ALC 2023 Student Workshop
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Book of Abstracts

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Day 1 — Session 1 (08h30 – 11h10)

Quantum world

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INV01
Time 09h40

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Day 1 — Session 2 (11h10 – 12h50)

Photobiomodulation at 830 nm Promotes Cellular Viability and Reduces Cell Death in Fibroblast Diabetic Hypoxic Wounded Cells

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T1
Time 11h10

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Hyperglycemia is a defining feature of diabetes mellitus (DM). Patients with DM are prone to developing chronic ulcers that are challenging to manage, treat and heal. Delayed wound healing in DM is linked to abnormal fibroblast migration, proliferation, and differentiation, and increased apoptosis. Hypoxia reduces cellular responses and is an important cause of delayed wound healing. Several treatment modalities for diabetic wounds have been explored, however, the effects of the available treatments are temporary with a high incidence of relapse. Hence, new effective treatment strategies are a required. Photobiomodulation (PBM), an application that uses low-powered light predominantly in the visible red and near-infrared (NIR) spectrum, has demonstrated to stimulate biological systems. The effect of PBM at the cellular and molecular level are not fully investigated, despite the strong evidence of its effectiveness in vivo. Therefore, the present study investigated the effects of PBM at 830 nm on cellular viability in fibroblast diabetic wounded and diabetic hypoxic wounded cell models. This study used commercially available human skin fibroblast (WS1) cells. The cells were grouped into two models, namely diabetic wounded (DW) and diabetic hypoxic wounded (DHW). Cells were incubated for 24 and 48 h post-irradiation and the effect of PBM on viability was determined by the Trypan blue exclusion assay. Cellular migration was assessed at regular time intervals (0, 24 and 48 h) using inverted light microscopy. B-cell lymphoma 2 (Bcl-2), anti-apoptotic, a regulator apoptosis, was assessed using the enzyme-linked immunosorbent assay (ELISA). PBM showed a significant increase in viability, migration rate and Bcl-2 in both irradiated DW and DHW cell models. These results suggest that PBM at 830 nm enhance in vitro diabetic wound healing by promoting cellular viability, migration rate and reducing cell death in experimental models. DHW models responded well to PBM, with significant increases in Bcl-2, this may be since these cells are more ‘stressed’. It is established that stressed cells respond more favourably to PBM, as is evident from the results obtained from this study.

Development of a Cost-Effective Fibre-based FSO System

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T2
Time 11h30

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Fibre optic technology has revolutionized communication, enabling rapid data transmission over long distances. However, in South Africa, uneven distribution of fibre infrastructure has resulted in unequal internet access. Free space optical communication (FSO) offers a potential solution, by connecting users to nearby fibre infrastructure. This talk presents a cost-effective bidirectional FSO prototype designed to couple light signals between two fibre cables separated by free space. The system employs standard telecom fibre cables, which are cost-effective, readily available, and compatible with existing telecom hardware. Selecting the appropriate telecom fibre cable (SMF, OM1 ,OM2, OM3, OM4, and OM5) for the prototype requires evaluating their light transmission and reception capabilities, particularly in the presence of atmospheric turbulence. Atmospheric turbulence remains a significant challenge for fiber-based FSO systems. One of the pronounced effects of turbulence is beam wander, which leads to focal point misalignment in terms of lateral, longitudinal, and angular displacement at the receiving plane. Consequently, this phenomenon results in power loss and deep fades, underlining the critical importance of precise alignment for efficient fiber coupling. To assess the resilience of standard fibre cables to focal point misalignment, a series of experiments were conducted. Misalignment was systematically induced on the fibre cables using a spatial light modulator. The aim was to understand how different fibre cables respond to controlled misalignment conditions and identify which cable exhibits the highest tolerance to misalignments. The OM1 fibre cable coupled the highest amount of optical power when faced with lateral, longitudinal and angular misalignments. The FSO prototype was tested across a distance of 400 m at the University of the Witwatersrand. The average power coupled into the OM1, OM4, and OM5 multi-mode fibre cables was measured, and the scintillation indices were calculated. The light source used was a bidirectional small form factor pluggable transceiver module operating at wavelengths of 1510/1590 nm. The power coupled into each fibre cable was recorded using an infrared optical power meter. The OM1 fibre demonstrated the best performance amongst the tested cables. It exhibited the highest optical power coupling while experiencing the least amount of scintillation. This superior performance of the OM1 fibre suggests its robustness in handling the effects of atmospheric turbulence, making it a promising candidate for a reliable FSO system.

The Efficacy of Active-targeted Zinc Phthalocyanine Nanobioconjugate on Melanoma Cells Grown as Three-Dimensional Multicellular Tumour Spheroids

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T3
Time 11h50

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Melanoma is one of the most dreadful forms of skin cancer, with an unpredictable evolution. Despite numerous therapeutic options, like surgery, chemotherapy, radiation therapy, and immunotherapy, the advanced melanoma prognosis remains grim. Photodynamic therapy (PDT) is an underutilised cancer therapy with a low rate of trauma, accurate targeting, synergism, and repeatability. Despite displaying great advantages in the treatment of tumours, classical PDT has shown some drawbacks that limit its clinical application in melanoma. Direct modification of photosensitizers (PSs) by nanotechnology or the delivery of PSs by nanocarriers can improve their targeting, specificity, and PDT efficacy for tumours. However, an appropriate preclinical evaluation of the real therapeutic potential of nanomedicines suffers from the lack of relevant models that are well representative of human disease and good predictors of the therapeutic response in patients. In this context, three-dimensional cell culture models are gaining popularity since they closely resemble in vivo avascular tumour features, allowing for the more efficient and precise screening of novel anticancer agents with various treatment combinations. In this study, we utilised A375 human melanoma spheroids to screen the phototoxic effect of zinc phthalocyanine tetrasulfonate ($ZnPcS_4$) conjugated to gold nanoparticles (AuNP) and an anti-melanoma inhibitory activity antibody (Anti-MIA Ab) to actively enhance PS bioavailability and thus improve the therapeutic efficacy of PDT in melanoma. An antibody-metallated phthalocyanine-polyethylene glycol-gold nanoparticle drug conjugate was successfully synthesised and characterized. PDT experiments were conducted using a 673 nm laser at a fluency of 10 J/cm^2. Results showed that the nanobioconjugate significantly increased the cellular uptake and cytotoxicity in the melanoma spheroids via the induction of apoptosis. Therefore, this novel gold-antibody-based nanocarrier of phthalocyanine shows promise as a more effective PDT treatment modality.

Cell Death Mechanisms Induced by Green Synthesized Silver Nanoparticles in Combination with Pheophorbide-a Mediated Photodynamic Therapy Against Resistant MCF-7 Cells Overexpressed with P-Glycoprotein

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T4
Time 12h10

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Globally, multidrug resistance (MDR) in breast cancer has become the major cause of morbidity and mortality among women. This study was designed to overcome resistance, reduce dose-dependence in photodynamic therapy (PDT) and evaluate cell death mechanisms induced by green synthesized silver nanoparticles (AgNPs) in combination with pheophorbide-a mediated PDT on superlative, and most architectured three-dimensional (3-D) doxorubicin (DOX) resistant MCF-7 breast cancer cells with overexpressed p-glycoproteins in vitro. In addition to the aforementioned scope, the combination of green NPs with PDT has been reported to yield a good disease prognosis which in most cases is accompanied with manageable adverse effects. Briefly, MDR MCF-7 breast cancer cells were cultured in a 96 well plate to form 3D tumor spheroids and later treated with optimized concentrations of AgNPs and pheophorbide-a in monotherapy. After 24 h treatment, 3-[4,5-dimethylthiazole-2- yl]-2,5- diphenyl tetrazolium bromide (MTT) assay was performed to determine the 50% inhibitory concentration (IC50) for both experimental models. Morphological changes were observed by using an inverted light microscope, viability by MTT assay, and cell death analysis by Annexin V-FITC-PI staining. Taken together, the results from this study displayed a dose-dependent decrease in cell viability which was accompanied by significant morphological changes. Furthermore, Annexin V-FITC-PI assay showed apoptosis as the most prominent cell death mechanism induced by PPBa-mediated PDT and AgNPs. Taken together, the findings from the present study highlight the advantages of green nanotechnology in cancer therapy.

Unveiling the Thermal Stability of Diketopyrrolopyrrole-Based Terpolymers: A Key Element for Enhanced Efficiency and Stability of Organic Solar Cells.

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T5
Time 12h30

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With the advent of novel polymers, organic solar cell (OSC) research has evolved significantly over the past decade. The molecular engineering of terpolymers has allowed for simple morphological control in binary devices over ternary blends, with the highest power conversion efficiencies (PCEs) exceeding 18%. However, research on the stability of OSCs is still lagging behind. In this regard, we examined the thermal stability of a series of terpolymers comprising one electron donor (thienyl-substituted benzodithiophene, BDTT) and two types of electron acceptors namely fluorobenzotriazole (FTAZ) and thienothiophene-capped diketopyrrolopyrrole (TTDPP), and their blend with PC71BM. The terpolymers demonstrated a broad absorbance ranging from below 350 to 900 nm. The thermal stability of the terpolymers was investigated as pristine thin films and as bulk-heterojunction films of the terpolymers blended with PC71BM by heating at 85 °C. We observed that thermal degradation had no sizeable effect on the properties of the pristine terpolymers while the blended films demonstrated significant changes in their morphology due to the inclusion and aggregation of PC71BM. After thermal annealing at 85 °C, the width of the symmetric C=C stretching Raman mode and the C=C/C–C intensity ratio of pristine terpolymers and terpolymer:PC71BM thin films revealed that incorporation of the FTAZ acceptor improves the thermal stability of the bulk heterojunction (BHJ) active layers. Furthermore, prolonged thermal annealing times ($>$ 3 h) resulted in the development of PC71BM aggregates and terpolymer decomposition with no evident changes in the molecular and chemical structure of the terpolymers. We revealed the thermally-induced morphological changes by means of atomic force microscopy, transmission electron microscopy, and optical spectroscopy. Our findings indicate that by gradually annealing the blended films using an appropriate annealing time, the diffusion of PC71BM molecules to form aggregates can be carefully regulated, resulting in a nanostructure critical to the efficiency of organic solar cells. Provisional transient-absorption spectroscopy results shed further light on the energy transfer pathways and timescales within the terpolymers.

Day 1 — Session 3 (14h00 – 15h50)

Laser Shock Processing Development in South Africa: Building the Foundations & Industrial Applications.

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INV02
Time 14h00

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Laser Shock Peening (LSP) is an innovative technology applied to improve the performance of critical components, using pulsed lasers to generate a high-pressure plasma on the surface of the target material. The benefits of LSP typically include deep levels of generated compressive residual stresses with reduced surface integrity modifications, combined with a high degree of process control. The South African LSP initiative, originating from a proficient cooperation established between the National Aerospace Centre (NAC), the University of the Witwatersrand (Wits), the Council for Scientific and Industrial Research (CSIR), and AIRBUS Operations GmbH, aimed at developing a local capability to boost the advanced laser-based manufacturing sector. A unique combination of Wits engineering skills and CSIR laser expertise enabled technology growth from a fundamental basis to achieve insight into process mechanisms. Primarily experimental development, with a strong focus on performance optimisation, has been carried out in collaboration with a number of local and international academic research institutions, while international and local industrial partnerships have ensured alignment to relevant applications. The initiative led to the establishment of a robust and flexible LSP research work-cell, perfectly suited for early stage proof-of-concept R&D activities. Initial process development for several materials and structural solutions were explored, e.g. in the aerospace, power generation and mining sectors, where refined analytical and experimental techniques enabled detailed feasibility studies to be conducted. The versatile approach allowed for several unique and novel contributions in terms of process diagnostics and applications.

A Study Of Mechanical And Compatibility Properties Of Aluminium Alloy 2024 Coated With Aluminium Alloy 6061 Using Low Pressure Cold Spray

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T6
Time 14h50

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The aerospace industry has always been faced with expensive maintenance costs, coupled with extended repair times due to the use of component swap method which entails complete part replacement on aircraft. Cold Spray (CS) is an additive manufacturing method that can be implemented to reduce these costs and cut down maintenance time as it can be performed in situ. It deposits solid particles onto a substrate without melting or thermal softening by using high-velocity gas streams. Low-pressure cold spray (LPCS) is a type of CS that is of interest in this study. Its major distinction from High-pressure cold spray (HPCS) is that the former functions at pressures equal to or lower than 1 MPa, while the latter functions at pressures above 1 MPa. In LPCS, the success of bonding primarily depends on the sprayed particles' critical speed. LPCS technique enables the repair and refurbishment of damaged components, the production of complex-shaped coatings, and the deposition of dissimilar materials. This study, in collaboration with AIRBUS Germany, and supported by the Collaborative Programme in Additive Manufacturing (CPAM), African Laser Centre (ALC) and samples processed in Wits Supersonic Spray Technology Laboratory, is focused on the feasibility of spraying Aluminium Alloy (AA) 6061 powder on an Aluminium Alloy (AA) 2024 substrate using helium, nitrogen, or air as the propellant gas. The controlled parameters in LPCS, such as gas pressure, temperature, stand-off distance and particle size, significantly influence the coating properties which include adhesion strength, porosity, and thickness. Preliminary results on the feasibility of LPCS process deposition of AA6061 powder onto AA2024 substrates using helium, nitrogen, and air as propellant gases were obtained. Nitrogen and air failed to form coat formation on AA2024 substrates. This was done using the following spray parameters on the SSM-P3800-001 LPCS machine: Pressure at 10 Bar, Temperature at 400°C with a fixed standoff distance of 25mm. No transverse nozzle speed was included at this point, as the objective was to primarily see if any coating could be achieved. With such observation, the substrates were annealed to modify the surface micro-hardness. This modification produced coats on the substrates. Helium was then used as a carrier gas, coats were successfully formed for both annealed substrates and those not annealed. This motivated the inclusion of transverse speed of the spray nozzle. Coats were formed for all the variations, with the following spraying combination: Pressure 12.5 Bar, 300°C, yielding the thickest coats. The results showed that among the used carrier gases, the use of helium as the propellant gas was by far the best compared to Nitrogen and air. These findings also showed that annealing substrates enhanced coat formation on the AA2024 substrates. In conclusion, the findings suggest that Helium is the best carrier gas that can be used in coating AA2024 with AA6061 and, if Nitrogen or air is to be used, a form of surface modification, namely, annealing has to be introduced on the substrates. These preliminary results lay the foundation for further research and development in optimising the LPCS process for this specific dissimilar material pair. Post spray modification of the sprayed coats with Laser shock peening technology will be performed to see if the surface modification brings any positive results on the surface quality of the AA6061 coats on AA2024 sample substrates.

Additive Manufacturing of Nb-Enhanced Ti-6Al-4V for Medical Applications of Spinal Rods

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T7
Time 15h10

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Additive Manufacturing (AM) has beneficial for medical device fabrication, offering innovative solutions for orthopedic and spinal surgeries. This study focused on the utilization of Laser Engineered Net Shaping (LENS^{TM}) technology to produce spinal rods using Ti-6Al-4V alloy with the addition of Niobium (Nb). These spinal rods are vital in the success of spinal fusion procedures in patients. Ti-6Al-4V is the primary material choice because of its exceptional biocompatibility and favorable mechanical properties. However, to optimize the mechanical properties and improve patient outcomes, research has been looking into alloying elements to enhance the mechanical properties of Ti-6Al-4V. This study explored the influence of varying Nb content on the microstructural characteristics and the Young's modulus of Ti-6Al-4V. The microstructural analysis revealed that the incorporation of Nb into the Ti-6Al-4V alloy resulted in a heterogeneous microstructure with an increased presence of defects, including un-melted Nb particles. The analysis further revealed that the grain morphology was altered, with increased Nb content, from columnar grains to equiaxed grains. Mechanical testing results indicated that the addition of Nb correlates to a decrease in the Young's modulus of Ti-6Al-4V. The changes in the grain morphology and microstructure appeared to be correlated to the decreased Young's modulus. A reduction of the Young's modulus is significant in reducing the risk of implant failure due to osseointegration, thus correlating to improved patient recovery. The study found that enhancing Ti-6Al-4V with Nb using LENS^{TM} resulted in an altered microstructure and improved mechanical properties, particularly Young's modulus which contributes to improved patient outcomes and post-operative well-being.

Day 1 — Session 4 (15h50 – 16h50)

Investigation of Sinkhole Development Triggered by Pipe Leakage Monitored with Fibre Bragg Gratings: An Experimental Study

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T8
Time 15h50

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Sinkhole formation resulting from leaky pipes constitutes a significant geotechnical concern, causing severe infrastructure damage and safety risks. This paper presents the findings of experimental investigations aimed at systematically interpreting the process of sinkhole propagation induced by leaking pipes, leveraging the effectiveness of fiber Bragg gratings (FBGs) as strain sensors. Designed laboratory-scale models were used to simulate sinkhole mechanisms under 1-g gravity conditions. The experimental setup entailed the gradual deflation of a balloon within a bed of saturated silica sand, thereby creating an underground cavity. FBG sensors, in the wavelength range 1530 nm to 1560 nm, were manufactured in the photonics laboratory of the University of Johannesburg and were strategically embedded horizontally and vertically within the soil mass at varying depths, facilitating the capture of strain and deformation profiles exhibited by the surrounding soil in the influence zone of the collapse. A leaking pipe was installed within the soil mass to trigger the sinkhole. The experimental results defined the sinkhole formation process into four distinct phases: (1) cavity formation process, (2) progressive weathering and erosion process, (3) catastrophic collapse, and (4) subsequent equilibrium conditions. The results reveal explicit dissimilarities in strain states and distributions between horizontal and vertical measurements. During the critical phase of sinkhole collapse, horizontal measurements predominantly show tensile strains, whereas vertical measurements indicate compressive strains. This investigation highlights the remarkable utility of FBGs as advanced monitoring tools for the early detection and comprehensive study of sinkhole phenomena. Furthermore, the study suggests the promising potential of FBGs for extensive deployment in geotechnical monitoring applications, facilitating enhanced understanding and mitigation of sinkhole-related geohazards.

A study of the effect of laser shock peening without coating at different parameters on AA7075 surface integrity

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T9
Time 16h10

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Aluminium alloys are the preferred material for modern airframe structures due to their ease of manufacture, light weight and good mechanical properties. However, these alloys are susceptible to localised corrosion, particularly in chloride environments, which can lead to pitting corrosion and stress corrosion cracking. To protect them, various coatings and surface modification techniques are used. Laser shock peening (LSP) is a promising surface treatment that provides deeper compressive residual stresses and improved surface finish, resulting in higher fatigue strength and delayed fatigue crack initiation than conventional Shot Peening (SP). However, research is limited on the influence of LSP on residual stress, fatigue resistance, surface integrity and localised corrosion and stress-corrosion cracking susceptibility, especially on heat treated, peak-aged aluminium alloys. This study investigated the surface modifications and resultant corrosion behaviour of conventional AA7075-T651 after LSP without a protective coating. The LSP process parameters were varied: power intensity (1-5 GW/cm^2), spot size (diameter 0.8-1.5 mm) and laser pulse density (2.5-40 spots/mm^2). For LSP samples, SEM micrographs showed rough surfaces with areas of re-melting and solidification with micro-cracks on some samples. Surface roughness measurements showed higher roughness due to intense surface ablation, with increased roughness as power intensity increased. The EDX analyses revealed increased oxygen on the peened surfaces. Potentiodynamic polarisation showed higher corrosion rates for most LSP samples than unpeened samples, although lower corrosion rates were obtained for some combinations of LSP parameters. The relationships between the LSP processing parameters and the surface roughness, microstructure, Vicker's microhardness and corrosion parameters are being determined to better understand the potential and limitations of the LSP process without coating. Further work is being done to investigate the effect of LSP on stress corrosion cracking using a three-point bending system in a 3.5 wt% NaCl solution.

Surface Modification of LPBF Ti6Al4V for Improved Implant Performance

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T10
Time 16h30

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As medical technology advances in conjunction with an ever-ageing population, the use of medical implants, for orthopaedic, cosmetic, quality-of-life, etc. applications, has grown. These implants historically and presently are manufactured of Ti or a Ti-based alloy. The most used alloy is Ti6Al4V, due to the combination of favourable properties, namely high strength-to-weight ratio, excellent corrosion resistance and relative biocompatibility. Unfortunately, Ti-alloys are difficult and expensive to produce via conventional means which often leads to implants with modular designs in a "one-size-fits-all" approach. Additive manufacturing, specifically laser-based powder bed fusion (LPBF), allows for complex patient-specific components of Ti6Al4V to be produced more easily and with less material wastage. LPBF components however have inherent tensile residual stresses (TRS) induced by the LPBF process. Further, for best performance, implants are often modified at the surface to promote and increase bone-implant interface. Coupons of LPBF Ti6Al4V were produced, on an SLM Solutions 125 machine, in three directions,0-, 45-, and 90-degrees relative to the baseplate and left as-built, with no post-processing or stress relieving. Laser shock peening without ablative coating (LPwC) was used as a technique to modify the surface state and residual stresses to increase osseointegration and increase implant life. The samples were processed at the Council for Scientific and Industrial Research National Laser Centre in South Africa, through the Rental Pool Programme, using a platform incorporating a Quanta-Ray Pro series Nd:YAG pulsed nanosecond laser. The effects and efficacy of LPwC treatments at increasing spot densities (Np) were investigated with optical and scanning electron microscopy, surface roughness and Vickers hardness measurements, and residual stress analysis using the incremental hole drilling method. LPwC effectively modified the surface of the samples and altered the residual stress states independently of the original surface state. The use of LPwC resulted in a total reversal of the TRS of the LPBF parts and induced compressive residual stresses (CRS) which approached a mean of -600 MPa at $N_p = 40$. Further, both the magnitude and depth of the CRS, surface roughness and hardness were observed to generally increase with increasing Np. Maximum increases in roughness for the 45-degree samples were from $R_a = 7.9 \pm 0.63$ to $R_a = 8.5 \pm 0.38$ μm at $N_p = 20$, and hardness increased from 338.2±6.3 to 426.2±6.1 HV10 at $N_p = 40$. Furthermore, LPwC induced a heterogeneous oxide layer composed of TiO_2 and Al_2O_3. The combination of increased roughness, an oxide layer and CRS will likely improve the performance of LPBF Ti6Al4V implants in both lifetime and osseointegration.

Day 2 — Session 5 (09h10 – 10h40)

Behind the Nobel: Physics 2023

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ST1
Time 09h10

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The recent Nobel Physics Prize in 2023 was awarded to Pierre Agostini, Ferenc Krausz and Anne L'Huillier *"for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter."* In this presentation, I'll discuss the nuanced science behind the technology of these attosecond lasers and share some applications of short-pulse lasers.

The prospect of Surface Plasmon Resonance in detecting two multidrug-resistant Tuberculosis (TB) genes

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T11
Time 10h00

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Tuberculosis (TB) is one of the most impactful infectious diseases globally killing approximately 1.5 million people annually. The burden of infection is disproportionately high in low-income and resource-limited settings. This disparity exacerbates the emergence of multidrug-resistant (MDR) and extensively drug-resistant (XDR) Mycobacterium tuberculosis (Mtb), the bacterium that causes TB. Early detection and treatment of TB remain key strategies to reduce the spread and disease progression to drug-resistant forms of TB. However, this is hampered by slow, insensitive diagnostic methods, particularly for the detection of drug-resistant forms. Therefore, optical-based diagnostic devices could solve this problem. Surface plasmon resonance (SPR) biosensors have been used for real-time detection of biological elements such as nucleic acids, antibodies, and cells to name a few. SPR biosensors offer various advantages including rapid analysis, high specificity, and sensitivity as well as requiring small amounts of samples for analysis. For this study, two multidrug-resistant genes, namely, catalase-peroxidase (katG) and enoyl reductase (inhA) were detected using a custom-built surface plasmon resonance (SPR) setup. Deoxyribonucleic acid (DNA) probes, specific for the two genes (katG and inhA), were used as biorecognition elements to capture katG and inhA target DNA. The SPR setup was used for the analysis of the binding interactions occurring on the gold-coated slides. The specificity and sensitivity of the SPR setup indicated the binding interactions through the changes in reflected intensities. The reflected intensities indicated the differences in the resonance angle shift between each experimental test. This is the initial step to potentially detecting drug-resistant mutations using an optical-based setup.

Enhancing Tuberculosis Detection with Surface Plasmon Resonance Phase Difference

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T12
Time 10h20

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Surface Plasmon Resonance (SPR) has emerged as a powerful tool in the field of optics for a wide range of applications, including biosensing and disease detection. In this study, we focus on the development and evaluation of a novel approach that uses the SPR phase difference biosensor for the early detection of tuberculosis (TB). Tuberculosis remains a major global health problem, and the ability to detect the disease accurately and quickly is crucial for effective management and control. Our research involves the design and fabrication of specialized SPR sensors optimized for tuberculosis biomarker detection. Using the phase difference in SPR signals, we aim to enhance the sensitivity and specificity of TB biomarker detection compared to traditional intensity-based methods. The phase difference provides an additional dimension of information that can improve the reliability of the detection process. The MPT64 antibodies were immobilized on a gold-coated biosensor chip, and the MPT64 TB antigen was added to the biosensing surface. To enhance the detection signal for biomolecular binding events, gold nanoparticles (AuNPs) were conjugated to the MPT64 secondary antibodies. Ultraviolet-visible (UV-vis) spectroscopy was used to characterize the conjugation. Our preliminary results demonstrate successful immobilization of MPT64 antibodies on the biosensing surface, facilitating the capture of MPT64 TB antigen. The characterization and optimization of SPR-PD are being carried out for the potential detection of TB antigens.

Day 2 — Session 6 (11h10 – 12h50)

Interfacial Strain Evolution with Thickness of $TbMnO_3/TiO_2$ terminated (001) $SrTiO_3$ Epitaxially-strained Thin Film

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T13
Time 11h10

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Interfacial strain in multiferroic rare-earth epitaxial layers is a key feature that can induce new functionalities for the next generational applications such as room-temperature magnetoelectricity and magnetocapacitance[1, 2]. Several studies have shown the modulation of strain in $TbMnO_3$ thin films as a promising route for the fabrication of perovskite-type oxides with correlated electrical and magnetic properties at desired temperatures. This work explores the evolution of interfacial strain evolution in $TbMnO_3$ thin films grown epitaxially on TiO_2 terminated (001) $SrTiO_3$ single crystal substrates using an ultra-high vacuum pulsed laser deposition technique (Nd-YAG laser: 2 Hz repetition rate, 10^{-8} base pressure, and O_2 ambiance). In-situ monitoring of the film growth using reflective high-energy electron diffraction (RHEED) shows the formation of Kikuchi lines, which verified the coherent orientation of the films with respect to the TiO_2 terminated (001) $SrTiO_3$ substrate. The film quality and variation of interfacial strain as a function of thickness were studied using a typical XRD $\theta - 2\theta$ scan and X-ray reflectivity. A rocking curve of the (002) peak shows the high crystalline quality of the films whereas the pure (00l)-oriented diffraction peaks from $TbMnO_3$ confirm full epitaxial growth of the films with c-orientation on TiO_2 term. (001) $SrTiO_3$ single crystal substrates. The film interfacial strain versus thickness analysis shows a reduction of interfacial strain along the c-plane with increasing thickness, suggesting that the c-axis is tensile-strained which could be due to residual compressive strain in the a-b plane of the $TbMnO_3$ crystal originating from the lattice mismatch between the film and substrate.

[1] G. Panomsuwan and N. Sait, Cryst. Res. Technol., 53, 8 (2018)
[2] V. Goian, R. Held, E. Bousquet, et al., Commun. Mater., 1, 74 (2020)

Rapid prototyping protocol to assess enhancement of up-conversion phosphors by metal nanoparticles

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T14
Time 11h30

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Up-conversion phosphors absorb two or more low energy photons and emit one photon of higher energy than that were absorbed. These phosphors have several potential applications in biomedicine, temperature sensors and forensics. Although some literature has reported enhancement of up-conversion phosphors by gold nanoparticles (Au NPs), there is still no general theory that predicts the parameters such as size or concentration of metal nanoparticles that can lead to the enhancement, hence there is a need for more experiments that can test a large variety of parameters that might lead to the enhancement. The main aim of this study is to develop a prototyping protocol that allows one to rapidly test a lot of different parameters that might lead to enhancement. In this protocol we prepared the phosphor and metal nanoparticles separately and then mixed them in aqueous solution, which allowed one to vary different parameters easily, in contrast to other reported approaches. Here we discuss this protocol with Y_2O_3 doped with Er and co doped with Yb as phosphor material and Au NPs as themetal nanoparticles. The concentrations of dopants were chosen to be 1 mol% Er or 1 mol% Er, 1 mol% Yb to give green emission, while for red emission 5 mol% Er or 1 mol% Er, 5 mol% Yb were used as these values had been reported to be optimal in literature. Different ratios of Au NPs to phosphor particles (1%, 1.3%, 2%, and 4%) were trialed. The phosphors were synthesized by microwave assisted hydrothermal method, while a reduction method was used to synthesize the Au NPs. The phosphor powders were put in distilled water to make a suspension while the Au NPs were already in water. Then the two solutions were mixed and sonicated to facilitate the distribution of the particles. Finally, the mixture was centrifuged and then dried in freeze dryer to extract the mixed powders. X-ray diffraction confirmed the structure of phosphor and crystallites size were calculated for different samples and were found to be between 24-26 nm, while transmission electron microscope confirmed the presence of Au NPs surrounding the phosphor particles. UV-Vis measurements were done for Au NPs in absorption mode that showed the maximum absorption of Au NPs was $\approx$ 537 nm, while diffuse reflectance of the mixed powder showed the absorption of the phosphor together with the absorption of the Au NPs. Up-conversion emissions were measured under 980 nm infrared excitation for the samples and compared to the phosphor with no Au NPs. In this study, for all of the doping types and Au NP ratios, only a decrease in the up-conversion efficiency was measured. This indicates that enhancement, as reported in the literature, is not easy to attain. In conclusion, using the rapid prototyping protocol, we were able to study four different Y_2O_3 phosphors that were doped or co-doped and optimized for green and red emissions, which would normally be done in four separate studies. Although enhancement was not obtained in these trials, in the future other conditions such as the size of the Au NPs and/or the phosphor and annealing can be tested using this protocol

Optical tweezers: the trapping of microscopic particles with light

Anneke Erasmus, Gurthwin W Bosman, Erich G Rohwer, Pieter H Neethling
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T15
Time 11h50

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Optical tweezing is an established optical trapping technique for spatially manipulating transparent, dielectric, micron-sized objects. Optical trapping occurs when light is tightly focused onto the object of interest within a sample. In the focus, the difference in refractive index of the object with respect to its surrounding environment causes a change in momentum of the light, which in turns imparts a force on the object towards the centre of the focus. This technique makes it possible to remotely investigate mechanical and physical properties of the object. Optical tweezers have been developed for various applications. These include studying intracellular dynamics, applying specific forces to trapped particles, as well as quantitative measurement of intracellular forces (for example, in vivo measurements of the forces exerted by molecular motors inside a cell). In this presentation the key components of an optical tweezers system and its force calibration will be discussed, as well as applications of such a system.

Intensity-Based Sensing of Refractive Index Using Metal Nanoparticles

Luke C. Ugwuoke and Mark S. Tame
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ST2
Time 12h10

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This tutorial covers the fundamentals of classical plasmonic sensing within the context of single-particle plasmonics of the dipole plasmon mode. We have put together the necessary theoretical framework required to investigate the sensing performance of single metal nanoparticles whose optical response can be expressed in analytical form within the Rayleigh regime. While both the wavelength and the intensity interrogation schemes are presented, this tutorial is mostly centered around the latter. The presented framework can be extended to metal nanoparticles with complex geometries using appropriate numerical methods.

Day 2 — Session 7 (14h00 – 15h30)

Uses of phosphor materials for practical applications

Hendrik C. Swart
Department of Physics, University of the Free State, Bloemfontein, South Africa.

INV03
Time 14h00

A short tutorial lecture on the background and applications of phosphor materials will be given. Phosphor materials are an integral part of our daily life. Luminescent compounds and materials have numerous uses, most notably in detectors of various sorts, but also in consumer products such as displays, light-emitting diode (LED) lighting, solar cells, and watches. The emission properties, whether of a fast decay rate fluorescent material or a slow decay rate phosphorescent material, are defined by the chemical composition and the physical structure of the luminescent material. Phosphor hosts, defects, dopant concentration and valence state are some of the important parameters to be considered when designing new phosphor materials. The crystal field that is determined by the environment in the host material in combination with the dopant ion with the correct valence state can be used to obtain emissions from the ultraviolet (UV) to the infrared (IR) wavelength ranges. Phosphor materials have been successfully used to improve the efficiency of various applications. ZnO nanoparticles both undoped and doped with different rare earth elements were synthesized by several synthesized techniques. The strong deep-level emission (DLE) and near-band edge emission could be tuned to cover a wide spectral range. The DLE emission was shown to be due to oxygen vacancies. The strong DLE, covering a wide spectral range of ∼375-650 nm, signifies the potential optoelectronics application in the near white LED applications. The major problem that limits solar cells' efficiency is their insensitivity to the whole solar spectrum which is the so-called spectral mismatch. Therefore, several mechanisms have been explored based on photoluminescence to convert the solar cell spectrum where the spectral response of the solar cell is low to regions where the spectral response of the solar cell is high. Quantum cutting (or downconversion), up-conversion and downshifting are some of the mechanisms that may be applied to improve the spectral response. In the case of up-conversion two or three IR photons combine to produce one higher energy photon that can be adsorb by the solar cell. In down-conversion one UV/visible photon split into two near-infrared photons. Both these photons can then be absorbed by the solar cell. Downshifting is a process of shifting one higher energy photon into one lower energy photon. The absorption of high energy photons by a solar cell generates heat during the fast thermalization of the hot charge carriers. Downconversion can be utilized to reduce the thermalization loss since the external quantum efficiency exceeds unity and hence the current doubling can occur. Examples of different phosphor materials with different applications will be shown.

Non-destructive testing with x-ray imaging systems for laser powder bed fusion

B. Mbuyisa[1], A. Du Plessis[1,2] and C.M. Steenkamp[1]
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[2]Comet Technologies Canada Inc, Montreal, Canada.

T16
Time 14h50

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Laser powder bed fusion (L-PBF) is one of the additive manufacturing (AM) techniques that uses a laser to selectively fuse powder material together. This technique is highly effective in the manufacturing of objects with complex and custom geometries, as well as joining different parts of a particular component into one functional product. However, defects such as porosities negatively affect the application of this process in the industry. Micro-computed tomography (micro-CT) is a non-destructive testing (NDT) tool that is mostly used to detect and quantify such defects. However, with standard absorption-mode micro-CT, it is a challenge to see sufficient contrast in light materials and alloys. Phase contrast imaging allows the visualization of shape and differentiation among materials of the same atomic number but different density, while dark field imaging only captures high angle scattered light, and potentially provides good contrast for sub-resolution features. In this study, AlSi10Mg samples were printed using L-PBF at various parameters with the aim of intentionally creating porosity of different distributions. X-ray phase contrast and dark field imaging is applied with the aim of seeing enhanced contrast of different porosity in these samples. The obtained results are compared against standard micro-CT results, and a conclusion on suitability of phase contrast and dark field x-ray imaging as an alternative NDT method is made.

Construction and characterization of integrated optical tweezers and microfluidic setup for live monitoring of cell metabolics

Le Roi A Du Plessis, Gurthwin W Bosman and Pieter H Neethling
Stellenbosch Photonics Institute, Physics Department, SU, South Africa.

T17
Time 15h10

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Optical Tweezers have become a unique and versatile tool for measuring mechanical force in the orders of femto newtons, making it the standard method in biophysics for measuring the forces of molecular motors and the mechanical properties of DNA [1]. The easy maneuverability and stability of single-beam optical traps make them ideal for single-cell studies, making it possible to monitor in real time the response of a single cell to different external environmental conditions such as pH, temperature and ion concentration, as appose to ensemble average measurements. To do this we propose the use of an optical tweezers in conjunction with a microfluidic chip to accurately control the external environment of the cells under study. This chip not can not only precisely control chemical concentrations, but can also allow rapid changes in the environment which allows for the monitoring of short-term responses and reversible processes of trapped cells [2]. By combining the manipulation capabilities of optical tweezers with the control that microfluidic chips offer, we can create a stable platform for measuring cellular uptake of therapeutic drugs under varying environmental conditions, and the cell's response to these therapeutics, which could lead to a better understanding of the bioavailability of these drugs and thus to better dosing protocols. Measuring the cellular uptake is important for determining treatment regimes as underestimation of the bioavailability can lead to the abuse of prescribed drugs [3]. In this talk, we will discuss the progress made on the construction of this integrated setup and the initial characterization measurements that have been made.

[1] C. J. Bustamante et al., "Optical tweezers in single- molecule biophysics", Nat Rev Methods Primers 1, 25 (2018).
[2] E. Eriksson et al., "A microfluidic system in combination with optical tweezers for analyzing rapid and reversible cytological alterations in single cells upon environmental changes", Lab Chip 7(1), pp. 71–76 (2007).
[3] A. Cragg et al., "Risk Factors for Misuse of Prescribed Opioids: A Systematic Review and Meta-Analysis", Annals of Emergency Medicine 74(5), pp. 634–646 (2019).

Day 2 — Session 8 (16h00 – 17h00)

Ion trapping for quantum control experiments

Siann Bester and Christine Steenkamp
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T18
Time 16h00

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Trapped ions are a prime candidate for use as qubits in quantum computers due to their intrinsic atomic properties and the potential scalability of these systems. Trapped ion experiments can be divided into two parts, reliably trapping ions and controlling them. We focus on how trapping and qubit control are practically implemented in our laboratory. The first goal is to stably trap ions. We selectively ionise $^{1}71Yb^{+}$ from neutral yterbium atoms using a two-step ionisation process. These ions are then confined within a linear Paul trap using high voltage radio frequencies generated with a helical resonator. We characterised this helical resonator system such that it could reliably be used to trap ions. There are three requirements for a trapped ion to be useful as a qubit, namely, initial qubit state preparation, controllable state evolution and final qubit state detection. We show how each of these processes can be achieved with trapped yterbium ions for the use in quantum control experiments.

Where did all the excitons go? A study of the ultrafast dynamics of electron-hole pairs in organic solar cells.

Kelsey Everts and Gurthwin Bosman
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T19
Time 16h20

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Organic solar cells (OSCs) are potentially cheaper and more scalable than established silicon solar technology and have attracted significant academic and commercial interest. However, low OSC efficiencies persist and optimising the organic solar harvesting layer is needed to make OSCs more economically viable. Here we investigate the ultrafast charge transfer dynamics in a popular organic polymer blend P3HT:PCBM, (poly(3-hexylthiophene-2,5-diyl) – (P3HT):phenyl-C61-butyric acid methyl ester (PCBM)).
OSC charge generation occurs in less than a nanosecond, and thus investigating its dynamics necessitates the use of an ultrafast technique. We use a combination of femtosecond transient absorption spectroscopy and steady state optical measurements on these P3HT:PCBM films. Firstly, we show electron-hole pairs (excitons) are generated on a sub-picosecond timescale in the donor polymer (P3HT). Unfortunately, these excitons fail to be converted to long-lived species which could be collected in a real OSC device. We show that adding an electron acceptor (PCBM) facilitates exciton separation and results in an increased yield of long-lived free charges persisting into the nanosecond regime.
Maximising these free charge yields is a known way to produce highly efficient OSCs, but typically charge recombination losses dominate. We demonstrate a simple method to distinguish between the different loss mechanisms without the use of an additional electrical or spectroscopic technique. Results suggest that simply tuning the pump beam fluence and controlling the initial density of transient species, in the same pump-probe configuration, can be used to clearly differentiate between the various recombination loss pathways.

Exploring Practical Enhancements in Plasmonic Biosensors Setups

Hanri Jacobs[1], Zahra Tayob[1], Gurthwin Bosman[2] and Willem Perold[1]
[1]*Institute for Biomedical Engineering, Electrical & Electronic Engineering, SU, South Africa.*
[2]*Stellenbosch Photonics Institute, Physics Department, SU, South Africa.*

T20
Time 16h40

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In this talk, we will present our recent work on two distinct optical setups for broadband plasmonic biosensing applications. The first setup is rooted in the conventional Kretschmann configuration, with the integration of a digital mirror to facilitate rapid scanning of resonances. In the second approach, we employ the principle of Extraordinary Optical Transmission (EOT) in conjunction with self-assembled gold nanoparticles, as opposed to the conventional nanohole array-type, with the former proving to be experimentally more feasible.

Day 3 — Session 9 (09h10 – 10h50)

How to create and measure interesting polarisation structures

Angela Dudley
School of Physics, WITS, Johannesburg, South Africa.

ST3
Time 09h10

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This tutorial will provide an overview of optical polarisation – how it is described, how one can create and control it in the lab and how one can measure it. Here we will discuss the various tools and optical components that can be used to generate exotic polarisation structures, as well as how we can use these components to control, monitor and measure polarisation in optical fields.

Can structured light be harnessed as a quantum process toolbox?

Paola Concha Obando
Stellenbosch Photonics Initiative, Physics Department, SU, South Africa.

ST4
Time 10h00

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Structured light has become topical of late, where controlling light in all its degrees of freedom has offered novel states of light long predicted. In the quantum regime, structured light represents a promising resource for probing fundamental science as well as for its applications. In this tutorial, I will outline the basic concepts of high dimensional quantum states expressed in a basis of spatial modes (structured light). Then, I will explain how to create, control and detect such photonic quantum states in the laboratory. Finally, I will highlight some example applications on quantum computational tasks.

Day 3 — Session 10 (11h10 – 12h50)

Recent advancements in CPL instrumentation: CPL laser scanning confocal microscopy and rapid handheld time-resolved CPL photography for life and material sciences

Davide F. De Rosa, Patrycja Stachelek, Lewis MacKenzie, Dominic J. Black, David Parker and Robert Pal
Department of Chemistry, Durham University, Durham, United Kingdom.

ST5
Time 11h10

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The molecular machinery of life is founded on chiral building blocks, but no experimental technique is available to distinguish or monitor chiral systems in live cell bio-imaging studies. Luminescent chiral molecules encode a unique optical fingerprint within emitted circularly polarized light (CPL) carrying information about the molecular environment, conformation, and binding state. Here we present a CPL Laser Scanning Confocal Microscope (CPLLSCM) capable of simultaneous chiroptical contrast based enantioselective live-cell diffraction limited imaging of endogenous and engineered CPL-active cellular probes [1].

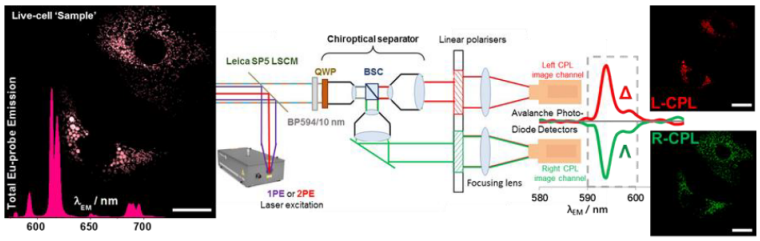

Figure 1. Simplified depiction of the CPL-LSCM developed for enantioselective differential chiral contrast (EDCC) imaging. Scale bars = 20 μm.

Spurred by recent instrumental advancements, the development of CPL active lanthanide based luminophores is going through a renaissance, since they possess superior circularly polarised brightness (CPB) and encode unique chirpotical fingerprints in their long-lived emission spectrum. However, their application as embedded CPL emitters in intelligent multi-layered security inks has not yet been fully exploited due to the lack of compact CPL instrumentation. Here we also present an all solid-state small footprint one-shot CPL photography (CPLP) camera with no moving parts to facilitate ad hoc time-resolved enantioselective differential chiral contrast (EDCC) imaging [2].

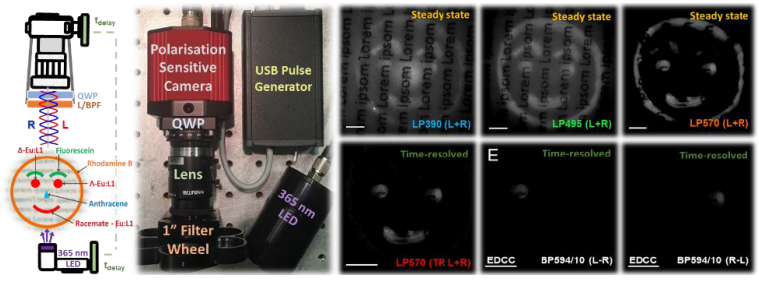

Figure 2. All solid-state camera for EDCC TR-CPLP.

[1] L. E. MacKenzie, P. Stachelek , D. Parker, and R. Pal, Nat. Commun., 2022, 13, 553-561; L. E. MacKenzie, L.-O. Pålsson, D. Parker, A. Beeby and R. Pal, Nat. Commun., 2020, 11, 1676-1683.
[2] D. De Rosa, P. Stachelek, D. J. Black, and R. Pal, Nat. Commun., 2023, in press.; L. E. MacKenzie and R. Pal, Nat. Rev. Chem., 2021, 5, 109–124.

Roadmap to free space optics in Africa, with a focus on structured light

Mitchell Cox
School of Electrical & Information Engineering, WITS, Johannesburg, South Africa.

ST6
Time 12h00

This tutorial-style talk introduces free-space optical (FSO) communications using structured light, emphasising its potential to enhance internet access in underserved areas of Africa, particularly in South Africa where the digital divide is evident. We will detail our lab's initiatives in crafting affordable FSO systems to make this technology more accessible. Attendees will gain insights into the digital landscape of South Africa and the role of FSO in addressing connectivity challenges.

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