscopy. In this work, it is demonstrated that a plasmonic thin film composed of Au nanoparticles embedded in a CuO matrix can be used to detect small changes (as low as 6×10^{-5} RIU) in bulk RI of gases at room temperature, using a High-Resolution LSPR spectroscopy system [1,2]. Such a thin film system was optimized by reactive magnetron sputtering, followed by an in-air annealing protocol treatment at 700 ºC to promote the Au nanoparticles' growth. To enhance the film's sensitivity, the effect of low power plasma etching was investigated on the surface properties and nanostructure of the thin film. A 5 min Ar plasma treatment was revealed to be enough to remove the top monolayers of the film and partially expose the embedded nanoparticles, thus maximizing the sensor sensitivity. The treated sample exhibit high sensitivity to inert gases (Ar, N_2), presenting a refractive index sensitivity to bulk RI changes of 850 nm/RIU. Furthermore, a 2-fold signal increase was observed for O2 and CO gases, showing that the thin film system is clearly more sensitive to these non-inert gases, due to, most probably, gas adsorption on the film surface. The results show that the Au:CuO thin film system is capable to detect small RI changes caused by different gases, at room temperature, supporting the potential of this thin film system to be employed as a gas sensor, particularly in CO detection.



Keywords: Plasmonic thin film; Au nanoparticles; High-Resolution LSPR spectroscopy; optical gas sensing.

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Photonic Crystal Design for Bloch Surface Wave Sensing

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Abstract. In the past few years, Bloch Surface Waves (BSW) have emerged as an alternative to Surface Plasmon Polariton (SPP) based sensing, which has been the predominant surface wave used in different types of optical sensors [1]. While SPP's are excited at the interface of a metal and a dielectric, BSW's are excited at the interface between a photonic crystal and a dielectric, thus displaying sharper resonances and better durability [2]. Nevertheless, due to the large number of parameters such as refractive indices, thicknesses and number of layers, the design of photonic crystals for the optimization of BSW-based sensors is not a trivial task, and several works have already approached this topic using different optimization techniques [3,4].

In this work, a strategy for designing 1D photonic crystals for BSW based sensing is presented, which builds upon previously published work. The goal is to establish a correlation between the parameters of a photonic crystal and the spectral characteristics of the BSW, which may provide important insights for future design of optical sensors.

Keywords: Bloch Surface Waves; Photonic Crystals; Optical Sensors; Nanophotonics

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Advanced refractive index sensor using 3-dimensional metamaterial based nano antenna array

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Abstract. Photonic researchers have increasingly exploiting nanotechnology. Due to the advent of numerous prevalent nanosized manufacturing methods that enable adequate shaped nanostructures to be manufactured and investigated as a method of exploiting nano-structured. Owing of the variety of optical modes, hybrid nanostructures that integrate dielectric resonators with plasmonic nanostructures also offer enormous potentials. In this work, we have explored a hybrid coupled nano-structured antenna with stacked lithium tantalate($LiTaO_3$)/Aluminium oxide(Al_2O_3) multilayer operating at infrared ranging from 400nm– 2000nm. Here, the sensitivity response has been explored of the hybrid nano-structured array made up of the gold metal elliptical disk placed on the top of a quartz substrate and excite the different modes in both materials. It shows large electromagnetic confinement at the separation distance(*d*) of the dimers due to strong surface plasmon resonance(*SPR*). The influence of the structural dimensions is investigated to optimise the sensitivity of stacked elliptical dimers. The designed hybrid coupled nano-structure with the combination of gold(*Au*) and Lithium tantalate($LiTaO_3$)/Aluminium oxide(Al_2O_3) with h_1=h_2=10nm each 10 layer exhibits bulk sensitivity(*S*), which is the spectrum shift unit per refractive index(*RI)* change in the surrounding medium was calculated to be 700 and 620nm/RIU with major axis,(*a*) = 100 nm, minor axis,(*b*) = 10nm, separation distance(*d*) = 10nm, height,(*h*) = 100nm. The outcomes from the proposed hybrid nano-structure has been compared with a single metallic(only gold) elliptical paired nano-structure to show a significant improvement in the sensitivity using hybrid nano-structure. Depending on these findings, we demonstrated a roughly two-fold increase in sensitivity(*S*) by utilising a hybrid nano linked nano-structure with respect to identical nano structure, which competes with traditional sensors with the same height,(*h*) based on localised surface plasmon resonances. Our innovative plasmonic hybrid nanostructures provide a framework for developing plasmonic nanostructures for use in various sensing applications.

Keywords: Nano-antenna, Surface plasmon resonance, plasmonic sensitivity, plasmons, refractive index sensing, and Localized surface plasmon resonance.

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Humidity and touch sensing by capacitive-type sensors obtained by electrochemical anodization

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Abstract. Capacitive-type sensor created from nanoporous anodic aluminium oxide (NP-AAO) were prepared by the one-step anodization method conducted in potentiostatic mode. A low-cost preparation system was set. A series of samples were prepared via an anodization campaign carried out on different acid electrolytes, in which the anodization parameters were adjusted to investigate the effect of pore size and porosity on the capacitive sensing performance. Two sensor test cases are investigated: highly uniform NP-AAO structures for humidity sensing applications; and, the use of NP-AAO as a capacitive touch sensor for biological applications, namely to detect the presence of small “objects” such as bacterial colonies of Escherichia coli.

25G Receiver and Analysis of Filters Frequency Response

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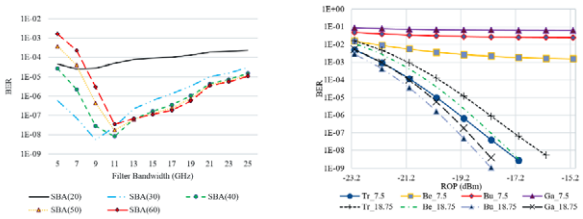
Abstract. Cost-efficient transmission is an important objective of access networks. One approach to achieve this in 25 Gb/s high-speed passive optical networks (HSP) could be using 10G opto-electronic receiver (Rx). To do this, bandwidth (BW) limitation would cause major degradation and high error rate. In [1], a 10G-Rx with an adaptive equalizer is suggested which introduces extra cost. According to the standard [1], 75% of the signal's bandwidth is required for an efficient Rx design capable of smooth signal reception. This indicates that 3 dB-BW of 18.75 GHz would be required for 25 Gb/s transmissions.

In this work, analysis of four electrical low-pass filters (LPF) for the Rx design are carried out. These are Bessel (Be), Gaussian (Ga), Trapezoid (Tr) and Butterworth (Bu) LPF. For Be, Ga and Bu, optimal performances are obtained when the filter order is set to 4 and 3 dB-BW is set between 13 GHz and 19 GHz. For Tr, BER vs BW at different stop band attenuation (SBA) was obtained as shown in Fig.1(a) with optimal performance at SBA = 30 dB and 9 GHz 3 dB-BW. Throughout the simulation, Tr stop BW (sBW) is set to 2*Bitrate (50 GHz).

We generate a 25 Gb/s signal from a Hybrid Modulation transmitter (HM_t) following the procedure in [2]. The modulated signal is transmitted over 20 km of SMF and decoded by a PIN-PD followed by a LPF and an error analyser. The four filters are configured with 3 dB-BW of 7.5 GHz and 18.75 GHz BW mimicking 10G and 25G Rx respectively.



(a) (b)

Fig. 1 (a) BER versus Tr BW at different SBA. (b) BER versus ROP for 20 km transmission of 25 Gb/s signal using different filter types (Be, Ga, Tr, Bu) with BW set to 7.5 GHz and 18.75 GHz.

The result of BER against ROP shown in Fig.1 (b) indicates the possibility of using 10G-Rx with Tr to decode 25 Gb/s signal. Whereas, this is challenging with other filters specified. The result pointed to the direction of designing low-cost 10/25G Rx for future 25/50 Gb/s access networks.

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Brain-inspired nanophotonic spike computing

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Abstract. Today's most successful artificial intelligence (AI) algorithms are inspired by brain-like neural networks. However, unlike our highly efficient brains, running these algorithms on computers consumes very large amounts of energy. These extremely inefficient central processing units hinder the development of efficient, scalable and portable AI systems.

Spiking photonic neural networks based on subwavelength excitable neuron-like devices are of paramount importance since they could enable the inherent parallelism and energy efficiency needed for brain-inspired AI systems. Despite the significant advances in neuromorphic photonics, compact and efficient nanophotonic elements for emission (and detection) of spiking signals, as required for spike-based computation, remains largely unexplored. Among numerous challenges, difficulties in achieving neuron-like non-linear properties, large non-radiative recombination rates leading to low-efficient sources, and challenges in light extraction and coupling to waveguides [1], all play a relevant role to realize on-chip brain-inspired nanophotonic hardware.

Here, we outline the main challenges, early achievements, and opportunities towards key-enabling photonic neuro-architectures using spiking nodes. Then, we present a platform based on resonant tunnelling diodes (RTDs) integrated with nanoscale light-emitting diodes (nanoLEDs) [2]. We utilize this nanophotonic hardware as the non-linear artificial optical neurons capable of producing non-linear spikes to realize neuron emitter and receiver spiking nodes. Such layout would exhibit small footprint and low-power consumption, all key requirements for efficient optoelectronic spike conversion. The future progresses towards the development of such a neuro-architecture integrated with optical interconnections, and configured with appropriate spike-based algorithms will pave the way for further progresses.

Keywords: Nanophotonics, nanoLEDs, neuromorphic computing, optical interconnects, spiking neural networks

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Two-photon polymerization simulation and fabrication of 3D microprinted suspended waveguides for on-chip optical interconnects

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Abstract. Quantum and neuromorphic computational platforms based on integrated photonic circuits require next-generation optical functionalities and increasingly complex on-chip light-routing capabilities enabling, for instance, high interconnectivity and superpositions which are paramount for the realization of artificial neural networks. In such integrated photonic circuits, the single optical interconnect would be individually designed and optimized; for complex networks, two-photon polymerization (TPP)-based microprinting allows for expanding the waveguides into 3D which is not achievable by standard planar lithography fabrication technologies. Here we present a 3D morphology prediction tool which considers experimental TPP parameters enabling on-chip 3D waveguide performance simulations that allow estimation of transmission and in-coupling losses based on the waveguide design and material prior to fabrication reducing the cost-intensive and time-consuming systematic experimental optimization process. Fabricated 3D waveguides based on simulated designs show optical transmission properties in agreement with simulation results, demonstrating the benefits of the developed morphology prediction methodology for the development of versatile on-chip and potentially inter-chip photonic interconnect technology. Furthermore, several waveguide design strategies to circumvent fabrication limitations and improve optical properties are presented.

Keywords: polymeric waveguides, 3D printing, two-photon polymerization (TPP), neuromorphic computation, photonic wire-bonding.

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Subwavelength structures for taper waveguides

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Abstract. In Photonic Integrated Circuits (PICs) it is often necessary some sort of mismatch adaptation between waveguides of different cross-sections. There are several instances of such a designing constraint, being the vertical coupling between the PIC and an optical fibre probably the most representative of all examples. Here, the beam of electromagnetic energy inside the PIC must be inserted/extracted through/to an optical fibre. Typical core diameters are approximately 10 µm and 5 µm, for single mode optical fibres operating in the near infrared and visible wavelengths, respectively. On the other hand, the optical interconnects linking individual structures in PICs are usually single mode waveguides, 400 to 500 nm wide and a few hundreds of nanometres thick. This presents a bidimensional mismatch between the optical fibre and the single mode waveguide within the PIC, that requires both lateral and longitudinal beam expansions. In this work, we have approached the lateral expansion of the fundamental mode propagating in a single mode waveguide, at the operating wavelength of 1550 nm and being coupled out into an optical fibre, through a grating structure 14.27 µm wide. To this end, we have designed and simulated a subwavelength metamaterial planar structure, which is able to expand laterally the fundamental mode's profile from 450 nm to 14.27 µm (typical width of the grating coupler), within 11.1 µm. Furthermore, we will be presenting the results obtained when comparing this structure with several linear inverted taper waveguides, regarding coupling and propagation efficiencies. Namely, we compared the coupling efficiencies of the modes propagating in an 100 µm long waveguide, when being excited by the analytically calculated fundamental mode and the fields obtained at the end of the designed structure. The results obtained for the designed structure 11.1 µm long and the calculated fundamental mode showed a coupling efficiency of -1.53 dB and -1.20 dB, respectively.

Keywords: subwavelength structures, metamaterial, planar waveguide, linear taper waveguide.

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MMI Splitters and Combiners for Multi-Micron Amorphous Silicon Nitride Rib Waveguides

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Abstract. Light distribution devices are vital elements found in almost every photonic integrated circuit. Interferometric sensors, such as, for example the Mach-Zehnder and Young configurations rely on light beam division and combination. In this article multi-micron rib waveguide-based power splitters and combiners are investigated, these devices are etched directly on the waveguide's core, significantly simplifying the manufacturing process by only requiring one lithographic mask. In order to maximize power transfer, tapered connections are employed for waveguide width conversion. The performance of multi-micron waveguides is less affected by side-wall roughness than nanometre scale devices, also benefiting from less costly lithographic manufacturing processes, due to its larger feature size. Single-mode strip waveguides for near infrared and visible light have dimensions on the order of hundreds of nanometres, a limitation that does not exist in rib waveguides, which are able to support monomodal operation with much larger dimensions, above the micrometre. The proposed photonic devices' technology is silicon-on-insulator (SOI), featuring a waveguide core of hydrogenated amorphous silicon nitride with multi-micron features, compatible with low resolution ultra-violet lithography and Plasma-Enhanced Chemical Vapor Deposition (PECVD), which allows a significant cost reduction. In this study we employ simulation tools based on the FEM, BPM and FDTD to assess the performance of multi-micron SOI rib waveguide multi-mode interference (MMI) splitters and combiners. The fundamental mode power loss of the proposed devices, for quasi-TE and quasi-TM modes, is less than 1 dB, for a splitter-combiner setup.

Keywords: Rib waveguide, Multi-mode interference, Splitter, Combiner, Photonics.

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Molecularly imprinted nanoparticles: plastic antibodies for optical sensing platforms.

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Abstract. Molecularly imprinted polymers (MIPs) are tailor-made biomimetic materials prepared by means of a template assisted synthesis: the monomers and the crosslinker are polymerized in the presence of the target analyte, called the template, so that stereo-chemical template-complementary prints are left on the growing polymer. MIPs exhibit exceptional recognition properties for the template, possessing selectivity, specificity and affinity on the par of natural antibodies [1-4], but being plastics, MIPs are resistant to thermal stress and to extreme pHs, cheaper in production respect to the biological macromolecules and suitable to mass fabrication.

With the aim to improve the determination of biomarkers in sensing platforms, the rational design and the preparation of MIP nanoparticles (nanoMIPs) suitable for the recognition of proteins and peptides will be discussed.

NanoMIPs addressed at the recognition of targeted proteins or peptides can be synthesized by radical polymerization of monomers. The prepared materials are characterized physico-chemically. Generally size of the nanoMIPs are ~50 nm [5]. The binding of the nanoMIPs for their targets show very high affinity and selectivity, indicating that nanoMIPs can be ideal biomimetics for sensing platforms.

Examples of integration of nanoMIPs to optical sensors will be discussed [6-7].

Keywords: molecularly imprinted nanoparticles; biomimetics; molecular recognition; optical chemical sensor

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Nanoscopy, Metabolic Imaging and Intracellular Sensing based on Nanophotonics and Nonlinear Microscopy approaches

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Abstract. We will provide the background of state-of-the-art fluorescence sensing and imaging techniques that deploy nanophotonics approaches to surpass the optical diffraction limit based on near field effects [1, 2, 3], that make use of various fluorescence spectroscopy parameters to measure metabolic states of cells [4] to distinguish several fluorophores at the same time using ultrabroadband lasers [5] and to measure intracellular temperature via luminescence nanothermometers [6,7] and magnetic fields via fluorescent point defects in diamond [8].

It will provide an overview on the recent methodological developments in our research group "Ultrafast Bio- and Nanophotonics" at INL, while providing an overview of the physical background of these laser-based imaging technologies.

Keywords: MIET-FLIM, Intracellular temperature, ultrabroadband lasers, multiphoton microscopy.

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Dehydropeptide-based plasmonic lipogels as bionanosystems for controlled drug release

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Abstract. The encapsulation and control over drug release, mainly of hydrophilic drugs, is currently a major challenge in the application of peptide-based hydrogels for drug delivery, as it might require screening several gelator structures to achieve the adequate release profiles. This can be overcome through encapsulation of the hydrophilic drugs in liposomes, which provides an additional barrier to the drug diffusion, besides enabling the spatiotemporal control and enhanced drug release through a trigger, such as photothermia.

Hence, in this work, silica-coated gold nanoparticles and liposomes (storage units) were combined with dehydropeptide-based hydrogels as a proof-of-concept to afford peptide-based NIR light-responsive lipogels. Several liposomes compositions were assessed to study its influence on the final assembly properties. Gold nanospheres were used to assess the preparation method that enabled a closer proximity of the nanoparticles to the liposomes. The control over a hydrophilic drug model, 5(6)-carboxyfluorescein, was achieved by its encapsulation in liposomes, in which the use of photothermia induced the liposomes phase transition and stimulated the drug release. Further, despite the liposomes and silica-coated nanorods inducing a lower elastic modulus, strongly enhanced the gelation kinetics. Hereby, this work advances strategies for the development of peptide-based hydrogels towards controlled release of hydrophilic drugs through photothermia under NIR light irradiation.

Keywords: peptide hydrogels; self-assembly; liposomes; gold nanorods; photothermia; drug delivery.

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Nanoscale distance sensing using fluorescently-labelled DNA origami tetrahedra on Graphene

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Abstract. We present a hybrid DNA origami-fluorophore-Graphene platform for nearfield sensing and emerging DNA memory applications. DNA origami are folded structures that can be three-dimensional and are usually based on binding short staple strands to a backbone, called a scaffold strand. They can have uses in many fields, e.g., biosensing or electronics.
Here, we add fluorophores at various positions along the tetrahedron architecture at specific distances away from the substrate, while the substrate supporting the tetrahedra is functionalized with Graphene. The functionalization with Graphene allows for Resonance Energy Transfer from the fluorophores to this material, which leads to a characteristic decrease in the lifetime of the fluorescence decay in the vicinity of the surface (quenching) [1]. A mathematical function can describe this effect, which converts fluorescence lifetime to distance to the Graphene layer [2]. DNA tetrahedra are prepared in a mixed solution of strands and then purified. The surface comprises a Graphene monolayer, functionalized by linker molecules and a DNA strand that binds to the origami. Binding sites are prepared at chosen heights in the tetrahedron so that new complementary strands substituted with a fluorophore can be added and set in place by DNA hybridization. These are the so-called *target strands*.
Fluorescence Lifetime Imaging Microscopy (FLIM) is used to characterize the fluorescence lifetimes of chosen sample areas. The distance distribution of the fluorophores relative to the Graphene layer is calculated and displayed using fluorescence lifetime fitting algorithms [3] and the fluorescence lifetime-to-distance conversion model [2]. We determined the fluorophore-to-Graphene distances based on this procedure, agreeing with the expected-by-construction distances. We demonstrate that the quenching effect can be manipulated by changing the Fermi level of Graphene through electrical gating. Both fluorescence intensity and lifetime changes in measurements performed under an applied gate voltage indicate that the tetrahedral origami structures are strained by the electric field, thereby changing the fluorophores' distances to the Graphene layer. We have determined that the tetrahedron can work either as a fluorescence switch or a high-resolution distance-sensitive sensor, depending on the applied voltage range, and we expect exciting developments in sensors based on this system.

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Development of pH-sensitive magnetoliposomes containing shape anisotropic magnetic nanoparticles for applications in dual cancer therapy

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Abstract. Liposome formulations sensitive to the tumor microenvironment, such as pH, are promising to enhance liposome cellular internalization, and promote drug release in cancer cells while preventing its leakage and premature release. At acidic pH (such as in tumor tissues), pH-sensitive liposomes promote cell membrane destabilization and improve the release of the encapsulated compounds at target sites [1]. In addition, the combination of sensitive liposomes and magnetic nanoparticles in a single multifunctional nanosystem, enables guiding the nanoparticles to the tumor site, ensuring a local temperature increase (hyperthermia) and triggering drug release (local chemotherapy), while reducing cytotoxic effects [2].

In this work, anisotropic magnetic nanoparticles of mixed calcium/magnesium ferrite were synthesized for their enhanced magnetic properties. After characterization and validation of their suitable structural and magnetic properties, the nanoparticles were encapsulated into pHsensitive liposomes composed of DOPE:Chol:CHEMS (45:45:10). The chemotherapeutic drug doxorubicin was loaded in this liposomes with high encapsulation efficiency, and the resulting nanosystems were characterized by DLS. Fluorescence emission assays were performed to study the release profile of doxorubicin at different pH values and promising results were obtained for application in combined cancer therapy.

Keywords: Anisotropic shape nanoparticles, superparamagnetism, magnetoliposomes, pH sensitivity, dual cancer therapy.

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Optical harmonic Vernier effect: properties and applications

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Abstract. In the past decade a new tool with the potential to magnify the sensitivity and resolution of fiber interferometric sensors has emerged. Inspired by the Vernier caliper, invented in 1631, this technique relays the Vernier effect concept into the optical domain, particularly using optical fiber interferometers[1]. The same way a caliper uses the overlap of two different scales to achieve higher resolution, here two interferometers with slightly detuned interferometric signals are used. The result is an envelope modulation that presents magnified sensing capabilities (i.e., magnified wavelength shift) compared to the signal of the main sensing interferometer employed in the system[2]. In this context, the magnification factor (M) is an important metric, which indicates how many times the sensitivity is improved compared to that of the individual sensing interferometer used. Recently, we have demonstrated an extended concept of the optical Vernier effect, where harmonics can be introduced to further increase the sensitivity by multiple integers of the magnification factor, while keeping the size of the Vernier envelope modulation constant[3]. This presentation will discuss the properties of the optical harmonic Vernier effect, with special focus on important aspects related with its potential and limitations. Subsequentially, both simple and more complex configurations for applications in strain, temperature, and refractive index sensing will be presented[4,5].

Keywords: Optical fiber sensors, Vernier effect, harmonic Vernier effect, fiber interferometers.

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Optofluidic fibre sensor for the real-time measurement of refractive index

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Abstract. In this work, a microfluidic system combined with a fibre-optic extrinsic Fabry–Perot interferometer (EFPI) is proposed to measure refractive index continuously and in real time. A microfluidic platform was designed and created for this purpose through 3D printing. The EFPI cavity is an integral part of the chip and is perpendicular to the sample flow. The light is conducted through a single mode optical fibre and the refractive index measurements were based on the wavelength shift of the reflected spectra. The developed optofluidic set-up was tested using different concentrations of glucose in aqueous solutions. Different EFPI cavity lengths were evaluated and the sensor with a ~1640 nm length was found to have a sensitivity to the refractive index of 1143 nm/RIU when using the higher frequency signal. Combining the intrinsic advantages of microfluidic systems and optical fibre sensors, the proposed sensing device has a great potential for applications where refractive index real-time measurement is required, such as food and beverages process control (e.g., wine fermentation), quality and safety (e.g., in water and pharmaceuticals), among others.

Keywords: Optofluidics, Fabry–Perot, Refractive Index, Real-time Measurement

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Simultaneous measurement of displacement and temperature using balloon-like hybrid fiber sensor

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Abstract. A hybrid sensor based on a silica capillary in a balloon-like shape for simultaneous measurement of displacement and temperature is proposed for the first time, to the best of our knowledge. The sensor is fabricated by splicing a segment of a hollow core fiber between two single mode fibers (SMF) and by creating a balloon shape with the capillary at the top-center position. The SMF-capillary-SMF configuration excites an antiresonant (AR) guidance and the balloon shape enhances a Mach-Zehnder interferometer (MZI). The different responses of the interferometers to external displacement and temperature variations lead to a hybrid application of the sensor for simultaneous measurement of these parameters. Experimental results show that, for a capillary length of 1.2 cm and a balloon length of 4 cm, AR is insensitive to displacement and its sensitivity to temperature is 14.3 pm/°C, while the MZI has a sensitivity to displacement of 1.68 nm/mm and twice the sensitivity of AR to temperature, of 28.6 pm/°C. The proposed fiber sensor consists of only one sensing element in one configuration exciting two interferometers at the same time, which makes it of simple fabrication as well as low cost.

Keywords: Antiresonant, Mach-Zehnder, Balloon-like, Displacement, Temperature

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Characterization of a D-shaped photonic crystal fiber with two silver-Al_2O_3 nanowire metamaterial layers

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Abstract. The metamaterial bulk properties are used in the control and to manipulate surface plasmon to produce a multiplasmonic D-shaped Photonic Crystal Fiber device. Two plasmon resonances can be tuned by the customization of two silver-silica nanowire metamaterial layers deposited adjacent to each other in the flat surface of the fiber. Using computational simulations based on finite element method (FEM), we show how to apply the sensor to address refractive index of surrounding media and the nanowire layer's constituent characteristics at different wavelengths. Such characteristics find large potential to provide several applications for plasmonic optical sensors

Keywords: surface plasmon resonance; photonic crystal D-shaped fiber; refractive index sensor; metamaterial; tunable sensor.

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Optical fiber sensor based on balloon-like interferometer structure and 3D printer for displacement sensing

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Abstract. An optical fiber sensor based on a balloon-like interferometer structure (BLIS) combined with a 3D printer piece has been presented and demonstrated, which can be used to measure displacement. This work presents preliminary results using this combination. BLIS has a compact size, easy fabrication, low cost, and it is repeatable. The sensor is based on the interference between the core and cladding modes, this is due to the curvature of the fiber, because a part of the light will be free from the core restriction and couple to the cladding when the light propagates in the curved balloon shaped section. The piece was developed so that there is an axial displacement in the balloon. The sensing head is embedded between two rods so that the dimension associated with the macro bend is changed when there is a displacement. From this, it is possible to analyse the variation of the transmitted optical power as a function of the displacement. Experimental results show that the BLIS offers a displacement sensitivity of 0.0003 dB/um and a dynamic range of 3000 um. Due to its and advantages presented above, this sensor is a good candidate for applications where displacement need to be analysed.

Keywords: Balloon-like interferometer, displacement sensor, bent single-mode fiber, displacement sensing, diameter variation

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Evaluation of the orientation impact in thermal behavior of cylindrical Li-ion batteries in different cycling conditions using FBG sensors

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Abstract. Optical fibre Bragg grating (FBG) sensors are nowadays widely used in several applications regarding the Li-ion battery (LiB) management [1]. In this work, FBG sensors were used to evaluate the thermal performance of an 18650 LiB operating under normal and abusive conditions while positioned in the horizontal and vertical orientations. In total, three FBG sensors were used to track in real time the temperature variation of cathode, middle and anode of the LiB. Tests for each orientation were performed, each of them consisted of two cycles: the first one with normal charge/discharge conditions (operating between 2.75 V and 4.2 V), and another in abusive conditions (2.0 V and 4.95 V). The battery was submitted to constant current charge and discharge steps, with rest intervals between each operation. The results suggest that, in general, the temperature variation while operation in vertical orientation is lower if compared to the horizontal one, mainly in the anode, while the LiB is submitted to the abusive charge procedure ($\Delta T = 2.7 \pm 0.2$ ºC); in addition, the FBG sensors were able to track in real time the temperature variation of three different locations of the battery simultaneously. The temperature variation registered for each sensor is shown and discussed.

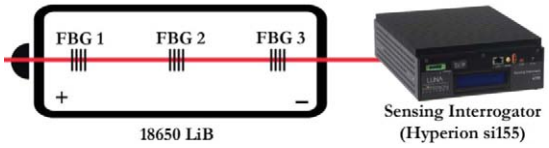

Figure 1- Experimental setup.

Keywords: Lithium-ion battery performance, fibre Bragg grating sensors, real time thermal monitoring, battery abusive operating, battery management.

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Magneto-piezoresistance in magnetorheological elastomer for low range conductive feedback

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Abstract. This study investigates the influence of Graphite (Gr) based magnetorheological elastomer (MRE) on magneto-piezoresistance effect which could be applied in optical soft electronics such as wearable and flexible sensors. Gr is used as a filler in the construction of isotropic and anisotropic MRE samples. The morphological, rheological, and piezoresistive properties of Gr-MRE are explored and compared to those of standard pure MREs. Field emission scanning electron microscopy (FESEM), scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDX) are used to analyze the morphology of Gr-MRE, while rheological properties are assessed using a rheometer. The piezoresistance qualities are next studied using the designated test-rig. Based on the piezoresistance evaluation, a curve was generated and drawn that describes the relationship between resistance (R) under different applied pressures (F) and magnetic fields (B). Furthermore, the FESEM pictures revealed the presence of Gr fractions, which contribute to the conductivity feature of MRE. It is also noticed that the addition of Gr improved the rheological and conductivity parameters such as storage modulus and resistance response as the magnetic field was increased. The results also shown that the addition of Gr in MRE can aid with the usage of force detection in sensing devices.

Keywords: Magnetorheological Elastomer, Conductive polymer, Graphite.

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Investigation on the operation modes of optoelectronic oscillators based on resonant tunnelling diodes

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Abstract. In this work we report the preliminary work on simple and compact optoelectronic oscillators (OEOs) that takes advantage of the optoelectronic properties of double barrier quantum well (DBQW) resonant tunneling diodes (RTDs) based photodetectors (RTD-PDs). OEOs are optoelectronic circuits capable of producing low phase noise electronic sine waves and modulated optical continuous wave signals. Generically, they comprise a laser diode (LD, an optical modulator, electric filters, electrical and optical amplifiers, a photodetector (PD), and a low loss delay-line such as an optical fiber, arranged in a way to convert light energy into stable, spectrally narrow RF/microwave reference signals [1]. OEOs applications range from radar technology, satellite communication links, precise metrological time and frequency measurements, reference clock distribution, and high-bit rate, optically supported, communication wireless links, including radio over fiber.

DBQW-RTDs are nanoelectronic semiconductor devices with N-shape like current-voltage characteristic capable of producing electronic oscillations (up to THz), due to its ultrawideband negative differential conductance and nanometric dimensions [2]. When incorporating moderately thick light sensitive layers an RTD can operate as an amplified photodetector, known as RTD-PD. Taking advantage of RTD-PD properties (such as electrical gain and light detection) simple and compact low-cost OEOs can be implemented, where the RTD-PD replaces the need of an optical modulator, and electrical and optical amplifiers. The RTD-PD self-oscillation signal drives the LD, with a fraction of the LD optical output being feed back into the RTD-PD through an optical fiber. Here we report the optoelectronic characterization of RTD-PD devices aiming their function as amplified photodetectors, including its operation as optical controlled voltage-controlled oscillators (OC-VCO) being used to implement RTD-PD based OEOs, and present the investigation on the modes of operation of these RTD based OEOs, including injection locking to an external source and self-injection locking.

Keywords: Resonant tunnelling diode, optoelectronic oscillator, laser diode, injection locking

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Optimizations of Si PIN Diode Phase-Shifter Combined with RC Equalizer Under Forward Biasing

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Abstract. Silicon (Si) forward-biased PIN-Phase shifter (PS) has an un-doped intrinsic area at the centre of a Si waveguide core. This area is sandwiched between p and n doped, half-etched Si conducting areas. Because of this simple component formation, the PIN-PS can be easily integrated with other optical components [1]. Applying a forward bias to the Si PIN diode causes a large number of free-carries to be gathered in the intrinsic territory and induce an optical phase shift via the carrier plasma effect [1]. Since both PIN and conventional PN phase shifters use the carrier plasma effect to form an optical phase shift, the quantity of electric charge necessary for the same optical modulation does not have much difference between these two kinds of phase shifter. However, Si PS performances can be reduced dramatically due to laser thermal drift, fabrication errors on the width and etching rib waveguide, the concentration of electrons and holes doping, and the doping location. To solve these issues, in this work we demonstrated an optimal design of Si PIN-PS based on carrier injection using a commercial 220 nm top silicon-on-insulator (SOI) rib waveguide. The optimizations were done on the doping concentration, doping location, key geometrical parameters of the rib Si waveguide structure, driver voltage, and the operating wavelength using optical and electrical simulations. These optimizations can be very useful to study how to select the optimal PS design that is suitable for the requirements of the telecommunication system. Commercial high-speed silicon Mach-Zehnder modulator required to be active around the quadrature bias point with low power consumption, small footprint, and small drive voltage. The bias controlling is done by an optical phase-shifter. However, the accuracy is limited by the drive voltage, laser thermal drift, and fabrication errors. To overcome these problems, we propose in this paper the study and analysis of Si PIN diode phase-shifter combined with the RC equalizer under forward biasing at 1550 nm wavelength using the standard 220 nm substrate silicon-on-insulator rib waveguide technology. Numerical investigations were carried out on the key geometrical parameters, doping concentration, doping locations, operating wavelength, biasing level. Results show that the optimal design can be operated with a lower voltage (V_π=1.629 v), lower attenuation (α=28.985 dB/cm), 34.11 GHz bandwidth, and short device length with an extremely small voltage-length product $V_\pi L$=0.815 vmm. Thus, this PS can be used for designing an efficiency high-speed MZM and to obtain better performances in the optical commutation system.

Keywords: MZM, Silicon, Phase-shifter

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Impact of Sm on microstructure and Faraday magneto-optical effects of transparent Y_2O_3 ceramics

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Abstract. Currently, crystals show large magneto-optical effects, however the diameter of monocrystalline materials are too small to use to the high-power optical isolator. Polycrystalline magneto-optical Y_2O_3 ceramics doped with selected rare earth elements were fabricated by arc plasma melting using rare-earth oxides as the precursors. No milling and /or sintering aids were adopted in this ceramic fabrication processing. X-ray diffraction analysis revealed only one phase. Rietveld Refinement shows the crystallite size of samples. The addition of Sm^{3+} leads to an increase lattice constants. The impacts of Sm^{3+} doping on morphology and Faraday magneto-optical effects were systematically investigated. The wavelength dispersion of the Verdet constants of transparent materials has been investigated at sensitive and wide spectrum range measurement setup [1]. The 1 at.% Sm doped specimen exhibits the high in-line transmittance of ~70 % at 532 nm and the Verdet constant of 58± 0.1 rad·/T m at 532 nm and 7 ± 0.1 rad/Tm at 1064 nm. Transparency of as-synthesized ceramics was higher than Ce or Pr doped Y_2O_3 [2]. The Verdet constants of magneto-optical RE:Y_2O_3 ceramics generally linearly increase with an incerase of Sm^{3+} concentration. Magneto-optical figure of merit for media was calculated.

Keywords: Y_2O_3, magneto-optical properties, arc plasma melting, optical isolator, microstructure

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Optical Fiber Sensors for Monitoring Cement Paste Carbonation

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Abstract. The use of concrete has been widespread in our society in housing and infrastructure [1], despite the environmental cost associated with its production [2]. Its decay poses a social, an economic and an environmental problem. Currently, the carbonation of cement paste [3] is monitored through the measurement of its pH [4]. Several optical fiber sensors (OFS) have already been produced for the continuous monitoring of cement pastes pH [5], but have not been tested in a representative environment. In the current work we focus on monitoring the carbonation of cement paste, through an OFS. Single fibre reflectance spectroscopy, previously employed to measure cement paste durability [6], is used in the current work to monitor the discoloration of cement paste caused by carbonation. As the carbonation front reaches the fiber tip embedded in the cement paste, the signal reflected onto the fiber increases. The accelerated carbonation of three limestone cement paste samples in an atmosphere of 100%CO_2 was successfully monitored. The applicability of the sensor for operational use with ambient CO_2, 0.04%CO_2, was confirmed through a measurement of carbonation at 3% CO_2 [7] . The cross interference from water ingress and egress was also evaluated, and it didn't hinder the measurements of carbonation. Therefore, a novel OFS capable of measuring cement paste carbonation and durability, is achieved.

Keywords: Cement paste, Carbonation, Low-cost Optical Fiber Sensor, Durability.

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Reducing the sunlight impacts in urban areas using asphalt mixtures with phase change materials: a review in Scopus in the last 3 years

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Abstract. Phase change materials (PCMs) have been incorporated into asphalt concrete pavements because during physical state changes they can regulate the temperature absorbing and releasing heat. This effect reduces temperature gradients of pavements and, consequently, increases its service life. In this work, a systematic review of recent articles published in peer-review journals (available in the Scopus database) involving asphalt mixtures with PCMs and focusing on mechanical characterization is presented. The generated literature list (56 papers) was checked manually (reading materials and methods and results) in order to exclude works in which wheel tracking and/or dynamic creep tests were not used. It is observed that most of the selected papers investigated the benefits of polyethylene glycol as a PCM. The most common strategy to avoid leakage during the phase transition involved the use of a porous material that acts as a carrier matrix for the PCMs. Besides that, it was possible to note that, in general, asphalt pavements with PCMs are systems with favourable thermal transferability and, therefore, demonstrated higher heat absorption and dissipation rates. Finally, in general, the asphalt mixtures containing PCMs showed lower mechanical performance compared with control mixtures, however, they still satisfy the required criteria. In any case, it is expected that with the incorporation of PCMs into asphalt pavements, the social and environmental effects (Urban Heat Island) of sunlight in urban areas can be mitigated by the thermoregulation phenomena.

Keywords: Phase change material; Asphalt mixture; Thermal properties; Permanent deformation

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