MANIPAL SCHOOL OF LIFE SCIENCES
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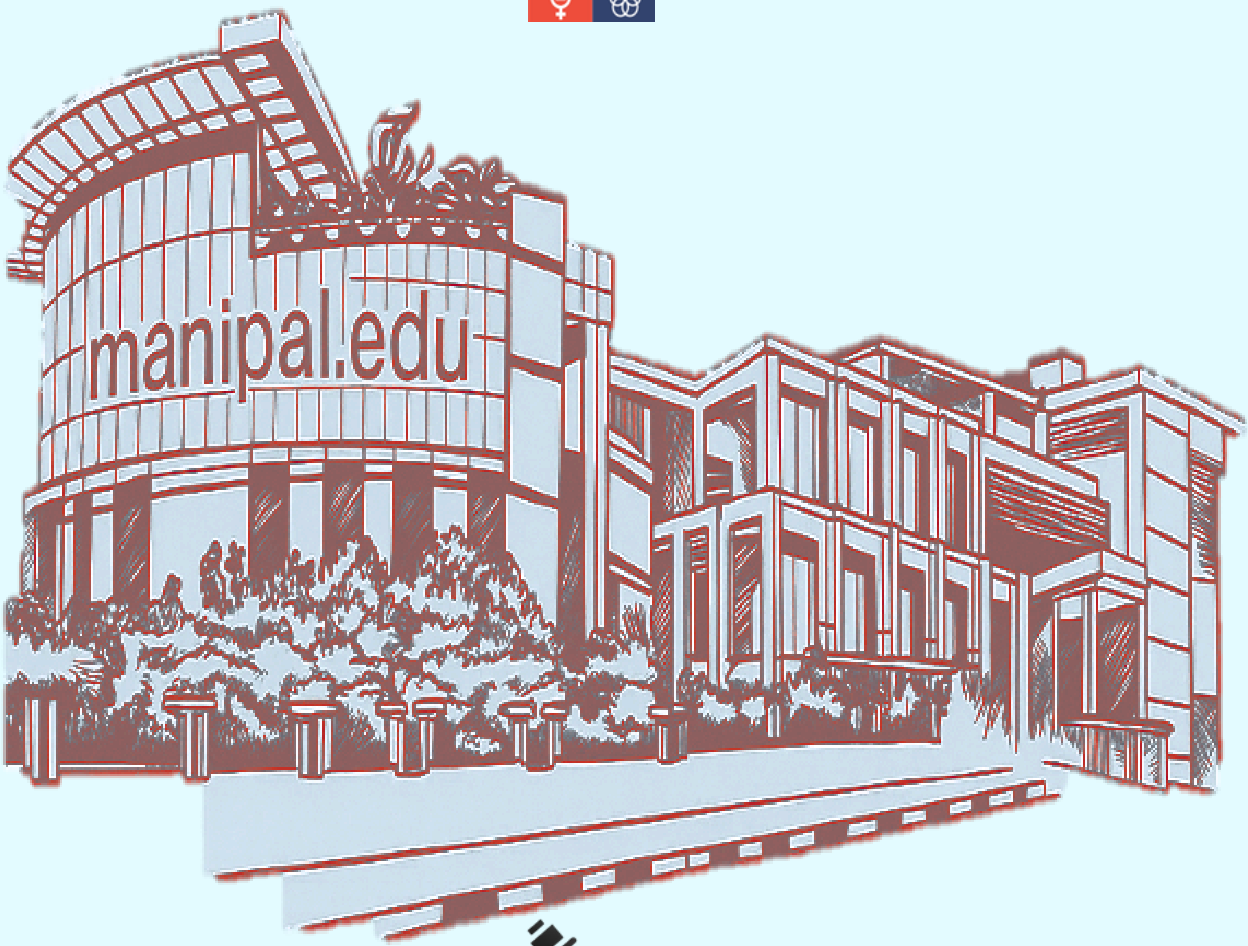
OPTICA
Advancing Optics and Photonics Worldwide
Manipal OPTICA Student Chapter



ICTBH 2026

International Conference on Translational Biophotonics in Healthcare

4 – 6 February, 2026

Manipal School of Life Sciences
MAHE, Manipal

MANIPAL
ACADEMY of HIGHER EDUCATION
(Institution of Eminence Deemed to be University)

01st February 2026

It is a matter of satisfaction to see Manipal Academy of Higher Education (MAHE), Manipal, continue to promote high-quality academic engagement through the organization of international conferences. Such initiatives play a vital role in strengthening interdisciplinary research, encouraging innovation, and enhancing the global visibility of the institution.

I am pleased to note that the International Conference on Translational Biophotonics in Healthcare (ICTBH) 2026 is being organized by the Manipal OPTICA Student Chapter at the Manipal School of Life Sciences, MAHE. Translational biophotonics is an emerging area with significant potential to advance modern healthcare by integrating fundamental science with clinical and technological applications. A focused conference on this theme provides an excellent platform for knowledge exchange, collaborative learning, and the exploration of future research directions. Events supported by OPTICA (formerly OSA) further add to the academic relevance and international outreach of such initiatives.

I extend a warm welcome to all delegates, speakers, and participants joining ICTBH 2026 from various parts of the world to the MAHE campus at Manipal. I am confident that the conference will be academically rewarding and will contribute meaningfully to professional growth, collaborative research, and the broader scientific community.

I wish the conference every success.

Dr. H. S. Ballal
Pro Chancellor, MAHE, Manipal

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01st February 2026

It is a pleasure to note that the Manipal School of Life Sciences, MAHE, continues its tradition of academic excellence by hosting another international conference. Over the years, this institute has played a pivotal role in fostering a strong culture of scientific understanding at the University, successfully organizing several such events that bring together scientists, researchers, academicians, and students on a common platform to exchange ideas, collaborate, and advance knowledge in their respective fields.

I am delighted to learn that the International Conference on Translational Biophotonics in Healthcare (ICTBH) 2026 is being organized by the Manipal OPTICA Student Chapter, based at the Manipal School of Life Sciences, MAHE, Manipal. Translational biophotonics has witnessed remarkable progress in recent years, particularly in its applications to healthcare, diagnostics, and therapeutics. Conferences such as this, organized under the aegis of OPTICA (formerly OSA), are highly relevant and contribute significantly to the growth and integration of the global scientific community.

I extend a warm welcome to all the delegates joining this conference from different parts of the world to the academic town of Manipal. I am confident that the participants will find the conference intellectually enriching, enjoy the renowned hospitality of the campus, and take back memorable experiences of Manipal and its vibrant academic environment.

With best wishes for a successful conference.

Lt Gen (Dr) M. D. Venkatesh
Vice-Chancellor, MAHE, Manipal

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01st February 2026

It is good to see that Manipal Academy of Higher Education (MAHE), Manipal is actively fostering initiatives that strengthen the interface between scientific research and healthcare practice. International conferences of this nature play an important role in advancing translational research and encouraging meaningful engagement across disciplines within the health sciences.
I am pleased to note that the International Conference on Translational Biophotonics in Healthcare (ICTBH) 2026 is being organized by the Manipal OPTICA Student Chapter at the Manipal School of Life Sciences, MAHE. Translational biophotonics has gained increasing importance for its ability to bridge laboratory discoveries with clinical diagnostics and therapeutic innovations. A focused forum on this theme provides an excellent opportunity to highlight emerging technologies, discuss clinical applicability, and explore pathways for integrating biophotonic approaches into healthcare systems.
I extend my best wishes to all delegates, clinicians, researchers, and students participating in ICTBH 2026 and welcome them to the MAHE campus at Manipal. I am confident that the conference will promote insightful discussions, interdisciplinary collaboration, and a deeper understanding of translational approaches that can positively influence healthcare outcomes.

I wish the organizers and participants a successful and impactful conference.

Dr. Sharath Kumar Rao
Pro Vice Chancellor (Health Sciences), MAHE, Manipal

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01st February 2026

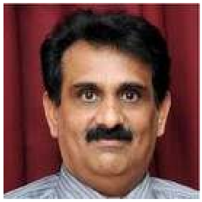
It is encouraging to note Manipal Academy of Higher Education (MAHE), Manipal, continuing its efforts to facilitate academic dialogue and international engagement through the organization of well-structured scientific conferences. Such events contribute significantly to strengthening institutional collaboration, research coordination, and scholarly exchange.

I am pleased to learn that the International Conference on Translational Biophotonics in Healthcare (ICTBH) 2026 is being organized by the Manipal OPTICA Student Chapter at the Manipal School of Life Sciences, MAHE. The conference theme reflects the growing importance of translational research in bridging scientific innovation with healthcare applications. A forum of this nature provides an effective platform for researchers, clinicians, and students to share knowledge, explore emerging directions, and build collaborative networks.

I extend a warm welcome to all delegates, speakers, and participants attending ICTBH 2026 at the MAHE campus in Manipal. I am confident that the conference will be academically productive and will contribute to meaningful interactions and professional growth among the participants.

I wish the organizing team every success in conducting the conference.

Dr. P. Giridhar Kini
Registrar, MAHE, Manipal



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On behalf of the Organizing Committee, it is my great pleasure to extend a warm welcome to all delegates of the **International Conference on Translational Biophotonics in Healthcare (ICTBH) 2026**, organized by the Manipal School of Life Sciences (MSLS), Manipal Academy of Higher Education (MAHE), in association with Manipal OPTICA Student Chapter, Manipal. We wish all participants three days of stimulating scientific deliberations and a memorable experience during their visit to Manipal.

Manipal School of Life Sciences, now completing twenty years as an independent constituent unit of MAHE—an Institution of Eminence recognized by the Ministry of Education, Government of India—has established itself among the leading biotechnology schools in the country. Through its commitment to quality education and frontier research addressing societal challenges, MSLS continues to contribute significantly to diverse fields, including biotechnology, molecular and cell biology, ageing research, plant sciences, radiation biology, toxicology, bioinformatics, and biophysics. The Manipal OPTICA Student Chapter, now in its tenth year of active engagement, has been instrumental in promoting scientific inquiry and fostering a culture of research among young scholars. It is therefore most appropriate that ICTBH 2026 is being hosted at MSLS this year. The conference offers a rich program comprising keynote lectures, technical sessions, and interactive discussions, bringing together eminent scientists, emerging researchers, and students on a common platform to exchange ideas and inspire collaboration.

It is my earnest hope that the deliberations during the conference will lead to innovative research directions, interdisciplinary partnerships, and transformative insights addressing critical healthcare challenges. I extend my sincere appreciation to all invited speakers, delegates, and the organizing team—comprising of faculty members, research scholars, administrative and technical staff, and students—for their dedicated efforts in making this event possible. I wish you all productive and inspiring scientific deliberations.

Best regards & wishes.

Dr. B. S. Satish Rao
Director
Manipal School of Life Sciences, MAHE

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It is a distinct honour and a great pleasure to be associated with the International Conference on Translational Biophotonics in Healthcare (ICTBH 2026) being held at Manipal School of Life Sciences. I would like to express my heartfelt appreciation for the Manipal OPTICA Student Chapter and the organizing committee for their meticulous efforts in conceptualizing a forum that addresses the critical bottlenecks in moving optical technologies from controlled laboratory environments to the complexities of clinical practice. In an era where the boundaries between disciplines are increasingly fluid, this conference stands as a vital intersection for healthcare and engineering. The compendium of abstracts presented in this volume represent the current state-of-the-art in our field. As we navigate the evolution of biophotonics, it is encouraging to see such high-caliber research dedicated to enhancing optical penetration depth, improving molecular specificity, and refining quantitative spectroscopic analysis. The methodologies presented here—ranging from advanced multimodal imaging to the integration of machine learning in computational optics—demonstrate a sophisticated understanding of how light-matter interactions can be harnessed to detect pathology at its earliest stages. True translational success in biophotonics requires more than just high-fidelity instrumentation; it demands a rigorous, interdisciplinary approach that bridges the gap between photonics engineering and clinical utility. This volume serves as a vital record of how we are collectively addressing challenges such as motion artifacts in real-time imaging, the standardization of diffuse optics, and the development of cost-effective, point-of-care diagnostic tools. I congratulate the authors for their scholarly contributions and thank the reviewers and organizers for their commitment to maintaining the highest academic standards. I am confident that the synergies fostered during ICTBH 2026 will accelerate the development of next-generation optical solutions for modern medicine. I wish the conference participants fruitful deliberations and hope this Book of Abstracts serves as a premier reference for your future research endeavours.

Dr. Shovan K. Majumder
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Manipal OPTICA Student Chapter is deeply committed to cultivating an environment that promotes learning and professional growth among students. Through a wide range of focused and student-centric initiatives, the chapter strives to motivate young minds to excel in optics and allied disciplines. Its activities are thoughtfully designed to address students' academic and professional interests, offering meaningful insights, practical exposure, and valuable opportunities for interaction and networking. The chapter regularly organizes workshops, seminars, and guest lectures delivered by distinguished academicians and industry professionals, with the aim of broadening perspectives and strengthening conceptual understanding. In addition, active mentorship initiatives connect experienced mentors with aspiring students, providing personalized guidance that supports academic progression and career development, while instilling confidence and a clear sense of direction. A core objective of the OPTICA Student Chapter is to foster collaboration and facilitate the exchange of knowledge across disciplines. In this context, the forthcoming International Conference on Translational Biophotonics in Healthcare (ICTBH) 2026 presents an exceptional opportunity for the scientific community. ICTBH 2026 is envisioned as an enriching platform that brings together researchers, clinicians, and industry experts from across the globe to share pioneering research, innovative applications, and emerging trends in biophotonics.

The conference will feature thought-provoking keynote lectures, interactive technical sessions, and engaging discussions that highlight the transformative potential of biophotonics in advancing healthcare and scientific discovery I am confident that the intellectual engagement fostered during ICTBH 2026, together with the welcoming atmosphere and cultural richness of Coastal Karnataka, will offer participants a meaningful and fulfilling experience in Manipal. I extend my best wishes for the successful conduct of the conference.

With regards & best wishes.

Dr. Babitha K. S.
Associate Professor & Head
Department of Biophysics
Manipal School of Life Sciences, MAHE

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01st February 2026

The International Conference on Translational Biophotonics in Healthcare (ICTBH) 2026 provides a unique platform for the members of the Manipal OPTICA Student Chapter to gain hands-on experience in organizing and managing an international scientific event, while actively engaging in high-quality technical and professional discussions. This conference creates meaningful opportunities for learning from distinguished researchers and practitioners working at the intersection of optics, biophotonics, and healthcare. ICTBH 2026 brings together a diverse global community of scientists, clinicians and industry professionals, enabling participants to present their research, exchange ideas, and build collaborations across disciplinary boundaries. The conference is designed to highlight the expanding role of optics in modern science and technology, as well as its translational impact in healthcare. The Manipal OPTICA Student Chapter has consistently demonstrated excellence in hosting symposia, workshops, competitions, exhibitions, and outreach programs, and the same dedication and professionalism are being directed toward the successful conduct of ICTBH 2026. The recognition of Manipal Academy of Higher Education (MAHE) as an Institute of Eminence by the Ministry of Education, Government of India, further strengthens the academic stature of this conference. Hosting the event at the Manipal School of Life Sciences, MAHE, adds significant value to its scholarly environment. I am confident that ICTBH 2026 will be a great success.

I trust that the intellectually enriching discussions, coupled with the vibrant cultural heritage of Coastal Karnataka, will make the conference experience at Manipal both rewarding and memorable. I extend my best wishes for the grand success of ICTBH 2026.

With regards & best wishes.

Dr. Krishna Kishore Mahato
Professor
Department of Biophysics
Manipal School of Life Sciences, MAHE
Faculty Advisor, Manipal Optica Student Chapter

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01st February 2026

I am delighted to be associated with OPTICA (formerly OSA), not only because optics is central to my research, but also because the society provides an exceptional platform for scientific advancement, professional growth, and personal development. Since its inception in August 2016 with a small group of dedicated members, the Manipal OPTICA Student Chapter has grown steadily and now proudly undertakes the organization of the International Conference on Translational Biophotonics in Healthcare (ICTBH), scheduled to be held from February 4–6, 2026. It is my great pleasure to extend a warm welcome to all delegates to this interactive forum, which aims to facilitate the presentation, discussion, and exchange of emerging scientific ideas and technological advancements in optics, photonics, and the broader scientific landscape. ICTBH 2026 is envisioned as a vibrant meeting point for researchers, clinicians, academicians, and industry professionals to engage in meaningful dialogue and foster interdisciplinary collaboration. We are privileged to be based at the Manipal School of Life Sciences, an institution that actively nurtures the scientific community through its strong research culture, effective teaching–learning environment, and continued commitment to hosting conferences, workshops, and scholarly events. This conference is particularly special as Manipal Academy of Higher Education (MAHE) has recently been conferred the prestigious Institute of Eminence (IoE) status by the Ministry of Education, Government of India, further enhancing the academic stature of the host institution. I am confident that ICTBH 2026 will be both a successful and enriching experience for all participants. On behalf of the Organizing Committee, Manipal OPTICA Student Chapter, and Manipal School of Life Sciences, MAHE, I cordially welcome all attendees and hope that your time in Manipal is productive, engaging, and enjoyable.

Best regards,

Dr. Nirmal Mazumder
Associate Professor
Department of Biophysics
Manipal School of Life Sciences, MAHE
Chapter Advisor, Manipal OPTICA Student Chapter

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I being a member of OPTICA (formerly OSA) opens doors to a wide spectrum of opportunities, and the privilege of hosting the International Conference on Translational Biophotonics in Healthcare (ICTBH) 2026 further adds to this enriching experience. On behalf of the Manipal OPTICA Student Chapter, it gives me immense pleasure to warmly welcome all delegates to ICTBH 2026.The Manipal OPTICA Student Chapter is now a ten-year-old chapter based at the Manipal School of Life Sciences, MAHE, comprising enthusiastic undergraduate and postgraduate students, along with dedicated research scholars. Over the years, our chapter has actively engaged in organizing science exhibitions, workshops, outreaches, competitions, and symposia. I would like to sincerely acknowledge the support and efforts of our institutional heads, faculty coordinators, research scholars, technical staff, and every chapter member, whose collective contributions have made our events successful and impactful over the years. This year, we are hosting ICTBH 2026 which will include scientific lectures, interactive discussions, and networking opportunities, fostering meaningful knowledge exchange and collaboration.Additionally, Manipal, along with its academic atmosphere, offers a rich cultural and natural beauty, which we hope you will take time to explore during your visit.On behalf of the organizing committee, I extend a heartfelt welcome to all participants of ICTBH 2026 and wish you a productive and pleasant stay in Manipal.

Best regards,

Ms. Gargi Joshi
President
Manipal OPTICA Student Chapter

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INVITED TALKS

Insights at the Interface of Biophotonics and Medicine

Advancement of Diagnostic Platform for Clinical Translation using Surface-Enhanced Raman Spectroscopy

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Surface-enhanced Raman scattering (SERS) is investigated as a highly sensitive spectroscopic modality where the signal intensity of molecular vibration is enhanced up to 10^8 –10^{14} folds compared to simple Raman spectra. Multiplexing capability of Raman fingerprints, molecular specificity, high sensitivity, and the capability to fish out complex biological compositions at the molecular level augmented SERS as a potential diagnostic modality in biology and medicine. Non-invasive, chemically specific, and spatially resolved analysis facilitates the exploration of SERS-based nanoprobes in diagnostics and nanomedicine with improved clinical outcomes compared to the currently available state-of-the-art technologies. In clinical diagnostic research using SERS as an alternative modality, we are currently pursuing three major clinical validation projects, viz., cervical cancer differential diagnosis, prevalence of cancer subtypes through blood plasma, and occurrence of Alzheimer's disease progression based on blood plasma analysis. Recently, we have developed a novel, non-invasive, label-free, and cost-effective diagnostic platform that enables surface-enhanced Raman spectroscopy-embedded artificial intelligence (SERS-EAI) for identifying molecular fingerprints for early cancer diagnosis using blood plasma and exfoliated cervical cells as a sample source. We have conducted a pilot study for ultrasensitive detection of various human cancer metabolic markers based on Raman spectra that includes breast, lung, head, and neck cancers, along with control volunteers. We obtained an estimated sensitivity and specificity of 91.5% and 91%, achieving an overall accuracy of 91% based on different deep-learning artificial intelligence algorithms. In another diagnostic platform, antibody-

conjugated SERS-nanoprobes have been developed for the detection of amyloid and tau proteins in Alzheimer's Disease (AD) progression using blood plasma. The SERS nanoprobes enable precise identification of characteristic Raman fingerprints associated with AD biomarkers, including the Aβ40, Aβ42, APP, t-tau and p-tau with enhanced specificity and sensitivity. Through ratiometric analysis based on the Raman peak of the respective biomarkers of this approach provides a robust and minimally invasive diagnostic technique for highly sensitive and specific detection of AD progression, starting from normal to mild cognitive impairment (MCI) to dementia. The integration of cross-ratiometric analysis of multiple biomarkers provides a comprehensive and reliable diagnostic approach, surpassing the limitations of current resource-intensive techniques.

Counting Every Molecule: Computational Strategies for High-Throughput Digital Assays

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Digital molecular assays enable ultrasensitive detection by partitioning samples and counting discrete binding events, bypassing the fundamental sensitivity limits of conventional analog readouts. The complexity of partitioning hardware however often limits deployment. We present a streamlined platform for digital diagnostics based on nanoparticle imaging, where sensitivity is defined by the algorithmic ability to resolve and quantify sub-diffraction reporters in heterogeneous environments. We will introduce a physics-grounded particle counting algorithm formulated as a statistical multiple-hypothesis test. Unlike heuristic thresholding or "black-box" machine learning, this method requires no training data, instead utilising explicit optical models and penalised likelihood scoring to robustly determine particle counts. We demonstrate the clinical utility of this framework by detecting SARS-CoV-2 DNA biomarkers, where the algorithm successfully discriminates positive samples with high statistical significance. To further scale diagnostic throughput by maximising the effective

field-of-view, we explore lensless holographic imaging. We address the inherent inverse reconstruction challenges using a physics-informed genetic programming algorithm. This evolutionary approach learns symbolic reconstruction policies that automatically configure iterative solvers based on measurement statistics. The resulting policies enable high-fidelity image recovery from single-shot measurements without the extensive supervised datasets required by deep learning methods. These advances in statistical signal processing and evolutionary computing establish a robust, hardware-efficient framework for next-generation point-of-care digital pathology.

Translational Electrochemistry and Laser Processing for Corrosion Evaluation of Medical Materials

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The Center of Excellence in Electrochemistry and Corrosion Technology (CoE-ECT) at King Mongkut's University of Technology North Bangkok is advancing translational research that bridges materials engineering, electrochemistry, and healthcare. While CoE-ECT functions as a national hub for advanced corrosion testing for industrial sectors such as food packaging and oil and gas, its capabilities are increasingly applied to biomedical materials and medical device research. We proposed to integrate laser processing of medical materials with electrochemical corrosion testing to evaluate surface modification effects, degradation behavior, and material stability in simulated physiological environments. CoE-ECT provides a reliable platform for translating laser-based material innovations into practical performance assessment. Through international collaboration and interdisciplinary research, the Center contributes to the development of safer and more durable medical materials, aligning with the broader vision of biophotonics and translational healthcare technologies.

Intelligent Cloud-Based Pressure Sensor Grid for Healthcare Monitoring

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The rapid ageing of the global population has heightened the need for intelligent, unobtrusive, and reliable health monitoring systems, particularly for fall detection and healthcare quality assessment among adults and the elderly. This project presents a cloud-based system integrated with a high-resolution pressure sensor grid embedded in a bed-sized mat to support two key healthcare applications: fall detection and sleep quality monitoring. Falls among the elderly are a major public health concern, often resulting in severe injuries and increased healthcare costs, especially for seniors living alone. The proposed pressure sensor grid captures real-time pressure distribution and movement patterns, enabling accurate detection of abnormal events such as falls. In parallel, the system addresses the widespread issue of poor sleep quality, which is prevalent nowadays and associated with various physical and psychological health problems. Unlike conventional wearable sleep trackers that rely primarily on accelerometers, this system directly monitors sleep posture through pressure mapping, achieving 90% recognition accuracy in its current stage. The project has been further enhanced to focus on a cloud-based sleep quality evaluation platform featuring automatic scoring, expert assessment, and self-evaluation tools. The system has strong potential for deployment in nursing homes, hospitals, rehabilitation centres, and private residences, while also supporting collaborative research, joint publications, and postgraduate supervision.

THz Spectroscopy and Flourescence Lifetime Imaging Microscopy for Biological Applications

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Currently available and commercially successful biomedical imaging technologies are X-ray, computed tomography (CT), magnetic resonance imaging (MRI), Infrared spectroscopy, Ultrasound and Nuclear Imaging scan. But Terahertz Time-Domain Spectroscopy (THz-TDS) offers significant advantages over conventional methods due to its unique combination of safety, sensitivity to hydration, and ability to detect structural, label-free bio samples. But providing molecular fingerprint is the most important advantage of both THz Spectroscopy and Fluorescence Lifetime Imaging Microscopy. THz spectroscopy detects both amplitude and phase of the THz Electric field transmitted through the sample providing ample dielectric signature of samples. The main advantage of Fluorescence Lifetime Imaging Microscopy (FLIM) is its high sensitivity to the fluorophore's molecular environment and interactions, providing unique information beyond intensity by measuring decay time, making it independent of probe concentration or excitation power, enabling label-free metabolic imaging, studying molecular dynamics via Forster Resonance Energy Transfer (FRET), and sensing microenvironment parameters like pH, viscosity, and oxygen, crucial for understanding cellular health and disease progression. In this talk, some of our recent results on THz spectroscopy of biomolecules and measurement of fluorescence lifetime of some standard molecules will be presented apart from an outlook on the direction of research in this area. Using a combined experimental and computational approach in the 0.2–4 THz frequency range, we investigated both qualitative and quantitative vibrational signatures of neurotransmitters such as serotonin, as well as peptide systems including phenylalanine dipeptides. The above results of terahertz spectroscopy demonstrate the molecular structure and collective dynamics. We also perform wide-field FLIM measurements of a dye Rh-6G (3 mM), which shows the spatial lifetime variations that distinguish monomer and aggregate distributions. Together, THz spectroscopy and FLIM constitute a powerful multimodal

platform with strong potential for biomolecular fingerprinting, detection, and comprehensive characterization.

From Nanostructures to Real Samples: Advances in SERS Substrates for Biological and Environmental Applications

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Surface-enhanced Raman spectroscopy (SERS) has emerged as a powerful analytical technique for the ultrasensitive detection of diverse chemical and biological analytes, owing to its molecular fingerprinting capability, rapid analysis, and compatibility with complex matrices. The effectiveness of SERS largely depends on the design of plasmonic substrates with high sensitivity, uniformity, and reproducibility. Recent advances in substrate engineering have enabled reliable detection of trace-level contaminants and biomolecules, thereby expanding the applicability of SERS in environmental monitoring and bioanalysis. This talk presents the fundamentals of SERS and recent developments in plasmonic substrate fabrication strategies, including photochemical synthesis, template-assisted growth, and cylindrical droplet-based platforms. Emphasis is placed on two major application domains: environmental monitoring, focusing on the detection of hazardous environmental pollutant dyes, and bioanalysis, demonstrating antibiotic detection and label-free discrimination of bacteriophages. Finally, future directions and emerging developments aimed at enhancing substrate performance, scalability, and real-world applicability will be discussed.

Development of Light Controlled Slow-Release Transdermal Drug-Loaded Porous Rubber Materials

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Natural rubber latex is widely used in the medical field as a drug delivery system due to its beneficial properties, including elasticity, flexibility, biocompatibility, and adhesion. This study focused on developing a cost-effective, reusable, industrially feasible, and drug-injectable shoe insole as a transdermal drug delivery system (TDDS) using a porous rubber sheet made from natural rubber (NR). The sheet was prepared via the Dunlop process. The porosity was assessed using BET analysis, while surface morphology was examined with a trinocular microscope. The swelling ratio was found to be approximately 253%. A model drug was subsequently injected into the porous rubber, and its release was evaluated using an artificial sweat solution prepared according to the EN 1811 standard. UV-Vis spectroscopy was used to measure the concentration and cumulative release of the drug. Additionally, to facilitate controlled drug release, labile imine or carbonate bonds were formed between the drug and a modified rubber. A model drug was used for imine bond formation, and a commercially available drug was used to synthesize the carbonate bond. Modifications were confirmed through Fourier-transform infrared spectroscopy (FTIR) and thermogravimetric analysis (TGA). Characterization of the carbonyl-containing drug involved methods like FTIR, UV-Vis, gas chromatography-mass spectrometry (GC-MS), and NMR. FTIR analysis validated the labile bond between the model drug and the aminated rubber. Drug release kinetics were evaluated in an artificial sweat solution, indicating that chemically bonded systems provide enhanced control. Future investigations will focus on the photo-induced cleavage of the imine and carbonate bond for controlled drug release at wavelengths of 440 nm and 365 nm, respectively. Additionally, further studies are underway to modulate the activity of the injected drug within a porous rubber sheet, utilizing red light emission from LEDs. These studies aim to enhance the

effectiveness of targeted drug delivery systems by utilizing light-controlled activation mechanisms.

Ultrathin Hexagonal Boron Carbon Nitride Films as universal SERS substrate

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Surface-enhanced Raman spectroscopy (SERS) is a powerful analytical technique for the detection of trace analytes. In this study, we demonstrate that ultra-thin, highly crystalline hexagonal Boron Carbon Nitride (hBCN) films can be used as a robust SERS substrate. These hBCN films were synthesized on Cu foil using atmospheric pressure chemical vapor deposition (APCVD). Four model dyes, Methylene Blue (MB), Crystal Violet (CV), Nile Blue (NB), and Rhodamine 6G (R6G), were used to systematically investigate the performance of the hBCN substrate on Raman scattering enhancement. We observed the highest enhancement for R6G with an analytical enhancement factor of 8.9×10^5, at least one order higher than the other dyes. We could detect very low concentrations of R6G dye molecules till 10^{-8} M. We conducted tests to check the uniformity, reproducibility, and recyclability of the hBCN substrates. Reproducibility tests conducted on 5 different samples from different batches showed minimum variation in Raman signals. The hBCN substrates could be recycled up to 5 times with only 10 % loss in intensity, beyond that there was a reduction of Raman signals by 50 %. The films retained the SERS performance after heating at 450 ◦ C and exhibited negligible degradation even after 180 days of ambient exposure, outperforming graphene and metallic SERS substrates in long-term and high-temperature stability. We demonstrate a synergistic enhancement when silver nanoparticles prepared using femtosecond laser pulses were used in conjunction with these substrates.

IR and Terahertz Spectroscopy and Machine Learning for Medical and Ecological Applications

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IR and terahertz spectra of gas samples of natural origin qualitative and quantitative analysis is useful to extract volatile molecular biomarkers in the patient breath air or atmosphere industrial molecular pollutions. The major problem in this field is that the composition of gas samples of natural origin is unknown. Such tasks are related to the “gray system” analysis. The problem of presence of unaccounted (latent) components requires more sophistical methods, including machine learning (ML), first of all, aimed on extracting new informative variables (features) of minimum quantity, which describe peculiarities in data analogously to initial variables. Original chemometrics and ML methods suitable for gray systems analysis will be presented including examples of their medical and ecological applications.

X-ray scintillator screens based on the efficient photoconversion of innovative phosphor powders and composites

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The X-ray scintillators are known for their special ability to convert high-energy X-rays into visible photons, which have shown enormous application potential in various applications, including medical diagnosis, radiation detection, and security examinations. A prevalent method to realize X-ray detection is to incorporate a photodetector with an X-ray luminescent phosphor, which is termed a scintillator. In the scintillation counter, the X-ray photons are usually converted into an electrical signal via a two-step process. The X-ray photons strike with a phosphor scintillator screen, which is usually made by the phosphor powder coating. The latter step yields visible photons, which are afterward converted to voltage pulses via a photomultiplier tube attached straight behind the scintillator. The density of electrons ejected by the photocathode is the key factor for the final image brightness and resolution. This density is proportional to the number of the converted visible photons that strike the photomultiplier, which in turn is proportional to the energy of the irradiating X-ray photons. Due to a large number of scattering losses from the micron-sized phosphor particles, the energy resolution of the detector is reduced, and as such it cannot be used to resolve X-ray photons due to K_{α} and K_{β} radiation Our research straightforwardly on this particular field adopt an efficient method to develop a multicomponent garnet broad-band emitting phosphor with high quantum yield and fast decay. To enhance their emissive performance and for easy integration to the X-ray scintillators, we develop phosphor-polymer composite films which are flexible in nature and thermally stable compared to their powder form. Most importantly, the composite films exhibit considerably faster decay kinetics (fewer afterglow) compared to single crystals or ceramics, which attribute to the low sintering temperatures for films during their fabrication that will lower the creation of antisite defects. This research in this sector offers the commercial-grade development of a new class of phosphor-polymer composites.

Bio-based Solutions for Translational Biophotonics in Healthcare

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The transition toward sustainable and biocompatible materials is revolutionizing the biomedical landscape, particularly in the realm of advanced drug delivery systems. This presentation explores a comprehensive suite of biobased solutions designed to overcome critical challenges in modern medicine, including poor drug solubility, mechanical instability of hydrogels, and the need for precision targeting. Our research highlights innovative methodologies to enhance the mechanical properties of biomedical hydrogels through the integration of biobased nanoparticles and the introduction of spider silk proteins, creating robust scaffolds for tissue engineering and sustained release. We further address

the limitation of poorly water-soluble drugs, such as curcumin, through various nanotechnology-driven strategies. This includes the development of electro-stimulated release systems utilizing Poly(Lactic Acid)/Carboxymethyl Cellulose/ZnO nanocomposite films and pH-responsive Carboxymethyl cellulose hydrogels for targeted gastrointestinal delivery. Furthermore, the versatility of biopolymers is demonstrated through specialized applications: Respiratory Therapeutics: Enhanced curcumin-loaded nanocellulose as a potential inhalable nanotherapeutic for treating respiratory distress, specifically in the context of COVID-19. Ophthalmic Delivery: The design of Chitosan/Gelatin/Nanocellulose-based systems to improve drug retention and bioavailability in ocular tissues. Gene Therapy: Utilizing cationic biopolymers to condense mRNA and siRNA into nano-sized polyplexes, providing protection from enzymatic degradation and facilitating endosomal escape for safer, non-viral gene delivery. Dermatological Innovations: The development of transdermal anti-aging sprays and patches that utilize sodium alginate hydrogels crosslinked with $CaCl_2$ to deliver bioactive compounds like ascorbic acid and curcumin nanoparticles directly through the skin. By leveraging smart, stimuli-responsive biopolymers (pH and electro-responsive), these systems offer "tunable" and safer alternatives to traditional synthetic carriers. This invited speech will synthesize recent peer-reviewed findings and ongoing research, demonstrating how biobased materials are paving the way for more effective, targeted, and patient-centric therapeutic interventions.

Morpho-Molecular Microscopy: Transforming Cancer Diagnosis and Surgical Decision-Making

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Tumorigenesis is a complex process that involves dramatic changes in the morphological, molecular, and genetic makeup of cells as they transform from normal to malignant. Raman spectroscopy offers the ability to study live cells without the use of external contrast agents. However, the clinical application of spontaneous Raman imaging is limited by its slow speed and low sensitivity. To overcome these challenges, we developed a novel technique known as morpho-molecular microscopy (3M), which allows for simultaneous measurement of both morphological and biochemical characteristics. Our 3M system draws on the combined strength of quantitative phase imaging - to probe the morphological features- with Raman microscopy that provides molecular fingerprinting characteristics. This talk will discuss the use of the 3M system in live-cell imaging and its applications in leukemia diagnosis. The other focal point of this talk will highlight our recent clinical translational efforts aimed at improving surgical decision-making in breast and bladder cancer.

Raman Theranostics in Cancer across Species: Insights from Animal Models

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Bridging insights from experimental cancer models with observations in human disease has remained a central objective of oncology research. Animal models provide opportunities to explore early events in carcinogenesis and to follow disease progression under controlled conditions, while studies in human subjects reveal the biological variability and clinical realities that shape outcomes. Progress in translational oncology depends on sustaining a meaningful dialogue between these approaches rather than allowing them to evolve independently. Raman spectroscopy has steadily gained recognition as a minimally invasive approach for examining biochemical changes associated with malignant transformation. Studies in experimental models, including the hamster buccal pouch model, have helped clarify how molecular composition evolves during epithelial carcinogenesis. When considered alongside investigations in human oral malignancies and patient-derived biofluids, these observations point toward recurring biochemical features that appear to be shared across species. Comparative oncology adds an important perspective to this translational continuum. Naturally occurring cancers in dogs mirror many aspects of human disease, including tumour architecture, microenvironmental interactions, and patterns of progression. Raman spectroscopy studies in canine cancers have demonstrated molecular features that closely parallel those observed in human tumours, reinforcing the relevance of cross-species approaches in cancer research. Current efforts are focused on consolidating these insights by strengthening cross-species comparisons, identifying disease- and stage-related spectroscopic features, and validating findings in larger and more representative cohorts. This study will reflect on the current position of Raman spectroscopy within a comparative oncology framework and consider its potential role in supporting a thoughtful transition from experimental research toward clinically meaningful applications in cancer diagnosis and monitoring.

Single Nanocrystals Spectroscopic correlation of Defect and Dopant Photoluminescence

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Broad intrinsic defect-related luminescence in semiconductor nanocrystals arises from a complex interplay of surface traps, structural imperfections, and charge-carrier dynamics. Doping of semiconductor nanocrystal hosts with a localized, essentially atomic-like and often magnetic, impurity constitutes one of the most active research fields, yielding fascinating properties. One of the most exciting properties of Mn-doped semiconductor nanocrystals is the ultrabright photoluminescence. The undoped ones possess broad defect luminescence and doped ones display alternate route of dopant emission following exciton transfer to a dopant ion and the deexcitation involves only dopant states. Ensemble spectroscopic results display both defect and dopant related emission are broad in nature. While broad spectral width of intrinsic defect luminescence is often assigned to the distribution of variable defects as well as sample heterogeneity due to size distribution. However, the involvement of the atomic-like Mn d states implies that the emission wavelength (~585 nm) of Mn is relatively unaffected by the size and even the chemical nature of the semiconductor host. The Mn d

emission has been invariably found to have a large spectral width (>300 meV), incompatible with an atomic-like $^4T_1$—$^6A_1$ Mn emission. This large width has been explained in terms of coupling of Mn d levels to the vibrational structure of the host. However, its microscopic origins remain difficult to resolve through ensemble measurements. In this work, energy mapped single-molecule fluorescence microscopy is employed to probe emission pathways in individual nanocrystals, enabling the isolation of heterogeneous optical behaviors that are otherwise obscured in bulk studies. The results experimentally evidence that the spectral line-width in undoped semiconductor nanocrystals is intrinsically broad. On the contrary, the Mn doped nanocrystals, display wide ranging colors from Mn emission in a semiconductor NC host and ultranarrow spectral linewidths (60–75 meV).

Light Scattering in Particulate and Turbid Media: Principles, Measurements, and Biophotonic Applications

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Light scattering fundamentally governs how optical radiation interacts with particulate and turbid biological media. This presentation will examine the core physical principles that describe these interactions, bridging fundamental optics and translational biophotonics. Beginning with classical frameworks such as Rayleigh and Mie scattering, radiative transport theory, and the discrete dipole approximation (DDA), the talk will elucidate how variations in particle size, morphology, and refractive index contrast influence angular scattering distributions, phase functions, and polarization characteristics. The discussion will extend to the Stokes-Mueller formalism, highlighting the physical significance of the Stokes parameters and the Mueller matrix elements in characterizing the polarization state of scattered light. Emphasis will be placed on Mueller matrix decomposition techniques that isolate key optical effects including diattenuation, retardance, and depolarization, thereby linking measurable polarization properties to the microstructural and compositional attributes of complex biological systems. Finally, selected applications in biophotonic diagnostics will be presented, including polarization-resolved

scattering studies of model SARS-CoV-2 virions and light-transport investigations in optically thick biological tissues. These examples illustrate how a rigorous understanding of scattering physics and polarization behavior underpins the development of compact, quantitative optical tools for disease detection, tissue characterization, and therapeutic monitoring.

He-Ne laser-mediated alterations in physio-biochemical traits and plant bioactive compounds

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The agriculture industry is expanding rapidly, and to fulfil future sustainable demands and goals, more innovations are needed to achieve greater heights. The distinct groups of photoreceptors control light, which is an extremely important environmental factor for seed germination, seedling growth, and related photo-morphogenesis. Among other light sources with different wavelengths, red light has been shown to have a major effect on the germination, development and biosynthesis of secondary metabolites in plants. To promote sustainable agricultural practices and increase agronomical characteristics, laser technology for plant growth promotion and disease resistance has recently been extensively investigated. Therefore, the present study highlights the impact of He-Ne laser irradiation on brinjal and ashwagandha seeds, which results in increased germination, growth, and synthesis of bioactive metabolites. Ashwagandha and brinjal seeds were exposed to various laser dosages and allowed to germinate in vitro. Significant seed germination was induced by lasers, and the morphological and physio-biochemical properties of the seedlings were observed. Compared with those in the non-irradiated control groups, the germination rate, total seedling length, and carotenoid content were greater in laser exposed groups. Interestingly, compared with those of the control groups, the RP-HPLC chromatograms of withanolide A, withaferin, and withanone contents in ashwagandha and the chlorogenic acid content in brinjal reached a maximum in the 20 J groups. Higher laser doses, however, can have a detrimental effect on

plant development and metabolite synthesis, as demonstrated in the 30 J groups, where the amount of chlorogenic acid decreased. Additionally, this study revealed increased primary and secondary metabolites in seeds and seedlings. In conclusion, this study demonstrated a novel method for enhancing plant growth and the synthesis of bioactive metabolites by laser biostimulation in vitro for both the industrial production of bioactive chemicals and sustainable cellular agriculture.

Structure-Engineered Uranyl Complexes: Luminescence Enhancement and Biological Evaluation

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In the biophotonic applications development of photoactive systems with prominent optical efficiency and strong biological relevance is highly desired. In this line, here we present the synthesis and comprehensive characterization of structure-engineered uranyl (UO_2^{2+}) coordination complexes and discuss their luminescence and biological properties. Detailed spectroscopic and structural analyses of the compounds confirm well-defined coordination geometries, which play key role in modulating their photophysical properties. The coordination complexes exhibit significantly enhanced luminescence intensity compared to uranyl salts, owing to the ligand-induced stabilization of the excited state and suppression of possible non-radiative decay pathways. Apart from the improved optical performance, the designed complexes exhibit favourable interactions with proteins, as demonstrated by the spectroscopic binding studies, indicating increased bio-compatibility of the complexes. Further, preliminary *in vitro* anticancer assays reveal that the current uranyl complexes display measurable cytotoxic activity, indicating the influence of coordination structure on biological response. By correlating structure, luminescence, and bioactivity of the uranyl complexes, this study demonstrates the importance of rational ligand design in the transformation of simple uranyl ions into structure-controlled photonic systems, offering transferable insights for the development of metal-based probes and light-responsive agents relevant to biophotonic and life-science research.

GynoSight v3.0: Real-Time Multispectral Transvaginal Probe for Early Cervical Cancer Detection

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Multispectral diffuse reflectance imaging is a powerful technique that enables detailed assessment of tissue absorption and scattering properties. These characteristics are essential for identifying crucial cancer biomarkers and anomalies, particularly those associated with precancerous cervical lesions. In this study, the GynoSight v3.0 imaging probe was designed and developed as a multispectral, portable, and hand-held transvaginal device. The probe utilizes a 20MP Ximea camera for high-resolution imaging. Illumination of the cervical region is achieved through four distinct LED wavelengths, each controlled by a high-current driving circuit. Real-time image acquisition and processing are conducted using a Raspberry Pi 5.0 system. Comparative shadowing analysis between conventional colposcopy images and those obtained from GynoSight v3.0 highlighted differences in pixel value distribution. Colposcope images exhibited pixel values skewed toward the lower end, whereas GynoSight v3.0 images presented a uniform distribution across the full gray-level range (0 to 255). To quantify the shadowing effect, several metrics were estimated for both GynoSight v3.0 and colposcopy images: Mean Pixel Intensity (MPI), Shadow Area Percentage (SAP), and Entropy. These metrics facilitated a comparative assessment of image quality and shadowing between the two modalities. The Optical Density Ratio (ODR) was mapped on the superficial cervical tissue by registering multispectral images using a proposed phase correlation-based technique. This registration enabled correlation between regions of interest in the ODR map and observed surface abnormalities on the cervix. An Artificial Intelligence (AI) algorithm was also developed utilizing the EfficientNet architecture for real-time identification of key cancer biomarkers. The algorithm successfully detected abnormal blood vessels, dense acetowhite

regions, and areas of negative Lugol's Iodine uptake, achieving an accuracy greater than 80%.

Imaging the Future of Healthcare: The India BioImaging National Network

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Biophotonics and advanced bioimaging technologies are central to translational healthcare, enabling non-invasive visualization, early diagnosis, and mechanistic understanding of disease across spatial and temporal scales. India BioImaging (IBI) represents a national effort to build a coordinated, sustainable, and accessible bioimaging ecosystem that bridges optical imaging innovation with biomedical and clinical translation. This invited talk will present the evolution, current landscape, and strategic roadmap of India BioImaging, highlighting its growing relevance to translational biophotonics in healthcare. India BioImaging is structured as a distributed network of imaging core facilities encompassing advanced optical microscopy, fluorescence and label-free imaging, live-cell and in vivo imaging, and emerging biophotonic modalities. Through shared access models, harmonized training programs, standardized workflows, and collaborative research platforms, IBI aims to democratize access to high-end imaging infrastructure and accelerate bench-to-bedside translation. Capacity building through hands-on training, workforce development, and the integration of artificial intelligence for image analysis and decision support are key pillars of the initiative. Founded in 2012 with a vision to democratize access to advanced microscopy and harmonize imaging training across India, IBI has made significant contributions to improving imaging expertise nationwide. Addressing the persistent challenge of equitable access to cutting-edge technologies, IBI is now entering a transformative new phase, uniting stakeholders across academia, clinical research, and industry to future-proof India's imaging ecosystem. The rapidly expanding network currently comprises 22 leading imaging core facilities spanning public, private, and clinical institutions. This renewed momentum was catalyzed by a revival meeting in December 2024 at IISER Pune, organized in partnership with Global BioImaging (GBI), and strengthened by the first India BioImaging Annual Meeting held on December 11–12, 2025, at JSS AHER, Mysuru.

Unleashing the potentialities of intensity modulation-based schemes for efficient signal readout

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Impregnating optical waveguides with suitable functional elements have enabled copious qualitative as well as quantitative sensing procedures. However, in most cases, the interaction procedure is activated through non green route. Entailing green route is promising as well as challenging task. The schemes, entailing a biodegradable functional element, havebeen proven to be highly functional and cost-effective as compared to other existing approaches. The excellent selectivity of analytes via proper tuning of linker or associated functionalities is a direct evidence of efficient signal readout. The use of direct intensity-based approach eliminates complexities making whole retrieval procedure very effective.

Spectroscopic Innovations in Translational Disease Diagnostics

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Recent advances in chemical, optical, and technical sciences have enabled a new path in biomedical diagnostics by coupling molecular-level spectroscopic precision with the computational power of artificial intelligence. In the present report, the application of fluorescence and photoacoustic spectroscopy for the early detection and monitoring of diseases such as breast, oral, and colorectal cancers, diabetes, and neurodegenerative disorders, enabled with machine learning, will be discussed. The outcomes demonstrate that photoacoustic spectroscopy provides sensitive insights into biochemical and structural alterations within tissues, while fluorescence spectroscopy captures dynamic molecular changes associated with protein conformational shifts and mitochondrial dysfunction. By employing data-driven methods such as support vector machines, generalized linear models, and feature-selection algorithms, we achieve high sensitivity and specificity in differentiating healthy and diseased tissues across preclinical and translational models. Selected studies explore photoacoustic signal-based classification of breast tumor progression *in vivo*, oral cancer identification through spectral-textural analysis, and dual-modality fluorescence–photoacoustic spectroscopy for mapping metabolic and vascular biomarkers. Further, our work on glycated protein autofluorescence provides promising diagnostic markers for diabetes and systemic oxidative stress. The synergy between optical spectroscopy and AI opens the door to the development of non-invasive, label-free, and real-time diagnostic tools that bridge fundamental chemistry with clinical applications. This integrative framework positions multimodal spectroscopic diagnostics as a cornerstone of next-generation chemical–biomedical innovation, aiming for precision disease detection and personalized monitoring.

Stable Isotope coupled Raman imaging for translational biophotonics

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All that is living is metabolizing, making metabolic pathways the heart of cellular life. Metabolism is spatially regulated inside the cells; therefore, chemical maps of metabolic activity and metabolites *in cellulo* is of high importance. Traditional techniques like fluorescence imaging and mass spectrometry imaging are highly efficient, but rely on dyes, tags, stains, or are inherently destructive. We report a label-free, vibrational imaging-based platform for real-time, direct visualization of metabolic pathway activity in microbial and mammalian cells. By enhancing the cellular abundance of naturally existing rare stable isotopes (^{13}C, ^{2}H, ^{15}N), we have non-destructively tracked the dynamics of newly synthesized metabolites. In microbes, we first investigated the shikimate pathway in *E. coli* and *S. cerevisiae*. Using phenylalanine as a reference peak, we captured spatiotemporal changes in metabolic activity. We also visualized both *de novo* and *ex novo* microbial oil biosynthesis in oleaginous yeasts. Quantitative chemical imaging revealed an enhanced distribution of microbial oil, which was further validated using unsupervised machine learning techniques such as K-means clustering and multivariate curve resolution. In the mammalian system, we utilized this approach to map glutamine metabolism. Our method tracked nitrogen flux from glutamine into nascent adenine, guanine, cytosine, thymine, and uracil in HEK293T cells. We further demonstrated its application to visualizing newly synthesized nucleotides in human and mouse cancer cells at the single-cell level using intensity mapping and vertex component analysis combined with a non-negative least squares algorithm. Furthermore, we also spatiotemporally mapped the essential amino acid (phenylalanine) to nascent non-essential amino acid (tyrosine) conversion in the cell. During this lecture, we will discuss the benefits of this versatile, label-free imaging approach which offers a new platform for the dynamic metabolic visualization in cells, from microbes to mammals through above mentioned examples.

Towards a Multifunctional 2-micron Thulium-doped fiber for High-precision Biomedical applications

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Fiber lasers offer high efficiency, excellent beam quality, and precise controllability, making them powerful tools for minimally invasive biomedical procedures. In particular, Tm-doped fiber lasers operating near 2 μm are increasingly replacing conventional surgical instruments by reducing thermal damage, surgical trauma, and post-operative healing time. Since tissue response is strongly governed by laser wavelength, intensity, beam profile, and exposure duration, flexible and tunable laser sources are essential for optimized therapeutic outcomes. Motivated by these requirements, we develop a versatile 2-μm fiber-based platform capable of delivering both narrowband high-energy pulses and broadband, spectrally controlled amplification. We demonstrate an all-fiber mode-locked Tm-doped laser employing a highly chirped fiber Bragg grating to engineer a net anomalous cavity dispersion of -100.9 ps^2 within an energy-managed architecture. This enables stable generation of narrowband picosecond pulses with energies up to 17.8 nJ and pulse durations of 15.2 ps. Such sources are highly promising for next-generation precision biomedical applications requiring controlled energy delivery and wavelength-selective tissue interaction.

Photon-Matter Coupling and Optical Density of States Engineering in S-Scheme Photocatalysts for Solar-to-Chemical Energy Conversion

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Solar-driven chemical transformation is inherently governed by light–matter interactions, where efficiency depends on how incident photon flux is absorbed, distributed within the optical density of states (ODOS), and converted into long-lived excited charge carriers that drive surface redox reactions. Despite extensive progress, conventional photocatalysts for CO_2 reduction and clean fuel generation remain limited by weak visible-light absorption, inefficient photonic utilization, ultrafast carrier recombination, and poorly matched band structures, leading to low photon-to-chemical conversion efficiency. Recent advances in photocatalytic photonics reveal that S-scheme heterostructures provide a powerful framework for engineering photon absorption pathways and excited-state carrier dynamics at semiconductor interfaces. By integrating materials with complementary ODOS and band alignments, S-scheme architectures selectively eliminate low-energy carriers while preserving highly energetic electrons and holes with strong redox capability. Built-in interfacial electric fields and band bending further regulate photon-induced charge separation, extend carrier lifetimes, and enable directional carrier transport under continuous solar illumination. In this presentation, we demonstrate the rational design of 2D semiconductor-based S-scheme and direct Z-scheme photocatalysts for three solar-driven processes: CO_2 photoreduction, green hydrogen evolution, and sustainable urea synthesis via N_2- CO_2 coupling. We elucidate how ODOS modulation, photon absorption depth, interfacial dipoles, and charge-transfer kinetics collectively govern light harvesting efficiency, excited-state lifetimes, and quantum efficiency. This work highlights how deliberate control of photon–matter coupling can enable scalable and efficient solar-to-chemical energy conversion for sustainable energy technologies.

Biophotonics of *Black turmeric*: Linking light scattering-guided signatures to Antibacterial Efficacy

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Black Turmeric (*Curcuma caesia*) has been used in traditional medicine for its strong antibacterial properties, but its mechanisms aren't well understood at the biophysical level. This series of studies uses light scattering techniques, including standard Mie theory, volume scattering functions, and radiative transfer modelling, to describe the rhizome's particle structure and connect it with its antimicrobial potential. Comparison analyses show different scattering profiles affected by temperature changes and processing methods, like those imitating Black Garlic analogs, which improve bioactivity. Key findings indicate that scattering signatures, which show specific angular patterns and intensity distributions, can predict antibacterial responses by

measuring nanoparticle clumping and the spread of bioactive compounds. These optical features not only support health claims but also provide a non-invasive tool for quality control in herbal therapies. By linking Physics and Pharmacology, this work highlights Black Turmeric's potential as a natural antibiotic alternative, opening doors for scalable, evidence-based solutions to combat antimicrobial resistance.

Harnessing Light for Precision Medicine: Photodynamic and Photobiomodulatory approaches for infection control and regenerative medicine applications

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Light-assisted precision medicine is an emerging therapeutic paradigm that enables targeted, non-invasive, and adaptable interventions across a broad spectrum of clinical applications ranging from infection control, wound healing to stem cell stimulation. This invited talk explores the possible utility of antimicrobial photodynamic therapy (PDT), photobiomodulation (PBM), and stem cell–directed PBM for infection control and regenerative medicine. aPDT provides precise antimicrobial effects through light-activated photosensitizers that generate reactive oxygen species, enabling effective eradication of broad-spectrum pathogens, specially, the antimicrobial drug resistant and virulent ones, while minimizing systemic toxicity. Our studies at LBAD, RRCAT have indicated that aPDT action spans beyond simple pathogen inactivation, including attenuation of infection induced hyperinflammation, collagen degradation, promotion of cell proliferation and enhancement of neo angiogenesis, which were not documented earlier. On the other hand, PBM employs low-intensity light to regulate cellular metabolism, inflammation, and tissue repair, creating a pro-regenerative microenvironment. Our previous studies have demonstrated beneficial role of PBM in chronic wound repair. Moving forward, our recent endeavours reveal that PBM can directly influence stem cell behaviour, including proliferation and migration. The integration of aPDT, PBM, and stem cell photobiostimulation represents a transformative framework for precision medicine, offering new opportunities for optimized healing, functional restoration, and translational clinical impact. This presentation will also highlight mechanistic insights into the shared photobiological foundations of aPDT and PBM modalities. Finally, in this talk, I shall provide some examples of emerging preclinical and clinical evidence supporting combined or sequential PDT–PBM strategies which can cater to patient-specific needs.

Femtosecond Laser–Enabled Fabrication of Functional Biophotonic Micro/Nanostructures

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Two-photon lithography (TPL) has emerged as a versatile micro/nanofabrication technique, enabling sub-diffraction-limited, 3D/4D patterning with exceptional spatial precision. Owing to its nonlinear light–matter interaction and inherent 3D capability, TPL offers unique opportunities for developing functional biomaterials and miniaturized devices for healthcare applications. This work places TPL in the context of translational biophotonics by highlighting its ability to integrate photonic precision with functional nanomaterials and biopolymers. The versatility of TPL is demonstrated through biophotonic platforms that span chemical sensing and bioengineering. The first study presents a miniaturized organo-arsenic sensor fabricated using TPL, where multimodal doped carbon quantum dots act simultaneously as two-photon initiators and functional nanoparticle, enabling selective fluorescence-based detection of organo-arsenic species at ppb levels. The second work focuses on ECM-free directed growth of skeletal muscle (C2C12) cells on TPL-fabricated nano/micro-scaffolds, where chitosan-derived carbon quantum dots impart intrinsic biocompatibility, eliminate the need for extracellular matrix coatings, and guide cellular alignment through structural cues. The third study demonstrates a femtosecond-laser-assisted, one-step process for *in situ* formation of nitrogen-doped carbon quantum dots within patterned chitosan, yielding fluorescent biopolymeric microstructures for localized pH sensing. These studies highlight how TPL can bridge photonics, nanomaterials, and biology to realize multifunctional platforms for sensing and healthcare diagnostics, underscoring its potential as a scalable tool for translational applications.

Surface Topography of Materials from Microscopic to Nanoscale

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Surface topography is a strategic factor influencing the physical, chemical, and electrical properties of materials with macro- to nano-scales. The surface features like roughness, texture, grain boundaries, and nano-asperities play a vital role in determining mechanical, tribological, optical, electrical, and catalytic behavior. This lecture presents an overview of surface topography characterization techniques, highlighting the evolution from conventional microscopic methods to advanced nanoscale analysis. The presentation covers fundamental concepts of surface morphology and roughness parameters, followed by commonly used techniques including optical microscopy, stylus profilometry, Field emission scanning electron microscopy (FESEM), Scanning tunneling microscopy (STM), and atomic force microscopy (AFM). Emphasis is placed on correlating surface topography with material performance in applications such as thin films, nanostructured coatings, semiconductor devices, biomaterials, and energy materials. By integrating multi-scale characterization approaches with practical examples, this lecture underscores the importance of surface topography analysis in materials design, quality control, and nanotechnology research.

Wavefront sensing for ophthalmic imaging and vision science

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Modern eye care needs tools to accurately measure how wavefront distorts (caused by cornea and crystalline lens) when passing through the eye. Traditional Shack-Hartmann wavefront sensors (SHWSs) are robust devices for this purpose but are inaccurate in eyes with multifocal intraocular lenses (M-IOLs), and in multi-layered samples (when imaging eccentric to the fovea). Due to the asymmetric pupillary power distribution in segmented refractive M-IOLs, they create SHWS images that result in artifactual coma aberrations. Our proposed method scans far and near vision zones of the M-IOL separately, giving better accuracy (35 nanometers error). This will help better post-surgery patient diagnosis and management. Centroiding algorithms that play a critical role in SHWS accuracy use an inherent approximation that the intensity is uniform across each pixel. We proposed an algorithm that accounts for non-uniform intensity variation across detector pixels, significantly improving measurement precision. We also developed AI tools (random forest + neural networks) that will help us in analyzing wavefront sensor data 74% more accurately (4 nm versus 17 nm error) than traditional algorithms. For thick-sample imaging, such as retinal and microscopy applications, we devised a Fourier-based method to estimate centroid-related artifactual aberrations arising from multiple reflecting layers. By using an appropriate coordinate transformation, this approach substantially accelerates the computation while preserving accuracy. This will help enhance retinal image quality in animal adaptive optics ophthalmoscopy, used for drug testing. Retinal images in adaptive optics ophthalmoscopes are scaled by using model eyes (Ronchi rulings on glass) that can give partial specular reflections, causing the well-known double-pass effect, making the adaptive optics loop unstable. In another work, we showed how this can be addressed by reducing the adaptive optics loop gain. These tools and technical advancements make wavefront sensors faster, smarter, and reliable for better surgery results, vision correction, and retinal studies.

Seeing Cancer Before It Forms: How Fluorescence and Infrared Spectroscopy Reveal Malignancy-Associated Changes in the Oral Cavity

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Oral cancer continues to exhibit high mortality and morbidity despite advances in therapy, largely due to late-stage diagnosis. Long-term survival remains below 50% because early premalignant changes are often asymptomatic and difficult to distinguish clinically. Histopathology remains the diagnostic gold standard, yet early lesions pose challenges due to subtle morphological alterations and the invasive nature of biopsy. These limitations highlight the urgent need for rapid, noninvasive, and molecularly sensitive diagnostic approaches. This talk traces a spectroscopic journey from oral habits to potentially malignant disorders and oral cancer, demonstrating how fluorescence and infrared spectroscopy can reveal malignancy-associated changes before overt disease develops. Autofluorescence spectroscopy was employed to evaluate endogenous fluorophores, including collagen, flavin adenine dinucleotide, porphyrins, and hemoglobin across normal individuals with and without oral habits, oral submucous fibrosis, leukoplakia, and oral lichen planus. Progressive alterations in fluorescence intensity, redox balance, porphyrin accumulation, and hemoglobin modulation were consistently observed with increasing disease severity. Multivariate analytical methods significantly improved diagnostic performance, enabling reliable discrimination between healthy and diseased tissues, as well as between habitués and non-habitués. Complementary Fourier transform infrared (FTIR) spectroscopic imaging further enabled differentiation of early-stage oral hyperplasia from adjacent normal epithelium and oral squamous cell carcinoma. Infrared spectral analysis revealed increased DNA content, protein denaturation, and lipid remodeling, with unsupervised hierarchical clustering providing objective tissue classification. Together, these findings establish spectroscopy as a powerful platform for mapping the molecular

continuum of oral carcinogenesis, advancing early detection, risk stratification, and improved clinical decision-making, bringing us closer to seeing cancer before it forms.

Light Driven Pulley-System

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We have developed a Light Driven Pulley-system based on Liquid Crystal Elastomers (LCEs) for advanced strategic applications. LCEs are a class of smart materials that combine the anisotropic properties of liquid crystals with the elasticity of polymer networks, enabling them to convert light energy directly into mechanical motion. Liquid crystalline elastomers (LCEs) are cross-linked polymer networks that combine the elastic properties of elastomers (rubber) with the anisotropic properties of liquid crystals (LC's). LC mesogens allow homogeneous molecular alignment across large scales due to their self-assembling properties, while polymer chains support the conformation. The co-existence of the characteristics of LC materials, elastomers and photo-sensitive dyes in a single system makes LCEs functional soft materials that can be controlled by light.

Role of optical sensors in healthcare

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Optical sensors have emerged as a transformative technology in modern healthcare, offering non-invasive, highly sensitive, and real-time monitoring of physiological and biochemical parameters. These sensors operate by detecting changes in light properties such as intensity, wavelength, phase, or polarization as light interacts with biological tissues, fluids, or analytes. Advances in photonics, microelectronics, and nanotechnology have significantly enhanced the performance, miniaturization, and affordability of optical sensing systems, enabling their widespread adoption in clinical and point-of-care applications. In healthcare, optical sensors are extensively used for vital sign monitoring, including pulse oximetry, heart rate, and respiratory rate measurement, as well as for biochemical sensing such as glucose, oxygen, and pH levels. Emerging applications include wearable and implantable optical sensors for continuous health monitoring, optical biosensors for early disease detection, and imaging-based sensors for diagnostics and therapeutic guidance. Techniques such as spectroscopy, fluorescence, surface plasmon resonance, and fiber-optic sensing have further expanded the scope of optical sensing in personalized medicine and tele-health. Despite their advantages, challenges remain in terms of signal interference, calibration, long-term stability, and integration with digital health platforms. Ongoing research focuses on improving sensor robustness, data accuracy, and interoperability with artificial intelligence and Internet of Things technologies. Overall, optical sensors represent a key to enabling technology in healthcare, with the potential to improve diagnostic accuracy, enhance patient monitoring, and support the shift toward preventive and personalized medical care.

From Photonic Signals to Actionable Intelligence: Designing AI-Enabled Clinical Decision Pathways for Translational Imaging

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Biophotonics has rapidly evolved as a cornerstone of next-generation diagnostics, offering high-resolution optical and spectral signatures capable of detecting disease states far earlier than conventional clinical modalities. Yet despite these advances, a critical translational gap persists: photonic data, while scientifically rich, frequently remains disconnected from clinical decision-making pathways that are essential for real-world impact. As healthcare organizations and payer ecosystems increasingly adopt artificial intelligence, intelligent automation, and digital modernization frameworks, the opportunity to integrate biophotonic outputs into scalable, AI-enabled clinical workflows becomes both feasible and urgent. This presentation introduces a comprehensive framework for transforming raw photonic signals into actionable intelligence through the design of AI-enabled clinical decision pathways. Drawing from experience in enterprise transformation, AI implementation, predictive modeling, and automation strategy, the session explores how machine learning pipelines can be engineered to derive interpretable risk stratification, diagnostic support, and triage insights from complex optical datasets such as hyperspectral imaging, fluorescence signatures, Raman spectra, and OCT-derived biomarkers. Additionally, the talk examines the operational and technical infrastructure required to deploy these capabilities in real-world environments, including intelligent process automation, low-code workflow orchestration, interoperability with EHR and payer systems, and alignment with regulatory and clinical quality requirements. Emphasis is placed on trustworthiness, transparency, model governance, and workflow safety—critical components for adoption at enterprise scale. By uniting translational biophotonics with AI-driven workflow enablement, this framework offers a pathway for accelerating early disease detection, improving diagnostic precision, and embedding photonics insights directly into the clinical and operational fabric of healthcare. This talk presents a roadmap for realizing the full translational promise of biophotonics by enabling seamless, automated, and clinically aligned decision support.

Bio-mimicking Diatoms to Simulate Natural Terahertz Material

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Diatoms represent one of the most versatile photonic architectures found in nature. They demonstrate plasmonic behaviour due to their unique nano- and micro-structured silica shells, which enhance optical resonance and light trapping. These shells also permit metal deposition within their pores, further strengthening their plasmonic properties. The frustules, along with their metal composites and hierarchical structures, make diatoms an intriguing yet relatively unexplored class of natural photonic materials. Electromagnetic waves with wavelengths comparable to diatom dimensions fall within the terahertz (THz) range. In this study, diatom structures are bio-mimicked using CST simulation software and subjected to terahertz radiation in the range of 1–5 THz to investigate their absorption behaviour. The effects of variations in diatom dimensions, pore diameter, and in-situ metal deposition are systematically analysed. The results reveal distinct absorption peaks within the THz range, which are tunable through dimensional variation. Furthermore, absorption intensity increases with both in-situ metal deposition and enlargement of frustule pore diameter. These findings indicate the strong potential of diatoms as naturally occurring, tunable terahertz absorbers.

Integrated photonics for biomedical applications

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Quantum information science has strong potential to revolutionize different sectors of science and technology, with applications ranging from communication, computation, finance as well as healthcare. In this talk, I will give an overview of quantum optical technologies and demonstrate how basic tools of quantum optics and integrated photonics can be used to enhance the performance metrics of existing bioimaging techniques.

Computational Phase Microscopy using Transport of Intensity Equation

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Quantitative phase imaging (QPI) through the Transport of Intensity Equation (TIE) has emerged as a powerful label-free, non-interferometric approach to phase retrieval in computational microscopy. Optical microscope

measures the intensity information, while phase information provides much more information about the object. In this manuscript, we present computational phase retrieval using transport of intensity equation, using single-shot acquisition techniques and optimization-based methodologies. Experimental results provide the effectiveness of this method as compared to standard FFT-based methods. Optimization based single shot methodology demonstrates significant potential for real-time phase imaging applications in biomedical microscopy, materials characterization, and optical testing.

Ultrasensitive Detection of Mycobacterium tuberculosis Cells Using a Smartphone

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Towards Tera-Voxel Multiview Expansion Tomography

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AI-Driven Quantitative Assessment of Collagen Remodelling in Histopathology

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Novel 2D Materials: Synthesis and Applications

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Single Benzene Fluorescent Dyes for Bioimaging Applications - A Journey from Academia to Entrepreneurship

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Recent Advances in Precision Medicine and Cancer

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Recent Advances in Biophotonics Research

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ABSTRACTS

POSTER PRESENTATIONS

Smart, Wearable and AI-Enabled Biophotonics

[S01] Design of a paper-based wearable microextraction patch for monitoring of volatile metabolic profiling in psoriasis before and after Ayurvedic treatment

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Psoriasis is a chronic, immune-mediated skin disorder characterized by keratinocyte hyperproliferation and systemic inflammation, often co-occurring with comorbidities such as psoriatic arthritis, nail psoriasis, and metabolic syndrome. Despite its high global prevalence, the clinical heterogeneity of psoriasis poses challenges for early diagnosis and therapeutic monitoring. Here, paper-based thin-film solid-phase microextraction patches were developed for immobilizing the volatile metabolites from the skin surface of a psoriasis patient. The patches were fabricated on a glass fiber substrate with a hydrophilic-lipophilic balanced coating and polydimethylsiloxane particles. After sampling from psoriasis-affected skin, the patches were desorbed using triple quadrupole gas chromatography–mass spectrometry equipment for the identification of volatile metabolites. The study was conducted on a patient diagnosed with plaque psoriasis, psoriatic arthritis, and nail psoriasis, before and after five days of Ayurvedic Virechena therapy. Several volatile compounds were observed to show a significant decrease after treatment, potentially indicating reductions in oxidative stress and inflammatory burden. The VOCs identified included 1-Phenyl-1-propanone, Benzenemethanol-2-nitro, 1,4-Benzenedicarboxaldehyde, 1-Nonanol, Pentane-3,3-dimethyl, and D-Mannotetradecane-1,2,3,4,5-pentaol. This study demonstrated the feasibility of using a simple glass fiber-based microextraction patch for non-invasive monitoring of metabolite changes during Ayurvedic treatment. This technique may be helpful in the future to monitor the efficacy of psoriasis treatment and improve patient health.

Keywords: Wearable sensor, TF-SPME, Psoriasis, Non-invasive screening, Metabolomics

[S02] Aedes mosquito detection from surveillance images using YOLOv12 integrated with IDX

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Mosquitoes are the most significant vectors of human diseases, with Aedes aegypti and Aedes albopictus playing central roles in the transmission of dengue, Zika, chikungunya, and other illnesses. Accurate identification of these species is critical for effective surveillance and control, yet traditional methods such as morphological examination and molecular analysis are time-consuming, error-prone, and resource-intensive. Recent advancements in computer vision have introduced automated frameworks such as Identification-X (IDX), which leverage optical imaging for scalable mosquito recognition. However, IDX's reliance on rule-based classification limits its generalization to new regions and diverse species. Deep learning-based detection models, particularly the YOLO (You Only Look Once) family, have demonstrated state-of-the-art performance in real-time insect detection. Building on this progress, we propose a hybrid framework that integrates YOLOv12 with IDX for the detection of Aedes mosquitoes within groups of moving insects. YOLOv12 enhances feature extraction, multi-scale learning, and fine-grained classification, while IDX contributes standardized imaging, verification, and dataset expansion. Together, this integration supports robust and scalable surveillance, enabling rapid species identification even in complex field environments. The proposed approach has the potential to improve outbreak prediction with 98.25% accuracy, guide targeted vector control, and reduce the operational burden of traditional surveillance, thereby strengthening public health responses against vector-borne diseases.

Keywords: Real-time mosquito detection, Aedes, Moving object detection, YOLOv12, IDX

[S03] Feature-Enriched Stacked Ensemble Learning for HER2+ Breast Cancer Tissue Image Classification

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Accurate determination of HER2 status remains essential for breast cancer diagnosis and treatment planning, as it guides the use of targeted therapies such as trastuzumab. Traditional immunohistochemistry (IHC) and in situ hybridization (ISH) assays, while effective, are labor-intensive, subjective, and resource heavy. Computational analysis of histopathology images offers a promising, objective alternative. However, convolutional neural network (CNN)-based approaches typically require extensive annotated data, GPUs, and high computational demands, hindering clinical deployment. This study presents a feature-based stacked ensemble framework for HER2 classification from H&E-stained whole-slide images across Yale and TCGA-BRCA cohorts. Handcrafted features—including GLCM texture statistics, local binary patterns (LBP), color histograms, and histogram of oriented gradients (HOG) were used to capture diagnostic morphological patterns from extracted tissue tiles. Three optimized XGBoost variants (Tree, RF, DART) formed the base learners, with SMOTE oversampling applied within stratified cross-validation folds to address class imbalance without data leakage. Furthermore, rather than relying on a single classifier, out-of-fold probability estimates from each base learner were generated through stratified cross-validation and combined to form a meta-level training set. A lightweight meta-classifier was subsequently trained to optimally integrate the predictions of the base models, resulting in a robust stacked ensemble. The experimental results demonstrate that the stacked ensemble achieves competitive performance compared to traditional CNN-based pipelines, while requiring substantially lower computational overhead and offering improved interpretability. These findings indicate that feature-based stacked ensemble

learning provides a practical, data-efficient, and transparent alternative to deep learning approaches for HER2 breast cancer classification.

Keywords: HER2 breast cancer, Histopathology image analysis, Stacked ensemble learning, Class imbalance handling, Machine Learning

[S04] High-Fidelity Generative Diffusion Models for Multimodal Translation in Brain Tumour Imaging: Bridging Radiology and Translational Biophotonics

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High-grade gliomas, representing most primary CNS malignancies, exhibit 85– 95% mortality within 1–2 years when diagnosis is delayed [6]. Manual detection from Magnetic Resonance Imaging (MRI) images is challenging for radiologists due to the heterogeneous nature of tumour cells. As such, the introduction of Ma- chine Learning (ML) and Deep Learning (DL) techniques in healthcare has proven useful in facilitating the study of intricate cell patterns, thereby furthering early tumour detection. Current approaches require sequential acquisition of multiple scans (T1-weighted and T2-weighted label-free biophotonic images), which has the potential for clinical inefficiencies and causes patient burden. Our approach, therefore, seeks to introduce a high-fidelity computational framework that leverages Denoising Dif- fusion Probabilistic Models (DDPMs) for cross-modality image translation in brain tumour imaging. This approach reframes the medical imaging process through iterative denoising that preserves structural integrity and tissue relation- ships in unpaired T1↔T2 MRI translation; unlike conventional DL generative net- works that produce anatomically implausible hallucinations. This proposed methodology extends directly into Translational Biophotonics through three mechanisms: virtual staining of label-free optical signals, ad- vanced denoising of scattered photoacoustic and endoscopic data, and seamless fusion of biophotonic molecular maps with radiological anatomical frameworks. Upon training the Diffusion model using

the RSNA-MICCAI Brain Tumour Radio- genomic Classification dataset, preliminary quantitative evaluation of the frame- work yields a training loss of 0.0059, with Structural Similarity Index (SSIM) and Peak Signal-to-Noise Ratio (PSNR) values of 0.0321 and 11.70 dB, respectively. These metrics, coupled with qualitative visual validation, demonstrate the model's ability to maintain high-fidelity anatomical alignment while synthesizing complex biophotonic markers from label-free structural data. Thus, this reproducible, non- adversarial pipeline lays the groundwork for seamless clinical integration of bio- photonics with radiological workflows, with enhanced diagnostic specificity while eliminating multi-modal acquisition demands and minimizing patient burden.
Keywords: Diffusion models, brain tumour imaging, multimodal translation, virtual staining, bio- photonics.

[S05] Comparative Assessment of Model-Based and Machine Learning Methods for Time-lapse Fluorescence Image Segmentation of Tissue

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Biological tissues exhibit autofluorescence due to inherently occurring fluorophores; however, prolonged illumination leads to photobleaching that reduces fluorescence intensity over time. This decay is generally undesirable in fluorescence-based studies, as it destabilizes signal intensity and degrades image quality. Nevertheless, the autofluorescence photobleaching dynamics can provide valuable information about the biochemical microenvironment, as they reflect signatures of altered concentrations of endogenous fluorophores (NADH, FAD, and protoporphyrin) along with tissue optical properties such as absorption and scattering. Thus, these photobleaching dynamics may serve as a potential

biomarker for tissue characterization and abnormality detection. In order to explore this, multi-wavelength time lapse images were acquired from normal and abnormal breast tissues at emission wavelengths of 460nm (NADH), 525 nm (FAD), 555nm (lipofuscin), and 620 nm (protoporphyrin) with 405 nm excitation. The observed fluorescence decay pattern is primarily governed by the excitation power, fluorophore concentration, and the tissue optical properties including the distribution and concentration of scatterer and absorbers. For extracting discriminative parameters over different tissue categories, two approaches, one conventional model-based and the other state-of-the-art machine learning based, were used. In the model-based approach, a double exponential decay function was employed to generate parametrically segmented images. In the machine learning based approach, semantically segmented images using pixel-wise temporal fluorescence decay profiles of each pixel were generated. Finally, a systematic comparison was carried out using the results from both the approaches as input. It was found that the machine learning-based method offered superior performance for image segmentation in time-lapse fluorescence imaging highlighting the potential of autofluorescence photobleaching dynamics as a robust biomarker for tissue characterization.
Keywords: Fluorescence photobleaching, time-lapse imaging, machine learning, parametric segmentation, semantic segmentation

[S06] Investigation of Starch Elastomers Crosslinked with Citric Acid and Enhanced with Silicon Dioxide Using Raman Spectroscopy

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Thermoplastic starch (TPS) is a bioplastic obtained from renewable starch-based sources such as potato, corn, or tapioca starch. Benefits of TPS include low production costs, environmental compatibility, and biodegradability. However, compared to commonly used petroleum-based

plastics, TPS has limited mechanical properties, characterized by low tensile strength and a low elastic modulus. To overcome the limited mechanical properties, silicon dioxide (SiO_2) serves as a reinforcing filler, while citric acid acts as a widely utilized crosslinking agent. SiO_2 improves film smoothness and mechanical strength of TPS. Although, at high concentrations, SiO_2 causes aggregates on the films, which causes elastomer brittleness. Citric acid, by ester bond linkages with starch, forms an even surface on films and vastly improves the mechanical strength of TPS films. Raman spectroscopy is a non-destructive vibrational spectroscopic technique that provides data on structural differences, bonding, and the electronic environment of a sample. In this study, a confocal Raman spectroscopic system was employed to analyze and characterize the structural differences of potato starch elastomers when modified with SiO_2 and treated with citric acid in the molecular environments. Successful incorporation of SiO_2 and citric acid was determined by observation of Raman peaks formed by silicon interactions and ester bond formation. Utilizing Raman spectroscopy to characterize modified polymers can lead to the formulation of TPS with enhanced physical and mechanical properties, providing an eco-friendly alternative to petroleum-based plastics with applications in food packaging industry.

Keywords: Thermoplastic starch, Raman Spectroscopy, biodegradable, citric acid, silicon dioxide

[S07] Machine Learning integrated Two-Photon Microscopy for Image Analysis of Prostate Cancer Tissue Images

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Prostate cancer diagnosis requires accurate tissue classification to distinguish between healthy and diseased specimens. Traditional histopathological methods are subjective and time-consuming, thus necessitating automated approaches for reliable

cancer detection. So, the objective was to develop an automated classification system for prostate cancer tissues using two photon microscopy combined with machine learning techniques for enhanced diagnostic accuracy. Prostate cancer tissue samples, including both healthy and diseased specimens, were imaged using second harmonic generation (SHG) and two-photon fluorescence (TPF) microscopy. The images in the dataset were first converted into greyscale. The grayscale images were then subjected to a sequence of image filtering techniques where histogram equalisation was selected based on superior structural feature enhancement. Key textural features such as Contrast, Correlation, Energy, Homogeneity, Dissimilarity, and Angular Second Moment (ASM) of the images were extracted using the GLCM algorithm and complied. Class imbalance in the dataset was addressed using the Synthetic Minority Over-sampling Technique (SMOTE). Machine learning classification was performed using supervised algorithms support vector machine (SVM) and XGBoost. The histogram equalization proved most effective for image enhancement among tested preprocessing methods. XGBoost demonstrated superior classification performance compared to SVM for the dataset. Class imbalance was successfully mitigated through SMOTE implementation, which generated synthetic samples for minority classes to achieve balanced distribution. The integrated approach combining multiphoton microscopy, histogram equalization preprocessing, GLCM texture analysis, and XGBoost classification with SMOTE balancing provides a robust framework for automated prostate cancer tissue classification.
Keywords: Multiphoton microscopy, Machine Learning, Texture analysis, Grey Level Cooccurrence Matrix (GLCM).

[S08] A Weakly Supervised Image Translation Framework for Unregistered Paired Microscopy Images

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Deep learning has enabled image-to-image translation by automatically learning complex features and patterns from the data. In microscopy imaging, this capability has enabled domain translation tasks such as virtual staining, image reconstruction, and modality conversion. However, existing

approaches face significant limitations, with supervised methods requiring pixel-wise registered image pairs, while unsupervised methods struggle to preserve the fine structural details critical for microscopy applications. Registration of microscopy images often introduces rigid deformations that compromise morphological integrity and structural content. On the other hand, unsupervised methods frequently introduce artifacts and hallucinations when enforcing cycle consistency. These limitations serve as a motivation to propose a weakly supervised framework that bridges the gap between supervised and unsupervised approaches by leveraging paired unregistered data. The proposed method combines three key components viz. a U-Net generator for image translation, a discriminator to distinguish generated images from real samples, and a siamese network that measures similarity between generated output and a reference set of unregistered images from the target domain. The discriminator and siamese network serve as an optimization objective, guiding the generator to produce translations without requiring precise spatial alignment. The preliminary results on experimental LDIHM (Lens-less Digital Inline Holography Microscopy) reconstruction dataset showed an average PSNR of ~24 dB and SSIM of ~0.78 without extensive hyperparameter optimization. These initial results demonstrate the feasibility of our approach, indicating substantial potential for performance improvement through systematic hyperparameter tuning and training process optimization.

Keywords: Weakly Supervised Learning, Microscopy Image Translation, Unregistered Paired Data, Domain Translation, Deep Learning.

[S09] Physics-Guided Adversarial Learning for Low-Photon Structured Illumination Microscopy Reconstruction

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Structured Illumination Microscopy (SIM) provides a reliable two-fold resolution improvement over conventional wide-field microscopy and is compatible with standard fluorescent probes and imaging protocol, making it a versatile choice for super-resolution live-cell imaging. However, traditional SIM reconstruction performs poorly in low-light conditions due to the requirement for high-intensity, coherent illumination, which exacerbates phototoxicity and photobleaching and thereby limits its applicability to sensitive live samples. To address these challenges, we integrate deep learning techniques with SIM to enhance image quality under low-light conditions while simplifying the system's operational requirements. We propose a novel physics-informed Generative Adversarial Network (GAN) architecture that reconstructs high-fidelity super-resolved SIM images directly from low-light raw patterned frames. This approach bypasses traditional parameter-sensitive Fourier-based methods and enables imaging at significantly reduced illumination intensities. In the proposed GAN architecture, we incorporate an Attention U-Net as the generator backbone and a PatchGAN as the discriminator head. The training incorporates a composite loss function that includes pixel-wise losses (L1 and L2), an adversarial loss, and a physics-based Fourier domain loss to enforce structural fidelity in the frequency domain. The model was trained on microtubule (MT) structures from the BioSR dataset. Performance was evaluated using Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM). For low-contrast (low-Photon) microtubule data, the proposed method achieved a PSNR of 29.68 ± 0.37 dB and an SSIM of 0.8954 ± 0.0295, accompanied by stable convergence of the minimal loss function.

Keywords Structured Illumination Microscopy (SIM), Physics Loss, Generative Adversarial Network (GAN)

[S10] Physics-Informed Machine Learning for Virtual Staining of Unlabeled Oral Tissue: A Preliminary Study

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Conventional histochemical staining remains the gold standard for oral tissue diagnostics but faces significant limitations including prolonged turnaround times (24-48 hours), chemical reagent consumption, and staining variability. Recent advances in deep learning-based virtual staining have demonstrated promising results by generating computational H&E equivalents from label-free imaging modalities, yet most approaches lack mechanistic grounding and exhibit poor generalization across diverse tissue samples. This preliminary review synthesizes key literature on virtual staining methodologies and evaluates the potential of physics-informed machine learning (PIML) as a theoretically robust framework for computational histopathology of oral tissues. A comprehensive literature review was conducted across peer-reviewed databases (PubMed, Scopus, Web of Science, Embase) covering (1) virtual staining techniques and generative adversarial network (GAN) architectures, (2) physics-informed neural networks (PINNs) in biomedical imaging, (3) tissue biophysics and fluorescence lifetime imaging (FLIM) principles, and (4) label-free imaging systems compatible with oral tissue specimens. Evidence demonstrates that purely data-driven virtual staining achieves 85-92% structural similarity (SSIM) with ground-truth H&E but exhibits substantial failure modes in out-of-distribution tissue samples. In contrast, physics-informed approaches incorporating tissue biophysics (light-matter interactions, fluorophore properties, morphological priors) show 8-12% performance improvement in generalization metrics and significantly enhanced interpretability. The mechanistic integration of optical physics and neural networks provides a principled pathway for robust virtual staining while reducing data requirements. This preliminary review establishes physics-informed machine

learning as a promising framework for virtual oral tissue staining, warranting systematic investigation through controlled proof-of-concept studies. The integration of biophysical constraints offers substantial advantages over conventional deep learning for achieving clinically viable, interpretable, and generalizable computational histopathology systems.
Keywords: virtual staining, physics-informed machine learning, oral histopathology, label-free imaging, computational pathology

[S11] Phase Unwrapping using Physics Informed Deep Neural Network

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This work attempts to build a unified and robust deep learning model based on Physics informed loss function. Although there are a handful of studies in literature for deep learning assisted phase unwrapping, Physics informed model for the same is yet to investigated. In this proposed model, we implement Poisson equation relating the unwrapped phase to the divergence of wrapped gradients for phase unwrapping problem while taking into account the integer correction defined as multiplicity factor of 2π between wrapped and unwrapped one. This Physics informed deep learning networks is based on six deep learning models viz. MobileNetV3, ResNet50, EfficientNetB7, VGG19 and DenseNet121-UNet and a simple U-Net networks incorporating the loss due to fitting the Poisson equation as well as the integer correction loss and gradient loss as Physics aware networks. PSNR and SSIM are also evaluated to compare the models. 32 dB PSNR and SSIM value of 0.24 are obtained from the efficiently worked MobileNetV3 model.
Keywords: PIDNN, Poisson loss, gradient loss, integer correction loss, PSNR, SSIM

[S12] Bismuth-Doped ZnO Nanorods for Radioactive Iodine Sensing Toward Wearable and Point-of-Care Applications

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Radioactive iodine, particularly iodine-131 (I-131), is widely used in nuclear medicine for diagnostic and therapeutic applications. Necessitating effective radioactive iodine monitoring strategies to ensure radiation safety and environmental protection. Zinc oxide (ZnO) nanostructures are promising sensing materials due to their high surface-to-volume ratio and favorable electrochemical properties for Iodine. In this work, we have reported the synthesis of bismuth-doped ZnO nanorods via a facile hydrothermal method for radioactive iodine detection, with relevance to wearable and point-of-care (PoC) monitoring applications. Bismuth doping ratios were varied to investigate the influence of dopant concentration on structural and electrochemical behavior. X-ray diffraction (XRD) analysis confirmed the hexagonal wurtzite structure of ZnO with a dominant (002) preferential orientation. Electrochemical characterization was performed using cyclic voltammetry (CV) on pristine and Bi-doped ZnO nanorods to establish their baseline electrochemical response toward iodine species. CV measurements carried out in potassium iodide (KI) solutions demonstrated stable and reproducible electrochemical behavior over successive cycles, confirming reliable baseline performance. The characterizations highlight the influence of bismuth doping in modulating the structural properties of ZnO nanorods for radioactive iodine sensing. Future work will explore surface functionalization of ZnO nanorods with iodide-selective ion exchangers to

improve iodine affinity, selectivity and sensing performance for wearable and portable PoC radioiodine monitoring. This work is useful for effective electrochemical detection of radioactive ions in environment and safety monitoring.

Keywords: Radioactive iodine, sensor, bismuth-doped ZnO, nanorods

[S13] Development of a cost-effective paper-based sampling kit for fast identification of *Klebsiella pneumoniae* bacterial pathogen

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Pneumonia caused by bacterial pathogens and antibiotic resistance is a major cause of morbidity and death in India, particularly in immunocompromised patients. The rise of carbapenem resistance in *Klebsiella pneumoniae* strains poses a significant challenge in clinical settings, resulting in unnecessary antibiotic use, primarily due to the shortcomings of existing diagnostic tests. In this study, we developed a disposable paper-based microextraction sampling patch for the detection of *Klebsiella pneumoniae* bacterial species. These patches were fabricated on a simple A4 sheet of cellulose paper with a coating mixture of mesoporous divinylbenzene and MXene particles. Elcometer, an automatic film applicator, was utilized to ensure a uniform coating on paper strips. The developed patches are cost-effective due to

utilization of regular paper sheets and laboratory-synthesised coating materials. The patches were validated with the McReynolds standard, and several operational parameters were optimized through mass spectrometry-based experiments. Later, the fabricated paper-based patches were exposed directly to the culture medium of *Klebsiella pneumoniae* (ATCC 13883) to extract bacteria-emitted metabolites and simultaneously introduced into a mass analyser for analysis of *Klebsiella pneumoniae*-emitted metabolites. We observed some unique metabolites associated with *Klebsiella pneumoniae,* including 2-pentanone, indole, tetradecane, and benzene acetaldehyde, as identified in the *in vitro* study. The Blue Applicability Grade Index score (BAGI: 72.5) confirmed the greenness of this method due to its minimal solvent consumption. Therefore, this study may provide an alternative and rapid approach for identifying *Klebsiella pneumoniae*-associated respiratory infections through metabolic profiling.

Keywords: Thin Film Solid Phase Microextraction, *Klebsiella pneumoniae,* MXene, Bacterial metabolites, Green analytical chemistry

[S14] Injectable ionic crosslinkable hydrogel for articular cartilage reconstruction

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Limited self- renewal capacity of cartilage tissue poses a significant clinical challenge in osteoarthritis (OA). Autologous chondrocyte implantation (ACI) & matrix-induced autologous chondrocyte implantation (MACI) entails a limitation of invasiveness, cost and long-term durability. Other biomaterial scaffolds used currently lack crucial matrix components, which constrains successful regeneration. Moreover, stem cell therapy encounters challenges like unpredictable differentiation. Extensive studies have established the tremendous potential of hydrogels owing to their biocompatibility, similarity to matrix components and excellent property in transport of metabolites & nutrients in cartilage tissue engineering. Over the past decades, injectable

hydrogels have become a focal point in soft tissue engineering. This is due to their minimal invasive application which eliminates extensive surgical procedures and infections accompanied by these interventions. Additionally, their ability to conform desired shape enable in healing of the wound. Kappa-carrageenan is a linear, sulphated, hydrophilic polysaccharide, consisting of disaccharide repeat units of galactose and (3,6)-anhydrogalactose connected by alternating α-(1,3)- and β-(1,4)-glycosidic links. It forms a hydrogel network by two crosslinking mechanisms- ionic (K+). We explored this potential to develop an ionic crosslinked kappa-carrageenan based injectable hydrogel for articular cartilage reconstruction. In this study, we considered the mechanical stability, rheological properties and biocompatibility of the fabricated injectable ionic crosslinked hydrogel achieving a modulus of 31 ± 3.0 kPa and rheological analysis demonstrated shear thinning property, making it injectable. Furthermore, the storage modulus (G') exceeded loss modulus(G") at all frequencies with various combination of ionic concentrations confirmed its suitability for cartilage reconstruction. The biocompatibility of this hydrogel support cell survival, proliferation and integration with native tissue. Together, these properties make this injectable dual-crosslinkable hydrogel a promising candidate for cartilage regeneration and trauma.

Keywords: Injectable hydrogel, ionic crosslinking, Kappa carrageenan, Articular cartilage reconstruction

[S15] A Flexible Adhesive SERS Platform for Rapid On-Site Detection of Pesticide Residues

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Pesticide contamination on fruits and vegetables continues to raise serious concerns for food safety and public health, necessitating rapid and on-site analytical solutions. In this study, we present a flexible, adhesive tape-based surface-enhanced Raman spectroscopy (SERS) substrate for direct detection of pesticide residues under real-field conditions. The platform is fabricated by immobilising silver nanopopcorns (AgNPCs) onto a commercially available adhesive tape, forming AgNPCs@Tape. Due to its inherent adhesive property, the substrate enables a simple press-and-lift sampling approach, allowing for the efficient transfer of pesticide residues directly from produce surfaces without any sample pretreatment. The developed SERS substrate exhibits excellent signal uniformity, reproducibility, and long-term stability, ensuring reliable analytical performance. The high density of electromagnetic hot spots generated by AgNPCs results in a low detection limit of 10^{-9} M with a strong enhancement factor. The combination of low cost, portability, mechanical flexibility, and user-friendly operation makes this tape-based SERS substrate a promising tool for rapid, on-site pesticide screening and food safety monitoring.

Keywords: Pesticides, Surface Enhanced Raman Spectroscopy (SERS), Silver Nanopopcorn, Enhancement factor, Adhesive tape.

[S16] Flexible AgNPs-Decorated Aluminium Tape SERS Platform for On-Site Detection of Pharmaceutical Analytes

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Surface-enhanced Raman spectroscopy (SERS) is an ultra-sensitive analytical technique capable of capturing the vibrational fingerprint of diverse analytes in bioanalysis, environmental monitoring, and food safety. Despite its potential, the practical use of SERS is often limited by the poor uniformity, low reproducibility, and limited stability of conventional substrates. In this work, we introduce a simple, cost-effective, and efficient SERS substrate prepared by depositing silver nanoparticles (AgNPs) onto a commercially available aluminium (Al) template. The Al surface was chemically treated to create a uniform, porous, and roughened structure that enhances nanoparticle anchoring and hotspot generation. The resulting AgNPs@Al substrate integrates the strong plasmonic activity of Ag with the mechanical flexibility and thermal stability of the treated Al template. Using this substrate, we

achieved low-level detection of sulphur and non-sulphur containing antibiotic residues. This robust and field-deployable platform offers a practical approach for rapid, on-site antibiotic screening.
Keywords: Surface-enhanced Raman spectroscopy, Silver nanoparticles, Antibiotics, Aluminium

[S17] In Silico Structural Omics of Starch–Amylase Interactions: Docking and Molecular Dynamics Insights into Early Digestive Processing

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Digestion begins with the recognition and cleavage of starch by α-amylase enzymes, and the structural diversity between amylose and amylopectin plays a key role in determining early digestive behavior. This work utilises an extensive computational workflow to explore how two starch types-linear amylose: Starch A (α-1,4 linked), and branched amylopectin: Starch B (containing α-1,6 branching)-interact with four key digestive α-amylases: human pancreatic (1HNY), human salivary (1MFU), porcine pancreatic (3L2L), and Bacillus subtilis α-amylase (1BAG). Both starch types were modeled using GLYCAM-based carbohydrate tools and docked into the enzyme's catalytic clefts using AutoDock Vina and CB-Dock2. Based on docking analysis, the amylose starch consistently showed better binding scores and was compactly fitted into the catalytic pockets, aligning well with established principles that linear α-1,4 glucans align more effectively within α-amylase grooves. CHARMM-GUI-based system preparation and GROMACS simulations of 300 ns resulted in approximately stable thermodynamics, well-preserved protein compactness, and low RMSF of catalytic-site residues for all enzyme–starch complexes. Ligand RMSD analyses revealed that amylose maintained a tight, stable orientation during the trajectory, while amylopectin, owing to its α-1,6 branch, sampled a broader range of conformations while remaining securely bound, consistent with reported structural mobility and enzyme accessibility differences. Overall, the findings demonstrate that starch linkage architecture significantly

affects binding stability and dynamic behavior in the early steps of enzymatic hydrolysis. The methodological in silico approach presented here offers a structural-omics framework to elucidate digestion-related molecular interactions at atomistic resolution and may thus be applied to other areas of enzymology, food science, and health-omics research.
Keywords: Structural omics, Starch digestion, Alpha-Amylase, Molecular docking, Molecular dynamics, Computational biology.

[S18] Polyethylene Glycol-Functionalized MXenes for Enhanced Photocatalytic Degradation of Organic Pollutants

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MXene a two dimensional layered material with high metallic conductivity and rich surface chemistry with its wide range of applications including photocatalysis. In this study, Polyethylene glycol–functionalized MXene (PEG@MXene) was developed as an efficient photocatalytic material for the degradation of cationic dyes/organic water pollutants under solar irradiation. The incorporation of polyethylene glycol enhances the aqueous dispersibility and structural stability of MXene nanosheets while preserving their intrinsic surface chemistry and catalytic activity. The PEG@MXene photocatalyst exhibits rapid degradation kinetics, achieving approximately 90% removal of representative cationic dyes within 30 min of solar light exposure, demonstrating significantly improved performance compared to unmodified MXene. The enhanced photocatalytic efficiency is attributed to improved surface accessibility, suppressed nanosheets aggregation, and strengthened interactions between the pollutant molecules and the PEG-stabilized MXene surface. The catalyst maintains stable performance over multiple reuse cycles, indicating good durability under photocatalytic operating conditions. The results highlight the effectiveness of polymer functionalization as a strategy to improve MXene-based photocatalyst for solar-driven water treatment.
Keywords: Photocatalysis, MXene, cationic dyes, degradation

[S19] Green-Synthesized Silver Nanoparticles from *Portulaca oleracea* L. as a DNA-Based Diagnostic Platform for Chromosomal Abnormalities

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Early diagnosis of chromosomal abnormalities, particularly Down syndrome (trisomy 21) and Turner syndrome (monosomy X), remains challenging due to the high cost, technical complexity, and limited accessibility of conventional cytogenetic techniques. Our study aims to synthesize silver nanoparticles using both a traditional chemical reduction method and a green approach employing *Portulaca oleracea* (L.) extract, and to evaluate their physicochemical characteristics and potential application as a DNA-based diagnostic tool for detecting chromosomal abnormalities. The synthesized nanoparticles were analyzed to assess their optical properties, size, morphology, crystallinity, and colloidal stability. Both methods of synthesis resulted in nanoparticles exhibiting characteristic surface plasmon resonance and phytochemical capping, confirming successful reduction and stabilization as confirmed by their UV-Vis peak at ~400 nm and strongly negative zeta potential values. The chemically synthesized nanoparticles were subsequently lyophilized and subjected to FTIR (Fourier Transform Infrared Spectroscopy), XRD (X-ray Diffraction), and electron microscopy analyses, revealing impurities and indicating the requirement for further purification. Further standardization and optimization of the green synthesis protocols will be required to achieve improved nanoparticle stability, size, and reproducibility, thereby enabling their development as rapid, sensitive, and cost-effective diagnostic platforms for the detection Down syndrome, Turner syndrome and other such chromosomal aberrations.

Keywords: Silver nanoparticles (AgNPs), *Portulaca oleracea*, Chromosomal abnormalities, Diagnostics, Cost-effective

[S20] Optical detection of Cadmium using Polypyrrole/BCN/Carbon quantum dot composite

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Heavy metals are metals with density greater than 5g/cm^3. Even though these metals are found naturally in the environment, anthropogenic activities such as mining, disposal of industrial waste and application of chemical fertilizers or pesticides introduce significant number of heavy metals into the environment. There are more than 40 heavy metals present out of which Cadmium (Cd) is considered one of the most toxic metal whose permissible amount in water is 3 ppb. The continuous exposure of the Cd for longer duration can cause serious health problems such as cancer, gastrointestinal problems etc. Hence there is an increase in need for detection of Cd. In the present work, fluorescence spectroscopy was employed for detection of Cd using Polypyrrole/BCN/Carbon quantum dots-based composite. The composite showed a good linear correlation with R^2= 0.916 and Limit of detection was found to be 2.51 nM.

Keywords: Cadmium, Fluorescence, Polypyrrole, Quantum dots, composite

[S21] Synthesis of CQDs from plant-based materials for antibiotic sensing

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Carbon quantum dots (CQDs) are nanoscale carbon-based materials known for their excellent biocompatibility, strong photoluminescence, and chemical stability, making them attractive for applications in sensing, drug delivery, bioimaging, and optoelectronics. In this study, CQDs were synthesized from plant-based biomass source namely *Tectona grandis (*teakwood*)*, *Artocarpus heterophyllus* (jackfruit), and *Hibiscus rosa-sinensis* (hibiscus), using a

sustainable, one-pot pyrolysis method and further evaluate for its potential in antibiotic sensing. The synthesis strategy utilizes readily available natural precursors, highlighting the prospective for cost-effective and environmentally friendly nanomaterial synthesis. The synthesized CQDs were extensively characterized for their optical, structural and morphological properties using UV-visible spectroscopy, dynamic light scattering (DLS) and Fourier transform infrared spectroscopy (FTIR). All three CQDs exhibited strong blue fluorescence with an emission maximum at 380 nm and demonstrated excellent stability under different pH, temperature and storage conditions. Particle size analysis confirmed monodisperse nanostructures with hydrodynamic diameters in the range of approximately 1-100 nm. FTIR analysis revealed the presence of surface functional groups, including carboxyl (-COOH), hydroxyl (-OH), and ether (C-O-C) moieties derived from the plant biomass. Photophysical investigations revealed strong excitation-dependent fluorescence behaviour and effective interactions between the CQDs and the antibiotics gentamycin and kanamycin. The CQD- based sensor exhibited high sensitivity toward these antibiotics, achieving detection limits in the nanomolar range. These findings highlight the potential of biomass-derived CQDs as robust and sensitive fluorescent probes for antibiotic detection, enhancing their application in biosensing platforms.

Keywords: Carbon quantum dots (CQDs), Plant-based biomass, Antibiotic sensing, Photoluminescence, Fluorescent probes.

[S22] Introducing C.H.R.I.S.T Lab-Additive Manufacturing & Coating Driven Devices: C.O.R.E

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The C.H.R.I.S.T Laboratory (Coatings and Heterostructure Research in Innovative Sensors and Thin Films) is established as an interdisciplinary research space dedicated to the design, fabrication, and validation of next-generation flexible biosensors and thin-film devices for applications in healthcare diagnostics, energy systems, and food quality and safety monitoring. The laboratory addresses a key gap between materials discovery and deployable sensor technologies by focusing on additive manufacturing and coating-based approaches that enable scalable, low-cost, and application-specific device fabrication. Core research activities center on the development of functional inks, coatings, and heterostructured thin films based on metal oxides, carbon nanomaterials, polymers, and hybrid nanocomposites. These materials are processed using extrusion-based additive manufacturing and related deposition strategies to achieve precise control over film thickness, interfacial chemistry, and microstructure. Such control is critical for realizing flexible and wearable sensor platforms that exhibit high sensitivity, mechanical compliance, and stable performance under bending, thermal cycling, and prolonged operation. Target applications include non-invasive biosensors for healthcare monitoring, printed and coated sensors for environmental and food safety assessment, and energy-aware sensing platforms that support low-power or self-powered operation.The C.H.R.I.S.T lab provides shared experimental infrastructure accessible to both internal researchers and external collaborators. Available facilities include refrigerators for material and sample storage, centrifuges, vortex mixers, hot air ovens, precision weighing scales, ultrasonication systems, and magnetic stirring hot plates for ink and coating preparation. These are complemented by an extrusion-based printing system for fabricating coated films, patterned sensors, and flexible device prototypes, enabling an end-to-end workflow

from material synthesis to device realization. The laboratory actively collaborates with eminent scientists and research groups at Binghamton University (USA), the University of Jaffna (Sri Lanka), Saveetha Engineering College, Manipal Academy of Higher Education, CRMIT, and HORIBA. The C.H.R.I.S.T lab remains open to new academic and industrial collaborations and actively seeks motivated faculty members, researchers, and students to contribute to its growing ecosystem in coatings, heterostructures, and additive manufacturing-driven sensor technologies.
Keywords: Flexible Electronics, Wearable Sensor, Microbial Coatings, Additive Manufacturing, Printable Antenna.

[S23] Modified Chitosan Coated Fabrics for Biophotonic Applications in Healthcare Industry

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Chitosan, a biopolymer derived from chitin, is widely used in biomedical and healthcare applications due to its biocompatibility, biodegradability, and non-toxicity. When applied as a coating on textiles, it provides antibacterial activity, supports hemostasis, and promotes tissue regeneration, making it suitable for sweat sensors, wound dressings, and surgical textiles. Chitosan coatings on cotton fabrics, enhanced with lauric incorporation via methods with and without coupling agents and crosslinkers, further improve antibacterial efficacy and water-repellency. Chitosan (CS) and lauric-chitosan (L-CS) were characterized by Fourier Transform Infrared Spectroscopy (FTIR), Powder X-ray Diffraction (pXRD) and Thermogravimetric Analysis (TGA); CS showed a characteristic FTIR band at 1587 cm^{-1} for -NH bending of the primary amine, while L-CS exhibited a peak near 1640 cm^{-1} corresponding to amide -C=O stretching vibrations. CS and L-CS coatings were applied using crosslinking agents through the pad dry cure method.

Antibacterial activity of CS and L-CS coated fabrics were assessed against *E. coli* and *S. aureus* using well diffusion, disk diffusion, and colony counting techniques. Both chitosan and lauric-chitosan demonstrated clear inhibition zones against *E. coli* (*i.e.,* CS-11.70 mm and L-CS-12.30 mm) and *S. aureus* (*i.e.,* CS-12.70 mm and L-CS-12.00 mm), and colony counting confirmed the antibacterial effectiveness of the coated materials. Water repellency test using the AATCC 22 method indicated that the coated fabrics exhibited higher water repellency ratings (*i.e.,* Unmodified – 0, CS – 50, and L-CS – 70), while contact angle measurements of some samples nearing super-hydrophobicity (*i.e.,* L-CS – 138.70°). Future studies may explore on chitosan-coated fabrics with plasmonic nanoparticles for non-invasive wound and skin monitoring via optical signals without dressing removal. Furthermore, incorporating these hydrophobic coatings into asymmetric hydrophilic-hydrophobic structures in biophotonic platforms can reduce sweat evaporation while preserving unidirectional flow, enabling stable, real-time biophotonic sensing of sweat biomarkers.

Keywords: Biophotonics, wound healing monitoring, chitosan dressing, antibacterial, water repellency.

[S24] From Static to Dynamic: Harnessing Protein Conformational Changes for Drug Discovery and Precision Medicine

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Proteins constantly reconfigure themselves for functional reasons, however, the importance of dynamic nature of disease-relevant proteins has been underappreciated in drug discovery. We introduce "Target DynOmics", a platform integrating experimental and MD-simulated conformations of all current FDA drug targets, facilitating efficient discovery of new indications for a given drug. For 857 protein families, we curated representative apo and drug-complexed experimental structures and identified functional residues and cofactors. We performed 1 μs MD simulations and PCA to yield most populated protein conformations, which will be used for purposes including

finding possible repurposing targets (and their corresponding diseases) for 5895 FDA-approved drugs. Here, we present our results of MD-derived conformers for NSP16 from SARS-CoV-2 and DPP4 involved in diabetes. Our 144 drug-complexed protein structures reveal true binding poses of FDA drugs, enabling a log-odds (LOD) score to identify true-binder poses and decoys, leading to the automated drug screening pipeline DRDOCK. DRDOCK calculates specific features for docked poses to derive feature distributions of true-binders and decoys. We trained and validated DRDOCK using datasets derived from the 144 complex structures. In summary, Target DynOmics enables direct use of protein conformers in drug development, providing benchmarks for accurate scoring functions and AI model building.
Keywords: protein conformations, molecular dynamics, new drug indications, automated drug screening

ABSTRACTS

POSTER PRESENTATIONS

LASERS and their Applications

[L01] Design of Optical Sensors to Detect Creatinine by Localized Surface Plasmon Resonance Process

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Creatinine is produced by the body as a waste product due to muscle metabolisms which is excreted by kidney to maintain homeostasis but decrease in kidney function leads to the accumulation of creatinine. Detecting creatinine is crucial for diagnosing chronic kidney disease (CKD). This project proposes an optical biosensor using localized surface plasmon resonance (LSPR) for early, cost-effective with high sensitivity and label-free detection of CKD. An optical fiber probe, with chemically etched cladding, is used to develop plasmonic nanostructures with functionalized surfaces. These structures bind with creatinine, altering LSPR properties for detection. The resulting optical shift is measured by a UV-vis-NIR spectrophotometer. This proposal aims to develop a cost-effective, robust sensor for an early CKD detection tool by simulations and strategic experimental methods.

Keyword: Plasmonic, Creatinine, Nanomaterials, CKD detection, optical sensor

[L02] Effect of Diode Laser Radiation on Seed Germination and Physio-Biochemical Traits of Ashwagandha - A Multipotential Ayurvedic Medicinal Plant

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Withania somnifera (L.) Dunal, commonly known as Ashwagandha is an important Ayurvedic medicinal plant belonging to the Solanaceae family. The plant contains significant bioactive compounds which is extensively used in traditional and modern medicine for its anti-inflammatory, anti-tumor, cardioprotective and hepatoprotective properties. Increased demand in local and foreign markets has raised rapid growth, enhanced bioactive compounds and conservation concerns for *W. somnifera*. Although, conventional propagation of *W. somnifera* is carried out via seeds, this method is limited by factors like poor viability, reduced germination rates, low seedling survival and lower withanolide content. Development of innovative, cost-effective, and eco-friendly methods are crucial for crop improvement and the use of laser is one such alternative approach. Advances in laser technology have enabled the use of lasers as biophysical elicitors to enhance plant growth and phytochemical content. Laser-facilitated plant growth enhances phytochemical content through biostimulation, in which plants absorb low-power laser light and convert it into chemical energy. This effect is attributable to the monochromatic, coherent, and collimated properties of laser light. Plant responses to laser treatment vary with laser type, wavelength, dose, and exposure duration. The objective of this study is to assess how diode laser irradiation influences morphological, physiological, and biochemical characteristics of *W. somnifera*. Healthy seeds of *W. somnifera* were selected and soaked in 150 µg/mL of gibberellic acid for 16 h. The laser irradiation of

seeds was performed with diode laser (785 nm) with selected doses such as 5, 10, 15, 20, 25 and 30 J/cm^2 and unirradiated seeds served as the control for the study. The seeds were then allowed to germinate in both *in vitro* and greenhouse condition. Diode laser–treated seeds exhibited a statistically significant improvement in germination compared with the control group. Results on morphological, physiological and biochemical characteristics will be presented and discussed.

Keywords: *Withania somnifera*, diode laser, biostimulation, seed germination

[L03] Investigations on selective pathogen killing with microbiome preservation via optimized antimicrobial photodynamic therapy

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The global concern of antimicrobial drug-resistant (AMR) pathogens poses a severe threat to public health, driving an urgent need for alternative, non-antimicrobial drug-free therapies. Among these, antimicrobial photodynamic therapy (aPDT) offers a promising strategy to manage AMR-associated recalcitrant infections. However, at sites such as the oro-nasal cavity, gut, and chronic wounds, anaerobic probiotic species may coexist with pathogens, necessitating optimized aPDT regimens to selectively eliminate pathogens while preserving homeostasis of beneficial microflora. To date, no studies have reported optimized aPDT regimens capable of achieving such homeostasis. In this study, we performed a comparative evaluation of methylene blue (MB)-mediated aPDT on different pathogenic and probiotic bacterial strains. It was found that while a lower MB concentration followed by a red-light exposure of different fluences led to a survival loss of ~1-2 $\log_{10}$ in the pathogenic strain without compromising the viability of the

probiotic bacterial strains, a higher MB concentration followed by red light exposure of the same fluences resulted in a significantly more survival loss (~3-4 log_{10}) in the pathogenic strain along with a substantial survival loss in probiotic bacterial strains (> 5 log_{10}). Zeta potential analysis indicated a lower net negative surface charge in probiotic strains which might be contributing to the cationic photosensitizer binding and the observed selectivity. Further studies are underway to validate photosensitizer binding affinity and strain-specific aPDT killing. These results will be presented.
Keywords: antimicrobial Photodynamic Therapy (aPDT), Methylene Blue (MB), Antimicrobial Resistant (AMR), Probiotic, Zeta potential

[L04] Experimental validation of *Simarouba glauca* leaf extract as natural photosensitizer for inactivation of superbugs

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The emergence of multidrug-resistant pathogens, particularly methicillin-resistant Staphylococcus aureus (MRSA), has necessitated the exploration of alternative antimicrobial strategies. Antimicrobial Photodynamic therapy (aPDT) is a promising antimicrobial approach that utilizes a photosensitizer, visible light, and oxygen to generate reactive oxygen species (ROS), which induce oxidative damage in microbial cells. Recently, the use of plant extracts as next generation aPDT agents is drawing significant research interest, as phytochemicals possess intrinsic antimicrobial, immunomodulatory and photosensitizing properties. In this context, Simarouba glauca offers good promise because of its previously known antibacterial and anti-inflammatory properties. We investigated the potential of Simarouba glauca leaf extract as a natural, plant-derived photosensitizer for use as an aPDT agent. Quantitative phytochemical analysis revealed a rich profile of bioactive

secondary metabolites, including flavonoids, tannins, and phenolics, while GC-MS profiling identified various constituents such as Caryophyllene, Quinic acid, and Vitamin E etc. For the extract concentration of 1 mg/ml and shorter incubation time, exposure to red light irradiation results in a 4 log10 reduction of MRSA. Further, for the extract concentration of 10 mg/ml and relatively longer incubation time, exposure to red light irradiation results in a 7 log10 survival loss in MRSA. Mechanistic evaluations confirmed Type-I and Type II photodynamic pathway mediated generation of ROS, bacterial cell envelope membrane damage and leakage of intracellular contents. While these findings highlight the potential of S. glauca-assisted aPDT as a green and targeted therapeutic strategy for photodynamic inactivation of Gram-positive bacteria, further studies are underway on various other microorganisms including the Gram-negative bacteria to explore its efficacy as a full-proof aPDT agent.

Keywords: Antimicrobial Photodynamic Therapy (aPDT), leaf extract, MRSA, Reactive Oxygen Species (ROS), plant derived photosensitizers, Simarouba glauca

[L06] Chromophore Absorption to Gene Expression: Cellular Mechanisms of Photo biomodulation Therapy in Oral Mucositis

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Photobiomodulation therapy (PBMT) employs low-intensity light to modulate cellular functions through photophysics and mitochondrial biology. Low-level laser therapy (LLLT) influences cells via chromophore absorption, initiating biological responses. Mitochondria are crucial due to their role in metabolism and signaling. LLLT enhances ATP production by activating Cytochrome c Oxidase(CcO) and modifying membrane potential. This therapy impacts gene expression through mitochondrial signaling and reactive oxygen species activation. PBMT shows potential in dermatology, neurology, oncology, and rehabilitation, offering benefits in tissue repair and pain relief. While safe, standardization of protocols remains challenging, requiring further trials.

Keywords: Photobiomodulation therapy, Low-level laser therapy, gene expression, reactive oxygen species

[L07] Development of a Multimodal Nonlinear Optical Microscope for Oral Cancer Evaluation

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Early diagnosis of oral cancer demands imaging techniques capable of providing label-free contrast with high spatial resolution and minimal invasiveness. Nonlinear optical microscopy, including two-photon excited autofluorescence and harmonic generation, offers significant advantages for such applications. However, its implementation remains technically demanding due to sophisticated requirements on femtosecond laser, ultrafast optics, beam conditioning, power control, and system integration. In this work, we report the development of a modular optical microscope platform aimed at enabling multimodal nonlinear microscopy for oral tissue assessment for cancer detection. The system architecture integrates an inverted microscope, an XY galvo-scanning unit, photomultiplier tube, and a Time-Correlated Single-Photon Counting (TCSPC) module, combined with a femtosecond laser source. A preliminary optical design of the nonlinear excitation and detection paths was carried out using 3DOptix, focusing on beam delivery and numerical aperture utilization. At the current stage, we are developing the system, focusing on calibration and optical alignment rather than tissue imaging. Power optimization and attenuation at the objective plane were systematically investigated using LED to enable controlled delivery of optical power suitable for both linear autofluorescence and future nonlinear excitation experiments. While ultrafast beam conditioning and dispersion compensation are presently under development, the reported

platform establishes the critical hardware, optical design framework, and power control strategies required for reliable nonlinear microscopy. This work provides a scalable foundation for label-free optical diagnosis of Oral Cancer.

Keywords: Nonlinear optical microscopy; Autofluorescence imaging; Oral cancer diagnosis

[L08] Studies on Cinnamaldehyde Induced Structural Damage in Post-Photodynamic Therapy Regrowth of Methicillin-Resistant *Staphylococcus aureus*

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The persistent and recurrent infections caused by Methicillin resistant *Staphylococcus aureus* (MRSA) combined with limited effectiveness of the conventional antibiotics for its treatment has garnered increasing interest in exploring alternate antimicrobial strategies. Antimicrobial photodynamic therapy (aPDT) is a promising new approach which utilizes light-activated photosensitizers to generate reactive oxygen species for effective killing of microbial cells. However, many a time, incomplete bacterial inactivation due to suboptimal aPDT leads to regrowth of surviving cells limiting its long-term effectiveness. In this study, we explored the feasibility of the use of cinnamaldehyde, a food additive and a natural antimicrobial compound, in suppressing the regrowth of MRSA following methylene blue mediated aPDT (MB-aPDT). It was found that MB mediated aPDT alone produced a reduction in bacterial viability depending on the concentration of the photosensitizer. However, regrowth of the surviving bacteria was observed at lower MB concentrations. In the case of cinnamaldehyde it was observed that it could also inhibit MRSA growth in a dose and inoculum dependent

manner. However, when it was combined with MB-aPDT, post-treatment regrowth was found to be strongly suppressed, and complete inhibition of regrowth was observed even for high bacterial loads where either of the treatments alone was ineffective. Morphological analysis revealed that while treatment with either MB-aPDT or cinnamaldehyde caused progressive membrane damage, combinatorial treatment of both the therapies led to extensive structural disruption of the bacterial cells. The findings of the studies reveal that cinnamaldehyde in combination with MB-aPDT may strengthen non-antibiotic approaches for controlling drug resistant bacterial infections.

Keywords: Methicillin resistant *Staphylococcus aureus*, Antimicrobial Resistance, Antimicrobial photodynamic therapy, Methylene Blue, Cinnamaldehyde.

[L09] Probing Silver Nanoparticle Assembly on DNA Origami as a SERS Substrate

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Surface-enhanced Raman scattering (SERS) is a powerful vibrational spectroscopic technique that enables highly sensitive molecular detection. The amplification of Raman signals is facilitated by localized electromagnetic hotspots formed at plasmonic nanoparticle junctions with nanometer-scale separations. A central challenge in SERS substrate development is the controlled organization of nanoparticles to achieve reproducible hotspot regions. Deoxyribonucleic acid (DNA) origami has been shown to provide a programmable nanoscale scaffold for organizing nanoparticles but, most DNA origami-based SERS substrates rely on overhang-mediated attachment strategies. However, such approaches often depend on AFM tip–based Raman measurements to probe localized hotspots, limiting their practical applicability. In this work, we present a simplified DNA origami–based SERS substrate that exploits direct electrostatic interactions between DNA origami and silver nanoparticles, eliminating the need for overhang engineering or chemical modification. Rectangular DNA origami nanostructures were synthesized and incubated with silver nanoparticles to form hybrid assemblies. These assemblies were deposited onto a polycarbonate membrane to fabricate a flexible SERS substrate and subsequently loaded with Rhodamine 6G (R6G) as a model analyte. Raman measurements were performed using a 785 nm excitation laser under various illumination conditions, with optimal enhancement observed at a laser power of 60 mW. Significant enhancement of the Raman signal of R6G was observed on DNA origami–nanoparticle assemblies achieving an enhancement factor of ~200 under optimized conditions. These results demonstrate that electrostatically driven assembly of silver nanoparticles on DNA origami can form efficient SERS-active architectures, highlighting the potential of DNA origami–based substrates for practical Raman sensing applications. The details of this study will be presented in the poster.

Keywords: SERS, DNA Origami, Metal Nanoparticles, Flexible SERS Substrate, Hotspot

[L10] Development of a Portable Multispectral Microscopic System for Surface Characterization

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This work presents the design and development of a compact, portable multispectral microscopic imaging system for high resolution surface characteristics. The system integrates a high-resolution imaging sensor with an imaging lens and a 10X Objective lens to enable detailed visualization of surface microstructures. Multispectral illumination was achieved using an indigenously developed light emitting diode (LED) driver circuit and an annular light emitting diode (LED) array comprising white, red (620nm), green (525nm), and blue (465nm) light sources mounted on a circular printed circuit board (PCB). A single board computer (SBC) runs the python – based graphical user interface (GUI) responsible for image acquisition, storage, registration and basic analysis. The optical configuration positions the objective lens at an appropriate working distance to achieve high-resolution magnification, while the imaging sensor and imaging lens are focused on the magnified image formed behind the objective lens. To reduce surface glare, a cross-polarization imaging configuration was implemented, enabling suppression of surface reflections and improved visualization of surface microstructures. The system performance was quantitatively evaluated using USAF 1951 resolution test targets and a micrometer calibration scale to assess spatial resolution and field of view (FOV). Experimental evaluation demonstrates a 2.6mm field of view (FOV) with a resolvable single-line width of 6.20µm.

Keywords: microscopy, surface characterization, multispectral imaging.

[L11] Preparing Label-Free SERS Approach for Trace Adulterants in Honey

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Honey adulteration is a significant global food-fraud issue that affects quality, consumer trust, and market integrity, and its detection remains challenging due to the limitations of conventional analytical techniques in identifying low-level adulterants. Surface-Enhanced Raman Spectroscopy (SERS), an advanced vibrational spectroscopic technique, offers exceptional molecular sensitivity by enhancing Raman signals of analytes adsorbed on nanostructured metallic surfaces, enabling rapid and label-free chemical fingerprinting. In this study, SERS was applied as a qualitative analytical approach to differentiate authentic honey from commercially available samples. Comparative spectral analysis revealed that genuine honey exhibits smooth, broad carbohydrate-related vibrational features characteristic of natural sugar matrices, whereas commercially processed samples display intensified signals and additional spectral features indicative of compositional anomalies. These spectral differences remain evident under enhanced Raman conditions, highlighting the ability of SERS to amplify subtle molecular variations. Overall, the study demonstrates the effectiveness of SERS as a sensitive, rapid, and reliable tool for honey authenticity assessment and underscores its broader potential in food-fraud detection and quality control applications.

Keywords: Honey adulteration; SERS (Surface Enhanced Raman Spectroscopy); AgNPs (Silver nanoparticles); Raman spectroscopy; Lee–Meisel.

[L12] Enhanced Raman Fingerprinting of Curcumin and Toxic Dyes in Turmeric Using SERS Substrates

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Ensuring the authenticity and safety of turmeric is of growing concern due to its frequent adulteration with synthetic colorants. In this work, a surface-enhanced Raman spectroscopy (SERS) strategy is presented for the sensitive detection of curcumin along with commonly used toxic dye adulterants. Silver nanoparticles (AgNP's) were synthesised and employed as effective SERS substrates to amplify Raman signals from turmeric samples. The AgNP's-assisted spectra revealed prominent curcumin vibrational features, particularly bands around ~1600 cm^{-1} and ~1270 cm^{-1}, which are weak or obscured in normal Raman spectra. Furthermore, distinct SERS fingerprints corresponding to adulterant dyes such as Metanil Yellow, Sudan I, and Sunset Yellow can be identified. These results highlight the capability of AgNP's-

based SERS as a rapid, reliable, and highly sensitive analytical tool for detecting harmful dye adulteration in turmeric.
Keywords: Surface-enhanced Raman Spectroscopy (SERS), Silver nanoparticles (AgNP's), Curcumin, Synthetic dyes, Food adulteration.

[L13] Development and Optimization of an Optical Imaging System for Cellular study

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In the recent decade, developments in optical imaging techniques have significantly improved the study of cellular morphology, obtaining improved diagnostic precision and insights into cellular behaviour. In this study, we have developed an optical imaging system based on the Transport of Intensity Equation (TIE), which produces label-free 3D phase images of biological specimens. Both label-free and labelled imaging modes are employed to verify the system, along with the morphological analysis. In this study, standard phase targets such as polystyrene beads and fluorescent polystyrene beads were used to verify the performance of the system, and phase retrieval was carried out using TIE for the visualization of structure. As the system is verified using standard samples, we have recorded the brightfield images of Fibroblast L929 cells, which were used to extract morphological parameters such as volume and thickness. As label-free images provide some of the

morphological parameters, the remaining cellular parameters are extracted by using fluorescence images of L929 cells. In this study, DAPI have been used as a fluorescent probe, which specifically labels the nuclear region. Fluorescence images reveal distinct and prominent nuclear morphological features like minor and major axes, perimeter and area of the nucleus of the L929 cells. As a result, the TIE-based label-free imaging technique provides thickness and volumetric parameters, fluorescence imaging technique allows the morphological analysis of the nucleus. In this study, both labelled and label-free optical imaging techniques are potential imaging approaches for comprehensive cellular analysis in the field of biomedical research and diagnostic applications.

Keywords: Optical imaging, TIE, Fluorescence imaging, L929 cells, Morphological parameters.

[L14] Optical Probe for Characterizing Structural Changes of Collagen

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This study presents the development of an optical probe for label-free detection and characterization of collagen degradation, aimed at understanding biochemical and structural changes associated with tissue remodelling and disease progression. A spectroscopic approach combined with advanced data analysis was employed to assess alterations in the optical and molecular properties of collagen under varying conditions. The integrated system demonstrated sensitivity to subtle changes in collagen structure, providing distinctive spectral signatures that reflect its chemical and physical state. Correlative measurements across multiple optical modalities supported the interpretation of these findings. The proposed method highlights the potential of photoacoustic spectroscopy as an innovative analytical tool for probing tissue integrity, offering a pathway

toward real-time and non-invasive diagnostics relevant to both biomedical and chemical research applications.

Keywords: Optical probe, collagen, spectroscopy, remodeling, machine learning.

[L15] SHG Imaging Reveals Structural Changes in Heat-Moisture Treated Pearl and Finger Millet Starch Granules

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Pearl (*Pennisetum glaucum*) and finger (*Eleusine coracana*) millet starches show promise for low glycemic index foods due to modifiable resistant starch content. Heat-moisture treatment (HMT) alters granule crystallinity and molecular order. Second harmonic generation (SHG) imaging is a label-free method that detects ordered molecular structures like starch helices, while X-ray diffraction (XRD) quantifies bulk crystallinity changes. This study assessed native and HMT-modified starch granules from pearl and finger millets using SHG imaging and XRD to examine treatment effects on molecular organisation and crystallinity. Starch was extracted from pearl and finger millet grains. Granules received HMT at 15% and 35% moisture (120°C, 3 h). SHG imaging produced z-stack images of native and treated samples. Average intensity, DoLP values were calculated from 3D stacks using ImageJ and MATLAB. XRD patterns determined the relative crystallinity for all samples. HMT reduced average SHG intensity across z-stacks compared to native granules in both millets, with greater decreases at

35% moisture, indicating disrupted helical domains. XRD confirmed decreased relative crystallinity with increasing moisture levels and reduced diffraction peak intensities. These complementary findings demonstrate HMT-induced structural changes suitable for functional food applications.
Keywords: Heat-moisture treatment, Second harmonic generation imaging, XRD analysis

[L16] Profiling of Low-Scattering Phantoms using Optical Coherence Tomography: A Preliminary Framework for Tissue Characterization

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Optical Coherence Tomography (OCT) is a standard for structural imaging, yet quantifying diffuse scattering in early-stage pathological tissue remains challenging due to signal degradation. A tissue-mimicking phantom was fabricated using PDMS mixed with 3µm polystyrene beads (5% stock) at a sparse concentration (approx. 0.05% final concentration) to replicate a low-scattering biological environment. The mixture was sonicated for homogeneity and cured at 80°C. Volumetric imaging was performed using a Thorlabs Hyperion SD-OCT (930 nm) with 20x A-scan averaging to suppress shot noise while preserving structural scatterers. To overcome the loss of diffuse signal inherent in low-scattering media, we developed a post-processing pipeline. Instead of traditional intensity-based attenuation mapping, we extracted higher-order statistical features, specifically Local Shannon Entropy and Speckle Contrast, over sliding spatial windows. These feature maps were then fed into an unsupervised machine learning algorithm to segment micro-architectural features without manual labeling. The averaging process successfully reduced background speckle, showing the bead scatterers as distinct, high-entropy signals against the PDMS

background. Analysis of the manually cropped ROI revealed that textural features provided superior contrast for micro-structure identification compared to intensity amplitude. The unsupervised algorithm successfully isolated sparse 3-μm bead aggregates, characterized by maximal textural complexity (μH ,Mean Entropy = 4.31) and elevated intensity (μI = 48.7). The method revealed previously hidden heterogeneity within the bulk PDMS matrix. The background was segmented into two distinct phases: a homogeneous phase (μI = 20.7) and a speckled phase (μI = 21.6). Despite these regions exhibiting indistinguishable backscattering intensities ($\Delta I < 1.0$), they were clearly separable based on their entropy signatures (μH = 3.13 versus 3.73). This methodology offers a promising roadmap for quantifying subtle scattering changes in biological tissues, potentially aiding in the early detection of fibrosis or edema where scattering densities are fundamentally altered.

Keywords: Optical Coherence Tomography, Backscattering Signal Analysis, Optical Scattering Phantoms, Speckle Statistic, Micro-structural Scattering

[L17] Population-Averaged Quantification of Sperm Swimming Dynamics using Differential Dynamic Microscopy

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Characterization of spermatozoons motility is an important study that directly correlates to the clinical analysis of the spermatozoa samples during fertility assessment tests. High quality spermatozoa, in a sample, showing high motility is decided by the fraction of living spermatozoa present in the sample and their progressive motility dynamics. This work is based on a high throughput technique called Differential Dynamic Microscopy [DDM] that helps in computing and analyzing dynamic parameters representing the motility of spermatozoa. This technique, known for its simple experimental set-up, provides us with population, averaged measures of ensemble particles/cells instead of focusing on individual entity, thereby reducing the time complexity of sperm analysis. The technique takes in a microscopic movie and focuses on the intensity fluctuations established when taking frame differences, and operates on the Fourier space of these difference images, to obtain the Intermediate Scattering Function [ISF]. The ISF is used to extract the dynamics shown by the spermatozoa which are represented by their appropriate length scales. Extracted parameters were helpful in finding out the values of the following dynamic quantities: Amplitude of Lateral Oscillation (ALH) = 2.14 μm, Beat Cross frequency (BCF) = 6.648 Hz, Head velocity calculated between successive frames (VCL) = 89.4 μms^{-1}, Actual path velocity (VAP) = 45.54 μms^{-1}, Fraction of Motile sperm in sample (α) = 0.8445. The estimated values can be compared with the normal range of values for a healthy semen sample. This can help us in quantifying the spermatozoon swimming behavior which plays a major role in the study of the gamete’s biology and DDM, helps us to analyze these samples and quantify the dynamics.

Keywords: Differential Dynamic Microscopy, Spermatozoa Motility, Fertility Assessment, Intermediate Scattering Function, Quantitative Cellular Dynamics

[L18] Autofluorescence for evaluating protein nitration

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Oxidation and nitration of proteins is one of the most common biomarkers for several diseases including inflammation, neurodegenerative diseases, diabetes. Studies have shown that nitrosative stress leads to protein

glycoxidation and both processes can be strongly corelated with development of cancer. In this study we have developed an autofluorescence device which can be used to evaluate protein tyrosine nitration treated with peroxynitrite. Additionally, techniques like ANS, ThT assays, FTIR and DLS were used to validate the device performance. The study gives an overview of how autofluorescence based device can provide a robust, label-free platform for sensitive fingerprinting of proteins.
Keywords: Autofluorescence, Protein-fingerprinting, Cancer detection

[L19] Optical and Physicochemical Characterization of Millet Starch by SHG, FTIR, XRD, and SEM

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Millet starch is of growing interest for nutritional and healthcare-related applications due to its structural diversity and functional properties. In this study, starch isolated from six millet varieties was characterized using a multimodal approach combining Second Harmonic Generation (SHG) microscopy, Fourier Transform Infrared spectroscopy (FTIR), X-Ray Diffraction (XRD), and Scanning Electron Microscope (SEM) to investigate structure-property relationships. SHG microscopy, a label-free nonlinear optical technique, was used to assess molecular ordering and crystalline domains within starch granules, revealing distinct signal intensities and spatial distributions among the samples. FTIR analysis indicated variations in functional groups associated with polysaccharide bonding, while XRD patterns demonstrated differences in crystalline type and relative crystallinity.

SEM imaging showed marked variation in granule morphology and surface features across the six millet starches. The combined optical and physicochemical characterization highlights the influence of molecular structure and microarchitecture on the optical response of starch. This integrated approach underscores the potential of SHG as a complementary tool to conventional techniques for evaluating biopolymeric materials relevant to food and nutritional applications.

Keywords: SHG, FTIR, XRD, SEM, Millet starch

[L20] A statistical study on the effect of the solvent and binder on the particle size of ZnO based ink for additive manufacturing

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Stable nanoscale dispersions are a critical prerequisite for formulating functional inks for additive manufacturing in electronics, sensors, and optoelectronic devices. Zinc oxide (ZnO), a wide-bandgap semiconductor with excellent optical and electronic properties, is a promising candidate for printed electronics, but its strong tendency to agglomerate in liquid media limits its suitability for ink-based processing. In this work, the combined influence of solvent composition and polymer binder concentration on the hydrodynamic particle size, dispersion stability, and optical response of ZnO-based inks is investigated using a data-efficient, model-driven approach. Dynamic light scattering (DLS) is employed to evaluate the particle size distribution, polydispersity index (PDI), diffusion coefficient, and optical transmittance of ZnO suspensions prepared using different water–ethanol ratios (1:1, 2:1, 1:2, and 100% water), both in the presence and absence of polyvinyl alcohol (PVA) as a binder. The results confirm that solvent polarity and binder concentration strongly affect the balance between particle stabilization and aggregate formation, with water-rich formulations yielding the smallest hydrodynamic diameters (≈1100–1500 nm), compatible with 21–100 μm inkjet nozzles, while ethanol-rich environments promote aggregation into larger clusters. To move beyond purely empirical interpretation, regression analysis and modern machine-learning models (Random Forest and support vector regression), validated via leave-one-out cross-validation, are used to examine the influence of ethanol–water ratio and PVA concentration on key dispersion characteristics. Nonlinear response surfaces and contour maps reveal a distinct optimization landscape, and model comparison shows that machine-learning models improve the coefficient of determination from ≈0.6 to ≈0.8 and reduce prediction errors by more than one-third relative to polynomial regression, highlighting intrinsically nonlinear solvent–binder interactions. Overall, this study provides a formulation-level framework that combines minimal experimental data with interpretable machine learning to tailor solvent–binder systems for controlled ZnO particle size distributions in printable inks, with implications for rheology, optical behavior, and functional performance in additive manufacturing.

Keywords: Additive manufacturing, Zinc Oxide, Ink formulation, Particle size distribution, Regression, ANOVA

[L21] Label-free profiling of RBCs to identify high-impact morphometric features under *Candida albicans* infection *invitro*

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Red blood cells (RBCs) play a critical role in host–pathogen interactions, yet their morphological response to *Candida albicans* exposure remains poorly understood. Most existing studies have focused on clinical bloodstream infections such as candidemia, and only one prior investigation has assessed how *Candida* affects RBC morphology via labelled stains rather than label-free imaging. As a result, the fundamental, unaltered morphometric signatures underlying RBC–Candida interactions remain unknown. This study employs label-free brightfield imaging and high-dimensional morphometric analysis to characterise changes in RBC shape, texture, and intensity features during in vitro exposure to *Candida albicans*. The goal was to identify discriminative features that may serve as biomarkers for future AI-based classification frameworks. Six donor samples were inoculated with *C. albicans ATCC 23344* in vitro, and label-free brightfield imaging was performed and analysed across seven timepoints (0–12 hours). Twenty-four quantitative morphometric features were grouped into three categories: shape/morphology (n=10), texture (n=6), and intensity (n=8). Statistical testing (Shapiro–Wilk, Mann–Whitney U), effect size computations (Cohen's d, Cliff's δ), and temporal trend analysis were performed. Textural features had the highest discriminative power (95.24% significance), followed by intensity (91.07%) and morphological descriptors (88.57%) ($p<0.0001$). Several features demonstrated 100% significance across all timepoints, with exceptionally high effect sizes: circularity ($|d|=7.136$), solidity ($|d|=6.887$), roughness ($|d|=13.177$), coarseness ($|d|=12.428$), contrast ($|d|=11.080$), entropy ($|d|=8.943$), Max_Intensity ($|d|=11.286$), and Min_Intensity ($|d|=10.857$). The temporal trajectories revealed distinct differences between infected and control RBCs, e.g., coarseness increased by 29.2% (infected) and 1.5% (control), and roughness increased by 25.5% and 3.6%, respectively. Label-free morphometric profiling reveals consistent and temporally evolving alterations in shape, texture and intensity features of RBC induced by *C.albicans*. These findings provide foundational biomarkers for future AI-driven diagnostic and prediction models, representing the first systematic label-free assessment of RBC- Candida interactions.

Keywords: Label-free morphometry, Red Blood Cells, *Candida albicans*, morphometric features, brightfield imaging

[L22] Beyond Extraction and Dyes: Redefining Single-Cell Oil Monitoring and Imaging Directly in Micro-Factories

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Each oleaginous cell is a microbial oil factory, producing single-cell oil that offers a greener alternative to plant oils and fossil fuels. These micro-factories can produce and accumulate oil up to 70% of their dry weight. Existing technologies, such as gas chromatography mass spectroscopy (GC-MS), colorimetric assays, and/or imaging modalities such as fluorescence microscopy and transmission electron microscopy are known to be highly sensitive. However, these gold standard techniques involve extensive sample preparation, extraction, and/or chemical dyes. In this study, we developed a micro-Raman spectroscopy-based novel extraction-free framework to monitor and visualize the microbial oil accumulation in the micro factory using vibrational signatures and virtual dyes. For this study, oleaginous microbial models, namely *Lipomyces lipofera*, *Yarrowia lipolytica*, *Rhodosporidium toruloides,* and *Rhodotorula glutinis,* were used. The oleaginous microbes were cultured under two bioprocess-relevant conditions - nitrogen-rich (control) and nitrogen-limited (high lipid accumulation) conditions, and the microbial oil was detected using Raman spectra. Microbial oil accumulation was monitored at the single-cell level in a qualitative and semi-quantitative manner. Further, we have also imaged the accumulation of microbial oil in lipid bodies of the cell using virtual dyes and advanced multivariate analysis. The finding of lipid droplet localization and single cell morphology was validated using scanning electron microscopy and fluorescence microscopy. Bulk lipids were also extracted, and the Raman microbial oil signature peaks from the cells were cross validated against the extracted and pure lipids. Additional validation of lipid composition and purity was performed using Fourier transform infrared spectroscopy, and detailed lipid profiling was conducted using GC-MS. Going beyond the reach

of GC-MS and fluorescence-based methods, we demonstrate that this framework can monitor microbial oil biosynthesis at the single-cell resolution. Our single-cell Raman platform turns each microbial cell into a readable micro factory, bridging the fundamental insights with real-world bioprocess innovation.

Keywords: Single cell microbial oil, Bioprocess monitoring, Raman spectroscopy, Raman imaging, Multivariate analysis

[L23] Spectroscopic and Microscopic Profiling of Tyrosine Nitration its Implication on Human Health

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Tyrosine nitration is a prominent oxidative post translational modification which results in the formation of 3-nitrotyrosine. It is a key molecular signature associated with nitrative stress and pathology of numerous diseases including neurodegenerative and cardiovascular conditions. The modification alters the protein pK_a and hydrophobicity thus compromising the protein folding, stability and enzymatic activity. Even though the formation of protein aggregation and β-sheet formation by nitration is known, a systematic study connecting to the nitration event is lacking. In the current study, Ribonuclease A is selected as a model protein to explore the mechanism of aggregation induced by exposure to peroxinitrite. Tyrosine nitration was investigated using progressive concentrations, with fluorescence spectroscopy, ultraviolet–visible absorbance, Thioflavin T assays, 8-anilinonaphthalene-1-sulfonic acid binding, Fourier transform infrared spectroscopy, dityrosine-specific fluorescence, scanning electron microscopy, Raman spectroscopy, fluorescence imaging, and dynamic light scattering.

Keywords: Tyrosine nitration, Spectroscopy, Protein modification, Protein aggregation, RNase A

[L24] Assessment of the Metabolic Preconditioning Induced by Snehapana Therapy in the Management of Type II Diabetes

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Loss of metabolic conditioning is an essential contributor in the development of metabolic disorders. Restoring metabolic conditioning requires a multifaceted approach, including Pharmacological interventions, conventional and alternative therapies, regular physical activity and strategic lifestyle modifications. Among these techniques preconditioning is highly efficient adaptive mechanism. Preconditioning enhances adaptive response by subjecting the body to brief, moderate metabolic stress, eventually enhancing metabolic flexibility and against conditions such as type 2 diabetes. This study explores the effect of Snehapana therapy with normal and medicated ghee on insulin resistance in a high-fructose diet-induced type 2 diabetes model in rats, using histological, biochemical, and biomolecular analysis to assess improvements in insulin sensitivity and signalling pathways. Snehapana therapy was administered for 14 days at varying doses to precondition the animals' metabolism, followed by a 14-day recovery period. An OGTT and lipid profile were performed on the last day of recovery. Subsequently, a high-fructose diet was given for 6 months to induce insulin resistance, after which OGTT, lipid, and insulin levels were assessed. Animals were then randomized into 7 groups and treated with metformin alone or in combination with Snehapana (200 mg/kg) for 14 days. After another 14-day recovery, OGTT, biochemical parameters, and western blot analysis (IRS-1, GLUT-4, HSP-70, P-AMPK, and AMPK) were conducted. Cholesterol levels, triglyceride levels, SGOT levels, total protein levels, urea and insulin levels are elevated in the high-fructose diet control group, consistent with the development of metabolic dysregulation. However, this increase was notably absent in the preconditioned with Snehapana groups. These findings suggest that Snehapana therapy, as a preconditioning strategy, confers resistance against

the deleterious effects of long-term high-fructose diet exposure. This protective effect may be attributed to the modulation of lipid metabolism and improved systemic glucose homeostasis induced by therapeutic treatment.
Keyword: Snehapana, High fructose diet, Type 2 diabetes.

ABSTRACTS

POSTER PRESENTATIONS

Biophotonics for Clinical and Precision Healthcare

[B01] Automated Oral Lesion Classification Using Label-Free Two-Photon Imaging

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Precise identification of oral squamous cell carcinoma, as well as oral potentially malignant disorders, is a key goal for early intervention, but histopathology is limited by invasive methods, staining challenges, and interobserver variability. Label-free two-photon fluorescence microscopy imaging has potential due to inherent biochemical-structural contrast based on non-linear optical effects from endogenous fluorescent molecules, thus overcoming current imaging modality limitations. In this study, we explore a hybrid AI solution that combines label-free two-photon imaging, deep feature learning, and traditional machine learning for multi-class classification of oral disorders. Images were obtained from ex vivo formalin-fixed, paraffin-sectioned oral biopsies proven to be pathologically inflammatory/control, OPMD, and malignant using a custom-built two-photon microscope without using any labels. Feature sets were obtained from a small-sized ConvNeXt model, taking advantage of a refreshed design for strong representation. Features were modeled using a radial basis function support vector machine classifier due to small dataset size with class imbalance. The resulting accuracy was 90% for the proposed pipeline. The results demonstrate the potential of incorporating label-free two-photon microscopy with feature extraction based on deep learning algorithms for the classification of oral lesions. Our work confirms the applicability of machine-based approaches for stain-free optical imaging for rapid screening before biopsy, opening up the direction for further studies in larger populations with the utilization of nonlinear imaging modalities.

Keywords: Multiphoton Microscopy; Autofluorescence; Nonlinear Optical Imaging; Deep learning, Machine learning

[B02] An Autofluorescence -Based Biosensor for Non-Invasive and Cost-Effective Bilirubin Detection in Neonates

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Neonatal jaundice is one of the prevalent clinical conditions seen in newborns, and timely monitoring of bilirubin levels is essential to prevent serious neurological complications such as kernicterus. Despite its clinical importance, bilirubin estimation still relies on blood sampling and costly transcutaneous devices. This limits accessibility, particularly in resource constrained environments. This study aims to develop an autofluorescence based optical biosensing approach for non-invasive, cost-effective bilirubin detection. The system is designed around the intrinsic optical property of bilirubin, which exhibits characteristic green light near 520 nm when excited with blue light at 440 nm. Bilirubin solutions across clinically significant concentrations were prepared and characterized using fluorescence and absorbance spectroscopy. Fluorescence emission measurements demonstrated a clear concentration dependent increase in signal intensity, yielding a strong linear correlation that supports quantitative assessment. Absorbance measurements supported the choice of excitation wavelength and confirmed the optical compatibility of the system. To evaluate the performance of the system in a biological matrix, bilirubin was spiked into whole mice blood, where measurable and concentration-dependent autofluorescence signals were retained despite the background interference from other components of the blood. These results highlight the reliability of bilirubin autofluorescence as a measurable biological signal and its potential applicability beyond ideal laboratory conditions. By avoiding chemical

reagents and invasive blood collection procedures, this approach serves as a simplified workflow for the healthcare providers as well as the newborns. Overall, the study provides a strong experimental basis for developing a portable, smart phone integrated screening tool that could bring bilirubin monitoring closer to point of care, enabling early diagnosis and improved management of neonatal jaundice, especially in settings where conventional diagnosis options are limited

Keywords: Jaundice, Neonatal care, autofluorescence, spectroscopy, optical device

[B03] Investigations on effect of osmotic stress in healthy and diabetic red blood cells using Diffraction phase microscopy

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Red blood cells (RBCs) from patients with diabetes mellitus often exhibit altered morphology and elasticity. Quantitative phase microscopy (QPM) is a non-invasive, label free quantitative imaging technique which can provide biophysical properties of a single cell with high precision at nanometer resolution. We investigated the applicability of diffraction phase microscopy, a variant of QPM, to investigate the relative effects of osmotic stress in red blood cells from diabetic patients and healthy individuals by subjecting the cells to hypotonic (250 mOsm), hypertonic (400 mOsm) and isotonic (300 mOsm) solutions. Significant changes in the morphological parameters like base area, surface area, cell volume, sphericity and concavity were observed due to changes in osmolarity in RBCs of both the groups. The degree of alteration in the elasticity of the RBCs from the heathy volunteers and diabetic patients was determination from the quantitative estimation of the percentage changes in the morphological parameters of these cells under

osmotic stress. Reduced alternations in cell parameters observed in RBCs from diabetic patients as compared to the ones from healthy individuals when subjected to osmotic stress indicate increased rigidity of the corresponding cells. The findings of this study highlight the potential of diffraction phase microscopy in monitoring the changes in morphological properties of RBCs associated with blood disorders. The details of these results will be presented.
Keywords: Red blood cell (RBC), Quantitative phase microscopy (QPM), Diffraction Phase Microscopy (DPM), Diabetes, Osmotic stress.

[B04] Label-free discrimination of live and starvation-induced necrotic cells using single-cell micro-Raman spectroscopy

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Nutrient deprivation and metabolic stress arising from irregular vascularization within the tumor microenvironment are major drivers of intratumoral heterogeneity, giving rise to coexisting populations of viable and necrotic tumor cells. Accurate identification of necrotic cells is clinically significant, as both the extent and spatial distribution of necrosis correlate with tumor aggressiveness, hypoxia, therapeutic response, and patient prognosis. Conventional evaluation relies predominantly on histopathology using H&E staining and immunohistochemistry, which are labor-intensive, require extensive chemical processing, and often subjective, providing limited insight into the intrinsic biochemical state of individual cells. Consequently, there is a pressing need for a label-free, non-destructive approach capable of discriminating live and necrotic tumor cells based on their endogenous molecular signatures. In this study, we investigated the applicability of micro-Raman spectroscopy with 785 nm excitation for distinguishing viable and starvation-induced necrotic single HeLa cells, thereby mimicking nutrient-deprived conditions characteristic of solid tumors. Necrotic cells exhibit a pronounced reduction in the Amide I band (~1661 cm^{-1}), reflecting a decreased intracellular protein content resulting from loss of membrane integrity and consequent cytoplasmic leakage. In contrast, a significant enhancement of the ~1450 cm^{-1} band, arising from CH_2/CH_3 vibrations of lipids indicating membrane breakdown and intracellular lipid vesicle/droplet accumulation during necrosis. Additionally, necrotic cells display an elevated DNA-associated Raman band (~1084 cm^{-1}), corresponding to phosphate backbone vibrations, which signifies chromatin condensation and nuclear disorganization. The concurrent alterations in protein, lipid, and nucleic acid signatures collectively represent a molecular fingerprint of necrosis, demonstrating the capability of micro-Raman spectroscopy to distinguish live and necrotic tumor cells at the single-cell level.

Keywords: Raman Microspectroscopy, Necrosis, Metabolic Stress, Intrinsic Molecular Signatures, Single cell Analysis.

[B06] Surface Enhanced Raman Spectroscopy of Liquid-based Cytology Samples from Human Cervix

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Cervical cancer is one of the leading causes of cancer-related mortality among women worldwide. Although cervical cancer is largely preventable, early detection plays an important role in reducing disease burden. The effectiveness of current screening and diagnostic methods, like Pap smear and HPV test, face many limitations related to sensitivity, specificity, and diagnostic reliability. Moreover, accurate differentiation between different grades of lesions remains challenging. Therefore, there is an urgent need for alternative approaches that enable early, and accurate detection of cervical cancer. An effective approach involves identification of cancer-associated cell surface biomarkers, such as folate receptors, which are highly overexpressed in cervical cancer cells. We here, report a novel Raman spectroscopy approach based on detection of overexpressed folate receptors on cervical cancer cells using conjugated gold nanoparticles (AuNps). Citrate-stabilized AuNp conjugates were synthesized using Turkevich method and were characterized by UV-visible spectroscopy, transmission electron microscopy, and zeta potential analysis to confirm their morphology, size, surface charge, and stability. The performance of thus synthesized AuNp conjugates were evaluated on HeLa and HaCaT cell lines. The clinical relevance was analyzed on liquid-based cytology samples from human cervix. The unique Raman spectral signatures enabled clear discrimination between normal and abnormal cells including different precancerous stages of cervical cancer. The results demonstrated that folate conjugated SERS nanoprobe offers enhanced diagnostic accuracy, sensitivity, and screening efficiency in clinical settings. The details of this study will be presented in the poster.

Keywords: Cervical cancer, Pap smear test, SERS nanoprobe, Folate receptors, Raman reporter.

[B07] Early Prediction and Label Free Detection of Radiation-Induced Fibrosis

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Radiotherapy is one of the major treatments for cancer and has side effects. One of the major long-term complications is radiation induced fibrosis which is characterised by accumulation of fibroblast, myofibroblast and extra cellular matrix like collagen leading to the loss of organ function. The chronic wound and persistent inflammation with activation of myofibroblast by

signalling pathways such as transforming growth factor- β (TGF- β), oxidative stress and immune-cell crosstalk. Early detection of fibrosis is still a challenge. This review aims to summarise early prediction and detection strategies for radiotherapy associated fibrosis focusing majorly on non destructive, quantitative technique for an early detection. Label free optical imaging techniques are growing rapidly as to detect fibrotic ECM changes. Second harmonic generation (SHG) microscopy is highly specific for collagen formation in fibrosis and generates 3D visualisation of collagen architecture. Studies has also showed that SHG can distinguish usual interstitial pneumonia from healthy lungs by detecting collagen microstructure alterations. While SHG can visualise and score collagen architecture, Raman spectroscopy can capture biochemical shifts in collagen. Studies show that Raman spectrometry can discriminate fibrosis associated changes like secondary structure alteration in collagen type 1 by applying spectral deconvolution to get more clearer collagen related molecular marker signals. For collagen organisation assessment, polarization microscopy is gaining popularity as it is a great ECM focused method. The studies done with polarized Picrosirius Red (PSR) fluorescence imaging provides more stable and orientation-independent quantitative signals fiber that measures subtle changes in collagen structure. The label free optical imaging support core principle of early detection of fibrosis as ECM remodelling is measured before the fibrosis becomes clinically obvious. SHG can detect early alterations in collagen architecture while Raman spectroscopy provides information on biochemical shift and ECM composition and polarization microscopy reports collagen fiber organisation. Together this provides the future of optical imaging techniques. Label free optical imaging will have major contribution for the future fibrosis detection as where there is much room for development like by using biomarkers, personalised radiotherapy or reducing the long-term side effects of radiotherapy by early management.
Keywords: Label-free optical imaging, fibrosis, second harmonic generation microscopy, Raman spectroscopy, polarized microscopy

[B08] Biophotonics-Based Assessment and Prediction of Tumor Radioresistance

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Radiotherapy, for decades, has been a stepping stone for the treatment of cancer. However, there are many tumours that exhibit resistance in both intrinsic and acquired forms, making the treatment unsuccessful. A plethora of factors, cellular and tumour microenvironment (TME), contribute to this radioresistance, such as genetic and epigenetic instability, hypoxia, tumour heterogeneity, the efficiency of DNA repair mechanisms, as well as the role of the immune system in response to radiation. A hypoxic environment in tumour cells is one of the most prominent areas of radioresistance in tumours and is primarily determined by irregular vasculature, tumour growth rate, and cellular composition, which leads to a delayed immune response in the cells. Moreover, hypoxia induces dormancy in cells, resulting in an altered state of metabolism in tumor cells, which increases the chances of radiation resistance. Enhanced DNA damage repair pathways increase the chances of survival and the proliferative capacity of the cell. Together, these biological changes necessitate the need for newer advanced detection and assessment of tumours beyond the current conventional methods of tumor response or radioresistance. Emerging biophotonics-based techniques, such as fluorescence lifetime imaging (FLIM), photoacoustic imaging (PAI), and hyperspectral imaging (HSI), provide an advanced non-invasive model for detecting the determining factors of radioresistance. FLIM is useful for analysing metabolic changes and alterations in the TME post-irradiation. FLIM in combination with Fluorescence Resonance Energy Transfer (FRET) or fluorophore dyed probes has been used for the detection of aberrations and interactions of proteins. Radiation-induced biochemical changes and hypoxic tumour regions can be identified using HSI. Poorly organized vasculature, stromal composition and growth rate of the tumours make up the key determinants in radiosensitivity which can be effectively monitored using

PAI. Thus, these biphotonic-based advanced techniques offer non-invasive strategies and insights into the molecular workflows for assessing tumour response to radiation and hold promise for improving the outcomes of these treatments in future.

Keywords: Radioresistance, Photoacoustic imaging, Fluorescence imaging, Tumour hypoxia, Hyperspectral imaging

[B09] Modelling Composite RBC Membrane Mechanics measured via Diffraction Phase Microscopy

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The mechanical integrity and deformability of Red Blood Cells (RBCs) are governed by a complex composite membrane consisting of a fluid lipid bilayer tethered to an underlying spectrin cytoskeleton. Unlike simple lipid vesicles, RBC membranes exhibit non-equilibrium fluctuations that violate the fluctuation-dissipation theorem, driven by metabolic activity. While the Helfrich shape equation accurately describes passive bilayers, it fails to account for the RBC's composite architecture. In the present study, we quantify the nanometric membrane fluctuations of RBCs using Diffraction Phase Microscopy (DPM), a high-sensitivity quantitative phase imaging technique. To interpret the experimental root mean squared (RMS) displacement data, we developed a bio-mimetic quasi-2D micro-mechanical model. The cytoskeleton is modeled as a network of Hookean entropic springs that pin the bilayer at specific junctional complexes. constraining the allowed Helfrich bending modes of a free bilayer. Our analysis reveals that experimental fluctuation data can only be corroborated by assuming selective

dissociation between the lipid bilayer and the cytoskeleton. This finding indicates that the membrane is not a static structure but undergoes dynamic rearrangement driven by non-thermal active forces, such as ATP hydrolysis. These results provide a mechanical framework for understanding how metabolic energy regulates cellular deformability and membrane stability.

Keywords: Cytoskeleton, Lipid Bilayer, Quasi 2D model, Diffraction Phase Microscopy, Membrane Fluctuations

[B10] Monitoring Hemoglobin Glycation using LED-Induced Autofluorescence

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Non-enzymatic glycation occurs when reducing sugars react with proteins, leading to the formation of advanced glycation end products (AGEs). AGEs represent a chemically heterogeneous group of molecules that play a crucial role in the development of diabetic complications, particularly vascular and renal damage. Hemoglobin (Hb) is a clinically relevant target for glycation studies as it reflects systemic glycaemic exposure. Although HbA1c is widely used as a marker of long-term glycaemic control, it represents an average glucose level and does not capture the chemical diversity of AGEs or reliably predict secondary diabetic complications. Therefore, there is a need for analytical approaches capable of detecting AGE accumulation and characterizing their heterogeneity. In this study, LED-induced autofluorescence (LED-IAF) was employed to monitor AGEs formed on glycated hemoglobin. Since many AGEs are intrinsically fluorescent, their characteristic fluorescence can be exploited to assess both the extent and nature of glycation. Standard hemoglobin was glycated in vitro using methylglyoxal (MGO), and AGE-specific autofluorescence was recorded at selected UV-visible excitation wavelengths. A concentration-dependent

increase in fluorescence intensity was observed with increasing MGO levels. At higher MGO concentrations, the fluorescence spectra exhibited broadening and the emergence of shoulder peaks, suggesting the formation of a heterogeneous population of AGEs, potentially including vesperlysine (A, B, and C), pentosidine, argpyrimidine, and crossline. These findings demonstrate that LED-IAF enables rapid, label-free detection of glycation-induced chemical heterogeneity and structural modifications in hemoglobin. The approach offers a simple, cost-effective alternative to conventional techniques and provides clinically relevant insights into protein glycation, with potential applications in improving diabetes monitoring beyond HbA1c and in predicting the risk of secondary diabetic complications.
Keywords: Hemoglobin, glycation, LED-induced autofluorescence, advanced glycation end products, fluorescence spectroscopy

[B12] Single-Cell Raman Tweezer Spectroscopy Reveals Radiation-Induced Biochemical Changes in Human Erythrocytes for Biodosimetry Applications

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Radiation biodosimetry is essential for the rapid assessment of exposure levels in radiological incidents, enabling triage and health risk evaluation. This study leverages Raman tweezer spectroscopy, a label-free biophotonic platform that combines optical trapping and vibrational spectroscopy, to detect and classify radiation-induced alterations in human red blood cells (RBCs) at the single-cell level. Human blood irradiated with X-rays (0.5–8 Gy) and red blood cells analyzed via 785 nm optical tweezers. High-resolution spectra captured molecular fingerprints from haemoglobin, membrane lipids, and protein backbones. Multivariate analysis, including

principal component analysis (PCA), revealed dose-dependent spectral shifts, with loading vectors highlighting oxidative modifications in lipids and proteins, alongside increased single-cell heterogeneity at intermediate-to-high doses. Optical tweezers demonstrated high sensitivity to radiation-induced biochemical changes, enabling label-free discrimination of exposure levels without sample preparation. These findings position biophotonic single-cell Raman spectroscopy as a promising tool for rapid, point-of-care biodosimetry in emergency response and radiobiological applications.
Keywords: Biodosimetry, Raman tweezer spectroscopy, optical trapping, single cell biophotonics, erythrocytes, radiation damage

[B13] Biodegradable Starch-Based Elastomeric Microfluidics for Cell Culture Applications

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Microfluidic devices have important benefits for biomedical uses because they consume minimal reagent, have high sensitivity, and allow precise control over cellular microenvironments. However, common microfluidic materials are mostly non-biodegradable and can be toxic to cells or leach harmful substances, which limits their use in long-term biological studies. This work focuses on creating a biodegradable starch-based elastomeric microfluidic device with biosensing capabilities. In the current work, starch-based elastomers from corn and potato starch were synthesized using a solution-casting method. The elastomers were optimized by varying the starch concentration (0.5–3 g), the amount of glycerol plasticizer (0.2–2.5 mL), and adding citric acid (5–50%) as a crosslinking agent along with silicon dioxide (0.08–0.16 g) as a reinforcement filler. These properties

were confirmed through Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Differential Scanning Calorimetry (DSC) and Scanning Electron Microscopy (SEM). Crosslinking changed the structure from semi-crystalline to mainly amorphous, with higher endothermic transition temperatures compared to native starch. A three-layer microfluidic device was built using the optimized elastomer which consists of a laser-engraved elastomer layer between glass substrates. The microchannels measured about 500 µm in width and 300 µm in depth, achieved at the best laser settings (90% power, 70% speed). Analytical calculations and computational fluid dynamics simulations showed stable laminar flow ($Re < 0.1$) at flow rates of 0.1–10 µL/min. The pressure drop was about 3.7 Pa, and the wall shear stress was around 9.8×10^{-3} Pa at 1 µL/min, indicating cell-compatible flow conditions. As a proof-of-concept biosensing method, an anthocyanin-based colorimetric pH sensor was developed that showed clear colour changes across pH levels from 1 to 14. Biocompatibility tests with various mammalian cell lines showed that initial cell viability was over 80–90% at 24 hours, followed by a decrease related to citric acid leaching (about 23% over 72 hours) and a drop in culture medium pH from about 6.7 to 4.7. Surface stability was improved with phosphate-buffered saline and bioactive coatings. Chitosan-coated elastomers demonstrated better cell adhesion, improved cytoskeletal organization, and antimicrobial properties. In conclusion, this study shows that starch-based elastomers can be sustainable materials for microfluidics. They enable precise microchannel fabrication, controlled fluid flow, and functional biosensing while highlighting key challenges related to long-term stability and leachate control for future cell culture and organ-on-chip applications.

Keywords: Starch, elastomers, microfluidic devices, cell culture, biosensors

[B14] Non-enzymatic reagent-free sensing and direct detection of lactic acid in microbial culture

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Lactic acid is a well-known metabolite with broad industrial applications in food preservation, cosmetics, pharmaceutical, and polymer industries. Direct detection of lactic acid in complex culture matrices in a reagent-free manner and a minimally invasive approach remains an analytical challenge. Conventional detection methods rely on enzymatic assays and high-performance liquid chromatography, which involve extensive sample preparation, limiting their ability to provide real-time insight. Here, we report a reagent-free Raman spectroscopic strategy for the direct detection and spatial mapping of lactic acid in microbial culture complex supernatant. Using Lactobacillus plantarum as a model lactic acid–producing organism and Escherichia coli as a control, characteristic Raman signatures of lactic acid were identified in culture supernatants. Extending beyond sample preparation towards a reagent-free approach, Raman imaging enabled direct spatial mapping and visualization of lactic acid from intact, unprocessed bacterial cultures without centrifugation or filtration. Raman maps revealed a diffuse distribution of lactic acid within the culture matrix, consistent with metabolic secretion by actively growing cells. This work pipeline highlights the analytical utility of Raman spectroscopy for a reagent-free, minimally invasive sensing platform for metabolite detection and spatially resolved analysis in complex biological systems.

Keywords: Raman spectroscopy; lactic acid; reagent-free sensing; Raman imaging; label-free

[B15] Fluorescence-Based Assessment of Anticancer Activity of a Docetaxel-Loaded Nanoemulsion in Breast Cancer Cells

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Biophotonics offers powerful tools to understand cellular responses to cancer therapy through optical and fluorescence-based signatures. In this study, we investigated the anticancer efficacy of a docetaxel-loaded oil-in-water nanoemulsion (DTX-NE) using fluorescence-based methods in MCF-7 breast cancer cells. The DTX-NE was prepared by ultrasonication and exhibited nanoscale droplet size, high physical stability, and sustained drug release. The therapeutic response was evaluated using optical microscopy and fluorescence assays targeting apoptosis, mitochondrial membrane potential, and intracellular reactive oxygen species (ROS). Dual acridine orange/ethidium bromide staining revealed a higher proportion of apoptotic cells following DTX-NE treatment compared to free DTX. Mitochondrial membrane potential analysis using Rhodamine 123 showed a significant loss of mitochondrial integrity in DTX-NE treated cells, indicating activation of mitochondrial-mediated apoptosis. Further ROS analysis by DCFH-DA fluorescence method indicated significant higher intracellular ROS generation, suggesting oxidative stress as a key contributor to cell death. Compared to free DTX, the DTX-NE formulation demonstrated improved cytotoxic efficacy, which correlated with the observed optical and fluorescence signatures. These results highlight the utility of biophotonics-based approaches for evaluation of nano-therapeutic performance at the cellular level. The study underscores the potential of integrating nanomedicine with biophotonics to enable rapid, translational assessment of anticancer drug delivery systems.

Keywords: Docetaxel; Nanoemulsions; Ultrasonication; Anticancer Activity

[B16] Investigation of bipyridine based compounds as anticancer agents in Non-Small Cell Lung Carcinoma

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Non-small cell lung cancer (NSCLC) represents a major global health burden, highlighting the need for novel anticancer agents supported by rigorous mechanistic evaluation and translational relevance. Bipyridine-based compounds have emerged as promising candidates due to their ability to disrupt DNA integrity, regulate cell cycle progression, and modulate intracellular signalling pathways. In this study, we investigated the anticancer potential of two bipyridine-based compounds, 3A and 3B, in order to evaluate their therapeutic efficacy and underlying mechanisms of action. The anticancer efficacy of bipyridine-based compounds 3B and 3A was investigated using MTT against the NSCLC cell line A549, with SAHA and AMSA include as positive controls in the study. To enable spatially detailed assessment of therapeutic response, biophotonics-enabled confocal fluorescence imaging was employed to visualize cellular morphology, nuclear integrity, and fluorescence-based staining patterns at subcellular resolution. MTT assays performed on the A549 cell line revealed that compounds 3A and 3B exhibited IC_{50} values of approximately 10 μM, demonstrating the potent cytotoxic efficacy of the synthesized compounds. Furthermore, confocal fluorescence imaging showed pronounced alterations in nuclear architecture, chromatin organization, and intracellular fluorescence distribution in treated cells compared to untreated controls, consistent with compound-induced cytotoxicity and DNA damage. The MTT assay and confocal fluorescence imaging results for bipyridine-based compounds 3A and 3B highlight their strong anticancer potential against NSCLC. Overall, this work demonstrates the applicability of confocal

biophotonics as a translational research tool for linking molecular drug action to functional cellular outcomes, which supports its use in preclinical anticancer drug evaluation and precision oncology for NSCLC.

Keywords: Anticancer, bipyridine, biophotonics, cell viability, confocal microscope

[B17] Optical spectroscopy-based assessment of probiotic metabolite-induced functional alterations in mesenchymal stem cells

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Bioactive metabolites secreted by probiotics also known as postbiotics, are gaining attention for their potential to modulate stem cell behaviour and enhance regenerative therapies. However, comprehensive analysis of these complex cellular responses induced by postbiotics often requires sophisticated approaches such as metabolomics and proteomics, which are invasive, costly as well as time consuming. In this study, we have investigated the effect of *Lactobacillus rhamnosus*-derived cell-free supernatant (LR-CFS) on human adipose-derived mesenchymal stem cells (hADMSCs) using optical spectroscopic approaches namely UV-visible spectroscopy and hyperspectral imaging (HSI). Characterization of cell free supernatant was done using gas chromatography (GC) analysis which confirmed the presence of key metabolites such as lactate, butyrate, succinate and acetate. These metabolites in lower amounts are well known to have stimulatory effects in cellular metabolism, potentially contributing beneficial effect on stem cells. UV–visible spectroscopic analysis revealed concentration-dependent changes in absorbance difference 530–560 nm corresponding to cytochrome c. The difference in absorbance intensities exhibited a biphasic response characterized by increased absorbance at lower

concentrations and a decline at higher concentrations. HSI, a non-invasive and label-free imaging technique, further revealed distinct spectral signatures associated with metabolic intermediates in hADMSCs treated with increasing concentrations of LR-CFS compared to untreated controls. Notably, a biphasic response was observed (up to 20 % increase) for both reduced cytochrome c at 550 nm and oxidized cytochrome c at 530 and 630 nm. These spectroscopic findings qualitatively correlated with biphasic changes in mitochondrial dehydrogenase activity and cell viability, as assessed by the MTT assay. Thus, these findings demonstrate that HSI can effectively monitor dose dependent postbiotic effects on stem cells, offering valuable insights for optimizing postbiotic applications in regenerative medicine.
Keywords: *Lactobacillus rhamnosus*, Cell free supernatant, Human adipose-derived mesenchymal stem cells, Hyperspectral imaging, MTT assay.

[B18] Peroxynitrite-Driven Oxidative Remodeling and Aggregation of Hemoglobin: Implications for Redox-Mediated Hemoglobinopathies

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Peroxynitrite (PN), a potent nitrating agent generated during oxidative stress, modifies protein structure and function, yet its influence on hemoglobin (Hb) aggregation remains poorly defined. The current study investigates PN-induced structural, chemical, and morphological changes in Hb using complementary spectroscopic and imaging approaches. Intrinsic fluorescence revealed concentration-dependent quenching with red-shifted emission, indicating oxidation of aromatic residues and disruption of the local microenvironment. UV–visible spectroscopy showed increased absorbance at 280 nm and within the heme Soret band, consistent with unfolding-driven chromophore exposure and heme perturbation. Thioflavin T assays confirmed the formation of β-sheet–rich aggregates, whereas 8-Anilino-1-naphthalenesulfonic acid (ANS) binding demonstrated marked increases in

surface hydrophobicity accompanying conformational destabilization. Fourier Transform Infrared Spectroscopy (FTIR) spectra displayed pronounced alterations in amide I and II bands, reflecting peptide modification, secondary-structure loss, and protein crosslinking. Fluorescence signatures attributed to dityrosine chemistry suggested heterogeneous tyrosine oxidation products and higher-order assemblies rather than discrete classical dimers. Scanning electron and fluorescence microscopy revealed a PN-dependent transition from dispersed native morphologies to dense, network-like aggregates. Dynamic light scattering quantitatively corroborated these observations, showing substantial increases in hydrodynamic diameter with rising PN levels. Together, these data demonstrate that PN promotes extensive oxidative remodeling of Hb, driving misfolding and aggregation through coordinated modifications of aromatic residues, heme chemistry, and secondary structure. This integrative framework links nitrative stress to Hb aggregation and informs mechanisms relevant to hemolytic, inflammatory, and oxidative disease contexts. These insights advance redox biology perspectives and support biomolecular targets for diagnostics, prevention, and therapeutic intervention strategies worldwide.

Keywords: Hemoglobin; Aggregation; Peroxynitrite; Oxidative stress; Protein Misfolding

[B19] Bio-Derived Carbon Quantum Dot Mediated Embryonic Grafting for Targeted Enhancement of Graft Union Formation

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Cereal grains are non-leguminous monocots that are grown in huge scales and provide the highest amount of food energy worldwide and their increased demand ultimately leads to overuse of chemical fertilizers. This research addresses this issue by grafting a cereal crop (*Oryza sativa* L.) with a legume (*Cicer arietinum* L.) that is a dicot, by means of embryonic grafting for intergeneric trait exchange resulting in the rice plant being able to naturally fix nitrogen. There remains need for more targeted regulations to enhance graft success and so, the approach implemented in the study is, targeted delivery of bio-derived or green synthesised carbon quantum dots (CQDs) at the graft junction, supported by the growing evidence highlighting their effectiveness in enhancing plant growth, yield and even in bioimaging. The CQDs are synthesised from *Dendrobium ovatum*, an epiphytic orchid as the source, through microwave assisted, hydrothermal methods and then evaluated for their potential in enhancing graft union and growth. They are biocompatible, intrinsically photoluminescent, nanoscale in size, non-toxic, amenable to surface functionalization and are identified, characterized, using instruments like fluorescence spectroscopy, X ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIS). To feed the ever-increasing population, chemical fertilizers are overused and this leads to soil and water contamination due to leeching, residual chemical remains in food, emission of harmful greenhouse gases like nitrous oxide that indirectly affect ecosystem stability and pose long-term health risks. So, the study explores a sustainable strategy to reduce fertilizer dependency and enhance crop yield, with potential benefits for food security and human health.

Keywords: embryonic grafting, nitrogen fixation, green carbon quantum dots, photoluminescence, food security

[B20] Evaluation of Compounds 3A and 3B as Dual HDAC and Topoisomerase Inhibitors in Human Melanoma Cells

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Melanoma is a highly aggressive cancer characterized by epigenetic dysregulation and genomic instability, necessitating therapeutic strategies

that target multiple oncogenic pathways at once. Dual inhibition of histone deacetylases (HDACs) and topoisomerases (Topo) has emerged as a promising strategy for modulating transcriptional regulation and triggering DNA damage mediated cell death. In this study, compounds 3A and 3B were evaluated as potential dual HDAC and topoisomerase inhibitors in human melanoma cell lines A375 and A2058. The antiproliferative efficacy was assessed through IC_{50} determination, which revealed a dose-dependent reduction in cell viability for both compounds. To demonstrate both mechanistic and translational relevance, biophotonics-enabled fluorescence imaging was used to visualize intracellular responses at the cellular level. Immunofluorescence staining revealed significant nuclear morphological changes indicating chromatin remodeling and DNA damage. Apoptosis induction was further confirmed using fluorescence-based apoptotic staining, indicating a significant increase in apoptotic cell populations after treatment with compounds 3A and 3B compared to controls. By integrating quantitative cytotoxicity profiling with advanced fluorescence imaging, this study demonstrates the role of biophotonics as a powerful tool for mechanistic validation in anticancer drug evaluation. The findings support compounds 3A and 3B as promising dual HDAC–Topo inhibitor prospect, emphasizing their translational potential in melanoma therapy.
Keywords: Anticancer, apoptosis, biophotonics, fluorescence, melanoma

[B21] Optics- Assisted evaluation of Anticancer Derivatives in MCF-7 and A549 cells

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Optical and spectroscopic techniques offer non-invasive, sensitive and quantitative platforms for assessing anticancer therapies and studying drug-cell interactions. Using optics-assisted analytical techniques, we outline the synthesis and *in vitro* evaluation of two derivatives of oleanolic acid and their anticancer efficacy against A549 and MCF7 cell lines. Optical density-based

colorimetric tests were used to quantify antiproliferative activity, which made it possible to compare cancer models and accurately determine dose-dependent cytotoxic effects. Fluorescence-based methods were used to examine intracellular biochemical changes brought on by treatment, such as the measurement of ROS production using fluorescence spectroscopy and the observation of treatment induced morphological changes linked to apoptosis using fluorescence microscopy. The optical characteristics and stability of the synthesized derivatives were assessed using UV-visible spectroscopy. The combination of spectroscopic and imaging-based optical readouts allowed for real-time, non-destructive monitoring of cellular responses, as well as mechanistic insights into anticancer action. The synthesized compounds showed notable antiproliferative activities against A549 and MCF-7 cell, indicating their potential as promising anticancer agents. Significantly, role of optical approaches in translational cancer research and drug development, as well as the importance of photonics- driven tools in linking molecular design, cancer biology and therapeutic evaluation.

Keywords: Anticancer, biophotonics, fluorescence, optical, spectroscopy

[B22] Isoform-Selective Chloronicotinamide HDAC Inhibitors as Potential Therapeutic Agents Against Neuroblastoma

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Epigenetic regulation of chromatin is primarily governed by reversible histone acetylation and deacetylation, mediated through the addition or removal of acetyl groups from lysine residues of histone tails. Dysregulation of HDACs has been widely implicated in cancer progression, where aberrant HDAC activity promotes uncontrolled cell proliferation and survival. Consequently, HDACis have emerged as promising anticancer agents due to their ability to modulate multiple signaling pathways essential for tumor growth. Although hydroxamic acids represent the most extensively studied class of HDACis, their lack of isoform selectivity and associated toxicities have driven interest toward alternative scaffolds such as benzamides, which exhibit improved selectivity toward specific HDAC isoforms. In the present study, a series of previously synthesized novel chloronicotinamide derivatives (3a–3f), derived from 2-chloronicotinic acid, were evaluated for their anticancer potential against the human neuroblastoma cell line SH-SY5Y. Cytotoxicity screening identified compound 3f as the most potent analogue, exhibiting an IC_{50} value of 7.84 µM. Enzymatic assays further revealed that compound 3f selectively inhibited HDAC1 with an IC_{50} of 7.74 µM. Cell-cycle analysis demonstrated a pronounced arrest at the G2/M phase, indicating interference with cell-cycle progression. Molecular docking studies supported these findings, showing strong binding interactions of the synthesized compounds, particularly with HDAC2. Collectively, these results highlight chloronicotinamide-based HDAC inhibitors, especially compound 3f, as promising lead candidates for the development of targeted therapies against neuroblastoma.

Keywords: Anti-cancer, benzamide, cell cycle, choro nicotinamide, HDAC inhibitors

[B23] Non-Destructive Raman Spectroscopic Profiling of Selected Millet Varieties

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Surface topography is a strategic factor influencing the physical, chemical, and electrical properties of materials with macro- to nano-scales. The surface features like roughness, texture, grain boundaries, and nano-asperities play a vital role in determining mechanical, tribological, optical, electrical, and catalytic behavior. This lecture presents an overview of surface topography characterization techniques, highlighting the evolution from conventional microscopic methods to advanced nanoscale analysis. The presentation covers fundamental concepts of surface morphology and roughness parameters, followed by commonly used techniques including optical microscopy, stylus profilometry, Field emission scanning electron microscopy (FESEM), Scanning tunneling microscopy (STM), and atomic force microscopy (AFM). Emphasis is placed on correlating surface topography with material performance in applications such as thin films, nanostructured coatings, semiconductor devices, biomaterials, and energy materials. By integrating multi-scale characterization approaches with practical examples, this lecture underscores the importance of surface topography analysis in materials design, quality control, and nanotechnology research

Keywords: Millets, Raman spectroscopy, Starch crystallinity

[B24] Sustainable Utilization of Dried *Eichhornia crassipes* Biomass for the Fabrication of Carbon Quantum Dots; Characterization and Bio-Imaging Applications

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Water hyacinth (Eichhornia crassipes) is one among the most invasive aquatic species in India and is known to cause significant environmental and socio-economic effects. This study aims to describe a green, hydrothermal synthesis of Carbon dots, known for their low toxicity, high stability and tunable fluorescence properties, from dried Water Hyacinth leaves as an attractive approach to maintain sustainability and control the hyacinth population. High quantum yield carbon quantum dots were synthesized from dried water hyacinth leaves by hydrothermal pathway and in an attempt to enhance their specificity to DNA the Carbon Quantum Dot surface was later modified with metal ions like Magnesium and/or Zinc, etc. The Mg-doped-Carbon dots, Zn-doped-Carbon dots, etc display appreciable fluorescence with excitation/emission maxima and excitation independent emissions. The thus synthesized Carbon Quantum Dots were characterized via UV-Vis spectrophotometer, Malvern Zetasizer, Fluorescence Spectroscopy, X-ray

Photoelectroscopy, Fourier Transfer Infrared spectroscopy, Scanning Electron Microscopy and Transmission Electron Microscopy. The Carbon Quantum Dots were tested for their applications in differential staining of DNA from plant and blood samples, in its isolated form (through gel electrophoresis) as well as in-cell with varying levels of success.

Keywords: Carbon quantum dots (CQDs), Water Hyacinth, Photoluminescence, Fluorescent probes, Surface modification

[B25] Experimental Implementation of Continuous-Wave Diffuse Optical Tomography for Structural Imaging

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Diffuse Optical Tomography (DOT) is a non-invasive imaging technique that uses NIR light for examining the internal structure of highly scattered materials. However, image reconstruction problems exist as a result of strong diffuse light and lack of spatial resolution. The paper outlines the experimental assessment and discussion of the Continuous-Wave Difference Optical Tomography (CW-DOT) system for structural imaging. The required images for the cylindrical reference object and those with inhomogeneity objects at various rotation angles were obtained by employing a near-infrared light source with a CMOS camera-based detector system for transmission imaging. Two-dimensional transmission images obtained in the process are averaged in one dimension in the vertical direction for cylindrical objects. Reference object images are obtained by stacking images obtained from projections of reference object images at various rotation angles, while object images use a logarithmic ratio for object and reference object measurements for attenuation images. Image reconstruction has been performed with simple back-projection of the attenuation sinogram. The experimental results show the ability to detect internal inhomogeneities of the medium in the scattered field. However, there are issues in the location and resolution of the image. There has also been the presence of boundary

dominated artifacts in the reconstructed images, as characteristic of the diffusive transport in CW-DOT. In this study, the feasibility and limitation of the CW-DOT in qualitative structural imaging can be observed. However, the outcomes of this research highlight the significance of photon diffusion in relation to methodologies, providing a distinct framework of experiments in future improvements.

Keywords: Diffuse Optical Tomography, Continuous-Wave DOT, Optical Tomography, Phantom Imaging, Back-projection.

ABSTRACTS

POSTER PRESENTATIONS

Review Posters

[R01] Spectroscopic Detection of Extracellular Matrix Biomarkers in Colorectal Cancer

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Colorectal cancer (CRC) is a serious condition affecting the lives of millions worldwide. The conventional diagnostic approaches lack sensitivity and often involve invasive procedures, and they focus mainly on the cellular and genetic alterations observed in CRC, but studies have shown that remodelling of the tumour microenvironment is a hallmark of disease progression. Extracellular matrix (ECM) is a major component of the tumour microenvironment and provides structural support, organizes cells, and helps regulate important signals that keep the tissue healthy. Its components, such as structural proteins, glycoproteins, proteoglycans, and glycosaminoglycans, are arranged in an order, and the basement membranes are intact, and the tissue has the right stiffness. In CRC, this balance is disrupted, and the ECM undergoes extensive structural and biochemical modifications. These changes create an environment that supports tumor invasion and migration. Therefore, the ECM in CRC has a distinct structure and biochemical profile. Such biochemical features can be detected as molecular signatures using spectroscopic techniques. This review provides an overview of how biomolecular fingerprinting of the ECM using spectroscopy-based techniques can be a strategy for CRC diagnosis. It discusses a range of spectroscopic approaches that allow label-free detection of multiple ECM components and also highlights the important ECM biomarkers observed in CRC and their characteristic spectral signature. The role of computational tools is also briefly discussed, along with key challenges and future directions toward clinical application.

Keywords: Colorectal Cancer, Extracellular matrix, Spectroscopy, Diagnosis, Biomolecules

[R02] A Review of Wearable Biophotonic Device Studies for Healthcare Applications

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The use of wearable biophotonic technologies for continuous, non-invasive monitoring continues to grow in importance as a solution for healthcare needs. In this review, we have examined current studies on wearable biophotonic technologies and provided an overview of their effectiveness, and application areas. We also discussed challenges and future trends that support health monitoring and personalized health management. To identify relevant articles, keywords such as "*wearables*", "*biophotonics*", and "*healthcare*'' were used as search strings in Scopus and Web of Science databases. Accordingly, in the initial screening process, Scopus identified 125 articles and Web of Science identified 226 articles. After applying a publication period filter from 2015 to 2025, 108 articles from Scopus and 189 articles from Web of Science remained. Titles and abstracts were then reviewed for relation to the study's aims, and the most relevant publications were thematically classified. The necessary references have been added to their respective sections, offering evidence-based insights into wearable biophotonic technologies. Several wearable biophotonic devices that have been identified in the study provide the ability to measure physiological parameters, including heart rate, circulation signals, and various diseases. The studies further demonstrate that their ability to measure more reliably with access to real-time data, along with the application of advanced analysis techniques, has enabled researchers to improve their ability to monitor individuals' health. Biophotonic-based wearable devices are a rapidly growing field in medical diagnostics and individual disease management. The studies taken into consideration in this review demonstrate how these devices can greatly improve the ability to collect and analyze health-related information, and they strongly suggest that wearable biophotonic systems will become widely adopted, further developed, and validated in the future.

Keywords: Wearable biophotonic devices, Non-invasive health monitoring, Biophotonics in healthcare, Wearable sensors and Personalized health management

[R03] Early Detection of Cervical Cancer: A Review of Screening Methods, Challenges and Future Detection

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Cervical cancer ranks among the top causes of morbidity and mortality among women globally. Identifying the disease early is crucial for improving prognosis and reducing the disease burden through timely intervention. This overview presents a review on novel and existing methods for the early identification of cervical cancer. Traditional screening methods such as pap smear test, visual inspection with acetic acid (VIA), along with advanced techniques like HPV DNA testing, colposcopy, and liquid based cytology testing are discussed. Advancement in digital pathology by integration of artificial intelligence and machine learning into cervical cancer diagnostics is also explored, highlighting their potential in improving accuracy and accessibility in both clinical and resource limited settings where expert cytopathologist are scarce.
Keywords: Cervical Cancer, pap smear, Deep Learning, LSIL, HSIL, NILM, SCC

[R04] Review of Rice Starch Modification Techniques: FTIR-Based Structural Changes and Their Influence on Glycemic Index

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Rice starch is a major dietary carbohydrate and is associated with rapid digestion and a high glycemic index (GI). Modifying starch helps to reduce digestibility and improve its nutritional profile. FTIR spectroscopy is used to assess starch structure, and the 1047/1022 cm^{-1} ratio indicates molecular order related to digestion. Various modification methods have been applied to rice starch to alter its molecular organization and digestive behaviour. This review focuses on understanding how different rice starch modification strategies influence FTIR characteristics and predicted GI. Five research studies were reviewed, covering rice starch modification by dietary fiber incorporation using okara, extrusion processing with soy and whey protein isolates, heat–moisture treatment (HMT) of black and red rice starch, enzymatic debranching followed by interaction with phenolic compounds, and pulsed electric field (PEF) treatment combined with α-amylase hydrolysis. Reported FTIR spectral changes, particularly the 1047/1022 cm^{-1} ratio, were compared with in vitro digestibility and predicted GI trends presented in each study. This shows that modification methods enhancing molecular order increase the FTIR 1047/1022 cm^{-1} ratio and reduce starch digestibility. Enzymatic debranching combined with phenolic compounds showed the greatest increase in molecular order and the strongest reduction in predicted GI. Heat–moisture treatment and PEF-assisted enzymatic modification also effectively lsowered digestibility, while dietary fiber incorporation produced moderate effects. In contrast, extrusion processing reduced molecular order and increased starch digestibility. Overall, FTIR analysis provides a useful approach for linking starch structural changes with glycemic behaviour.

Keywords: Rice starch, modifications, FTIR, starch digestibility, glycemic index

[R05] Spectroscopy in Cancer detection

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Carcinogenesis can be detected by using several techniques which include imaging tests such as MRI or ultrasound, biopsies, and endoscopy. These techniques, however, are accompanied by drawbacks which involve invasiveness, time-taking, as well as limitations in molecular sensitivity. Spectroscopy, on the other hand, offers label-free, objective, and non-invasive characterization by making use of samples such as biofluids. Spectral fingerprints that arise from biomolecules in the body are analyzed for the detection of alterations associated with biochemistry. Several spectroscopy techniques are associated with the detection of the disease. Combining the acquired spectra with computational approaches can help identify significant patterns to classify the samples as carcinogenic or otherwise. This workflow allows the classification in an objective manner. Spectral analysis allows a shift from invasive diagnostic techniques to one that relies on a more molecular basis. While more work is required in terms of larger scale validation and regulatory approval for clinical application, constant advances in technical approaches and AI involvement is paving the way towards a much more efficient and cost-effective model for the detection of cancer that has potential to complement and even augment the clinical gold standards.

Keywords: Spectroscopy, cancer diagnosis, biomolecules, spectra, extracellular matrix

[R06] Chalcone-Based Chromophores for Bioimaging Applications

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Chalcones are a class of α,β-unsaturated carbonyl compounds that are broadly investigated due to their ease of synthesis, flexible structural features and extensive applications in the field of medicinal chemistry. Adaptable π-conjugated system of chalcone scaffold allows systematic substitution and heterocyclic integration which results in fine control over electronic distribution, molecular planarity and physicochemical properties. These factors have motivated the exploration of chalcones not only as pharmacologically active molecules but also as functional chromophores. In recent years, chalcones have gained increasing attention as small-molecule fluorescent probes for bioimaging applications. Natural donor-acceptor architecture of chalcones, especially when paired with electron-rich or electron-deficient substituents, facilitates rapid intramolecular charge transfer, which results in fluorescence emission with high stokes shifts and environment-sensitive optical responses. The incorporation of heterocyclic units including quinoline, indole, thiophene, furan, benzothiazole and coumarin improves fluorescence intensity, photostability and target specificity by extending π-conjugation and enhancing biological interactions. These features have allowed chalcone-based chromophores to be used as probes for cellular imaging, subcellular localisation, ion sensing and detection of biomolecular targets such as proteins and amyloid aggregates. Significantly, several heterocyclic chalcones exhibit aggregation-induced emission, fluorescence turn-on behaviour or solvatochromism which makes them useful for imaging in complicated biological processes where traditional fluorophores frequently experience quenching due to aggregation. Their relatively low molecular weight and synthetic flexibility enable additional optimization for biocompatibility and selectivity. This review critically investigates the structural characteristics, synthesis techniques and

structure-property connections of chalcones, with a focus on their progression into heterocyclic fluorescent probes for bioimaging. Current issues in water solubility, photobleaching resistance and *in-vivo* applicability are explored.

Keywords: Bioimaging, Chalcone, Fluorophore, Heterocyclic, π-conjugation

[R07] Biophotonics Approaches to Detect and Combat Bacterial Virulence Factors in the Wound Microenvironment

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The wound microenvironment and wound-associated infections are influenced not only by the local bacterial burden but also by the dynamic expression of virulence factors secreted by these pathogenic bacteria. Gradients of oxygen, pH, redox state, nutrients, host immune mediators, and mechanical stress drive early phenotypic switching in bacteria. This alters quorum sensing, toxin production, adhesins, motility, biofilm maturation, and stress-response pathways within, thereby determining the fate of wound healing processes. This review corroborates current evidence on how wound-specific physicochemical and biological cues reprogram bacterial virulence at early stages, emphasizing temporal transitions rather than static endpoints. We critically evaluate how biophotonic technologies, including optical spectroscopy, fluorescence lifetime imaging, hyperspectral imaging, Raman-based approaches, optical coherence tomography, and photonic biosensing, can non-invasively interrogate these transitions in situ. By linking optical readouts to virulence-associated metabolic states, signalling networks, and biofilm phenotypes, biophotonics offers a route to real-time stratification of infection risk and mechanism-informed intervention. We further summarize light-enabled anti-virulence strategies, including targeted photomodulation and photodynamic approaches, that suppress pathogenic behaviours without

imposing the selective pressures typically associated with bactericidal antibiotics. Also, we discuss translational challenges, including signal specificity in polymicrobial wounds, depth penetration, standardization, and clinical validation, and propose a framework for integrating biophotonic diagnostics with AI-enabled precision anti-virulence therapies. Together, these insights position early optical detection of virulence reprogramming as a foundation for next-generation wound management that prioritizes functional disarmament of pathogens over eradication.

Keywords: Wound microenvironment, Bacterial virulence reprogramming, Biophotonic diagnostics, Anti-virulence therapy, Optical imaging and spectroscopy

[R08] Naphthoquinone-Based Biosensing Approaches: Chemical Mechanisms and Emerging Opportunities

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Naphthoquinones are chemically versatile, redox-active scaffolds that have long attracted interest in medicinal chemistry because of their broad biological activity and tunable electronic properties. More recently, elements of naphthoquinone chemistry have begun to appear in biosensing research, where interactions such as redox processes, molecular binding, or changes in the local environment can be converted into measurable signals. This review captures various applications of naphthoquinone-based systems in biosensing, including electrochemical, colorimetric, and fluorescence-based approaches used to detect biologically relevant species such as metal ions, redox-active molecules, thiols, and microbial activity. Instead of providing a list of individual sensors this review mainly tries to capture the chemical principles that given signal generation which also includes redox mediated responses and modulation of optical properties through molecular design. Current naphthoquinone-based biosensors are largely developed as isolated systems, with limited effort devoted to establishing generalized design

principles that link molecular structure to sensing performance. As a result, structure–function relationships within naphthoquinone scaffolds remain poorly unified across different biosensing applications. In this context, the present review focuses on naphthoquinone scaffolds and examines how their intrinsic chemical and redox properties can be systematically leveraged as biosensing components. This perspective aims to outline a rational framework for integrating naphthoquinone scaffold design with biosensing functionality, thereby guiding future development in this area.

Keywords: Biosensors, Fluorescence-based detection, Naphthoquinones, Optical sensing, Redox-active scaffolds

[R09] Fluorescence imaging of rice chromosomes using Carbon Quantum Dots

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The rice genome is one of the most intensively studied plant genomes. Despite the wide molecular studies done in it, there are limited focus towards cytological characterization of rice genome specifically for each cultivar. Cytogenetics is a combination of cytology and genetics, and includes a detailed study of structure, nature, functions and abnormalities in chromosomes. Current techniques in chromosome analysis involves staining using Giemsa and DAPI, which can be used in advanced chromosome identification and FISH, which uses full chromosome paints as probes, helps in finding significant number of distinct landmarks for physical chromosomal mapping and precise karyotype comparison across different cultivars. Major disadvantage seen is that Giemsa, even though it has low toxicity, doesn't show multicolor imaging or specificity for live imaging, and DAPI showing photobleaching and photoconversion from green to red or vice versa forms under UV, which causes signal loss. Thus, these limitations have made way for using nanoparticles like Carbon quantum dots (CQDs). CQDs are widely used nanoparticles in many fields especially in bioimaging because they are chemically stable, and have good optical properties. Compared to conventional dyes and fluorescent stains, CQDs show better photostability, which is mainly due to their unique structure and composition. CQDs and nanoparticles can be used as alternative to the current techniques used as they also offer high quantum yields, longer decay times and reduced toxicity compared to other stains used. They bind to DNA and RNA differently allowing the chromatin labelling without any amplification steps, thereby lowering the costs. Synthesizing the CQDs from low-cost precursors like citric acid minimizes the use of expensive reagents. Thus, current techniques can be replaced with CQDs, reshaping cytogenetic analysis in plant root tips using simple available methods.

Keywords: Cytogenetics, Carbon quantum dots, fluorescent stains, chromosome, low-cost precursors.

[R10] Nanogel Based Strategies for Blood Brain Barrier Penetration in Targeted Drug Delivery

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Blood brain barrier is the biochemical and physical barrier that impedes treatment of central nervous system disorders as its highly selective in nature which blocks all macromolecules and most of the small molecule drugs from entering the brain. Blood brain barrier blocks drug entry mainly through tight junctions between endothelial cells that prevent passive diffusion of large molecules. Nanogels are 3D crosslinked network of polymers that could be an emerging platform for drug delivery because of their colloidal stability, biocompatibility and tuneable size. Nanogels can overcome the barrier by using multiple strategies such as passive targeting using thermosensitive polymers to enhance cellular uptake, surface modifications such as cell penetrating peptides, lipophilic coatings and protein corona modification to facilitate receptor mediated endocytosis. To ensure the functioning of these nanogels, characterization is required. Characterization techniques ensure successful chemical conjugation, elemental analysis, and validation of physical characteristics. Additionally, techniques like High Performance Liquid Chromatography and UV-Vis spectroscopy can be used to assess the quantification of drug loading efficiency and stimuli-responsive release. Nanogels offer a promising clinically translatable approach for management of central nervous system disorders through incorporating microenvironment responsive precision.

Keywords: Blood Brain Barrier, Central Nervous System, Drug delivery, Nanogel, Surface modification

[R11] Nano-engineered Biomaterials for Localized Drug Delivery in Dental Therapies

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Oral cavity tissues serve as a reservoir for a wide range of pathological conditions including potential cancerous lesions. Periodontitis is one such example of a chronic progressive inflammatory condition that leads to tissue loosening around the gums and eventually tooth loss. This condition is caused by microorganisms that invade the space between the tooth and gingival tissues, and the increased biofilm formation also leads to connective tissue damage. Herein, the drug delivery within the oral cavity poses challenges due to continuous salivary flow and shear forces present. Consequently, nanotechnology-based therapy approaches in dental applications have demonstrated significant advantages such as enhanced wound healing, controlled and targeted drug release, and reduced side effects. Biomaterials including, gelatin, alginate, chitosan, calcium phosphate are utilized as drug loading matrices, wherein, they support many drug delivery strategies namely hydrogels, fibers, nano-encapsulations and hypodermic delivery techniques. These nanoparticles are not limited to treatment delivery but are used as vessels for cancer diagnosis as well. Silver or zinc integrated combinational

nanoparticles are widely recognized for their antimicrobial properties due to their ability to penetrate cells and induce cell lysis, therefore, supporting their application in oral cancer therapy. A range morphological characterization and biological evaluation techniques can be employed depending on the type of nano-based drug delivery system fabricated to understand its efficiency and durability. Recent advances in nanotechnology holds significant potential improve and enhance dental treatment.
Keywords: Biomaterials, Dentistry, Drug Delivery, Nanotechnology, Oral Diseases

[R12] Histone Deacetylase Inhibitors for Imaging in Biophotonics: Molecular Probes for Cancer Detection and Therapy Monitoring

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Histone deacetylase inhibitors (HDACis) refer to the molecular modulators of histone deacetylases (HDAC), a group of 18 enzymes which are further categorised into various classes- I, IIa, IIb, III and IV. They are responsible for the regulation of both chromatin structure and the chromosomal protein function. HDAC-targeted therapy, though effective, lacks the necessary non-invasive methods required for the real-time assessment of pharmacodynamic response and HDAC target engagement in living beings. Traditional histological and biochemical techniques present static and indirect information, obstructing precise imaging and efficacy of the treatment. To bridge this gap, HDACis have been extensively modified by introducing imaging probes, making them suitable for biophotonics along with nuclear imaging techniques. Similarly, radiolabelled HDACis for PET imaging, such as [^{18}F]NT160, [^{18}F] SW-100 derivatives, and benzamide-based probes (e.g., CN147, CN133), allow both body and brain imaging, explaining *in vivo* distribution, and specific target binding.[^{11}C]Martinostat PET imaging explained dose-responsive HDAC target occupancy in rat brain, wherein self-

blocking decreased the tracer binding to ~36.5% of baseline (specific binding > 60%), allowing quantitative analysis of *in vivo* binding. CN147 displayed remarkably higher brain penetrance (~20:1 ratio compared to ~1:10 for CI-994) and with notable HDAC2/3 binding showed antidepressant-like effect. [^{18}F]NT160 allowed high-contrast PET of HDAC class IIa, displaying strong neurovascular permeability and localised uptake, foremost in hippocampus, cortex and thalamus. Expeditious tumor accumulation and elevated tumor signal to background (SeCF-IRD800 TBR ≈5.2), enabling fluorescence-aided surgery and therapy regulation in hepatoma. Future approaches in biophotonics-based HDAC imaging comprise of enhanced isoform-specific probes, multimodal optical platforms for PET, and clinical implementation of cancer medicine and neuroepigenetic diagnostic tool.
Keywords: Biophotonics, Fluorophore, HDACi, HDAC probe, Imaging

[R13] Optical Microscopy for Investigating Cellular Dynamics of Melanogenesis

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Melanogenesis is the cellular process through which melanocytes produce and distribute melanin, determining pigmentation. During melanogenesis, coordinated changes in melanocyte cellular architecture, melanosome biogenesis and intracellular transport govern pigmentation outcomes. Despite extensive knowledge of the underlying biochemical pathways, non-invasive and reproducible visualization of melanosome formation, spatial redistribution and transport within melanocytes remains challenging. These processes generate intrinsic optical contrast through melanin accumulation and refractive-index heterogeneity, which can be directly interrogated using optical microscopy. Conventional optical microscopy techniques such as brightfield, phase contrast and differential interference contrast (DIC) enable label-free visualization of melanocytes undergoing melanogenesis by revealing changes in cell morphology, dendricity, melanosome density and intracellular organization. Phase contrast and DIC microscopy enhance sensitivity to melanosome-rich regions by exploiting refractive-index variations arising from pigment accumulation and organelle redistribution. Beyond qualitative visualization, optical microscopy supports semi-quantitative analysis through visual scoring, image-based melanin estimation and comparative assessment across experimental conditions. Quantitative phase imaging approaches, including Spatial Light Interference Microscopy (SLIM), provide reproducible measurements of optical path-length variations associated with melanosome content and intracellular mass redistribution. Together, these complementary optical modalities offer insight into the spatial and functional dynamics of melanogenesis. Integrating conventional optical microscopy with quantitative phase imaging frameworks improves reproducibility and interpretability, establishing optical microscopy as a practical and versatile tool to study melanocyte biology and pigmentation regulation.

Keywords: Optical Microscopy, Quantitative Phase Imaging, Melanogenesis, Melanosome Dynamics

[R14] Seaweed-Derived Carbon Nanodots: Green Synthesis and Application in Nontoxic Live-Cell Imaging

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In translational bio photonics, creation of biocompatible fluorescent probes is essential for accurate and efficient cellular diagnostics. The conventional synthetic fluorophores have deleterious effects like cellular toxicity and photobleaching. Thus using an ecofriendly alternative such as Seaweed biomass for green synthesis of fluorescent carbon nanodots, provides highly effective results. This study focusses on utilizing specific Sargassum ssp. (a brown seaweed). As their organic components namely, nitrogen rich amino acids and polysaccharides lead to the formation of self dopped nitrogen-carbon dots (N-CDs) using one-pot hydrothermal carbonization technique. This eliminates the usage of any external chemical dopants.The Sargassum derived N-CDS are capable of longterm monitoring because of their remarkable photostability and high fluorescence quantum yield of 18.2%. A narrow size distribution of 2 to 8 nm is showcased by structural characterization, which facilitates effective cellular uptake and focused intracellular architecture labelling. These nanobots are most effective and nontoxic substitute for traditional agents. This is conferred by quantitative cytotoxicity assessments using CCK8 and MTT assays which verify their ability of maintaining high cell viability. Thus these carbon nanodots made from Sargassum is a marine-based nanotechnological clinical application which provide a scalable route for high-contrast cellular bioimaging and diagnostics.

Keywords: Sargassum ssp, Carbon Dots, Green Synthesis, Bioimaging, Biocompatibility, Hydrothermal Carbonization

[R15] Optical Biosensing of Streptococcal Metabolic Fingerprints for Early Oral Cancer Detection

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During the progression of oral malignancies, numerous ecological factors within the oral niche undergo changes. Among them, oral microflora and microbial metabolites are key determinants that decide the fate of the cancer microenvironment. Recent studies suggest that oral *Streptococcus* sp. portrays a complex commensal-pathogenic dysbiotic shift as oral cancer progresses from a pre-malignant state to a malignant state. These interactions generate a distinct biochemical milieu in saliva and the mucosal surface, which constitutes a streptococcal metabolic fingerprint that can be tracked to access oral cancer non-invasively. Biophotonic technologies emerge as powerful tools that enable the precise detection of *Streptococcus*-associated metabolic changes using label-free and targeted optical readouts. Raman and infrared spectroscopy enable molecular-level detection of lactate, short-chain fatty acids, nucleic acids, and biofilm-derived extracellular polymeric substances. Autofluorescence and fluorescence lifetime imaging (FLIM) can

elucidate shifts in NADH/FAD redox ratios associated with Warburg-like metabolic remodeling within the tumor microenvironment. Optical biosensors incorporating pH-sensitive, redox-responsive, and ROS-sensitive fluorophores can be used to detect intracellular and intratumoral changes driven by streptococcal colonization and tumor-microbiome interactions in saliva and mucosal swabs. In this review-based perspective, we corroborate the current understanding of streptococcal metabolism in oral carcinogenesis using optical biosensing platforms, including surface-enhanced Raman spectroscopy (SERS), fiber-optic probes, microfluidic saliva chips, and wearable oral sensors. We propose a translational framework of *Streptococcus*-driven metabolic perturbations that can be converted into quantifiable optical signatures for the early detection of oral cancer, risk stratification, and therapy monitoring, thereby effectively managing oral cancer.

Keywords: Biophotonic Technologies, Dysbiosis, Optical Biomarkers, Oral Cancer, *Streptococcus*.

ABSTRACTS

ORAL PRESENTATIONS

Bridging light and life sciences to drive scientific innovation

[OP01] Development and Characterization of a Biodegradable Starch-Reduced Graphene Oxide Composite Film for Wound Dressing Applications

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Chronic wounds require a stable, moist, and biocompatible environment to support effective tissue regeneration, yet many conventional wound dressings act only as passive barriers and rely on non-biodegradable synthetic materials. Biopolymer-based dressings offer a sustainable alternative but often suffer from limited mechanical stability and functional performance. This study reports the development and characterization of a biodegradable potato starch-based composite film reinforced with reduced graphene oxide (rGO), intended for use as a base matrix for wound healing dressings modifiable with bioactive agents. Composite films were fabricated using a solution casting method with optimized concentrations of rGO incorporated into the starch matrix. Physicochemical and structural characterization was performed through thickness analysis, moisture content evaluation, Fourier transform infrared spectroscopy (FTIR), and X-ray diffraction (XRD) to assess film integrity, molecular interactions, and material stability. The incorporation of rGO resulted in a significant increase in film thickness and moisture retention compared to starch-only films, indicating improved hydration capacity relevant to wound healing applications. FTIR analysis confirmed successful integration of rGO within the starch matrix through altered characteristic absorption bands, while XRD patterns reflected changes in crystallinity associated with nanofiller incorporation. Biological evaluation focused on cytocompatibility assessment using in vitro cell viability assays, which demonstrated acceptable biocompatibility across functional rGO concentrations, with cell viability remaining above established safety thresholds. These findings indicate that controlled incorporation of rGO enhances material performance without compromising cellular compatibility. Overall, this work establishes a sustainable and biocompatible starch-rGO composite film as a foundational wound dressing matrix. The results support

its potential for further functionalization with therapeutic or sensing agents, offering a translational platform for next-generation biodegradable wound care materials.

Keywords: Wound Healing, Biodegradable, Starch, Reduced graphene oxide, Composite Film

[OP02] Nanoengineered Biphasic Calcium Phosphate: Tunable nHAP/β-TCP Composition via a One-Pot Wet-Chemical Protocol

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Autologous bone tissue transplantation is one of the major procedures performed to repair the bone tissue defects. However, repairing large, complex, or non-healing bone defects remains a major orthopedic challenge. Currently, hydroxyapatite (HAP) or β- tricalcium phosphate (β-TCP) based bone graft are widely used to develop bone graft as an alternative. HAP provides excellent biocompatibility and osteoconductivity but degrades slowly, limiting remodeling, while β-TCP degrades rapidly to enhance regeneration but lacks long-term mechanical stability. However, biphasic bioceramic having characteristic beneficial properties of both the HAP and TCP phases is widely recognized for advanced bone tissue graft development. However, synthesis of such biphasic bioceramic with ability to control the ratio of biphasic component remains a challenge. To overcome the current bone repair challenges, we propose a one-pot synthesis of biphasic calcium phosphate (BCP) with tunable HAP and β-TCP phase ratios. This method leverages bioactive polymer and microwave assistance to facilitate Ca^+ ions nucleation, forming an amorphous precursor that converts into β-TCP upon sintering along with a part of HAP. By adjusting synthesis parameters, the HAP/ β-TCP ratio, particle size (nanoscale), bioactivity, and degradation rates can be precisely controlled. This streamlined strategy enhances reproducibility, enables controlled bioceramic properties, and offers improved osteogenic potential for advanced bone regeneration solutions. This

innovative one-pot synthesis of BCP yields up to 300 nm nanoparticles with precisely tuneable HAP/β-TCP phase ratios. The process enables control over degradation and bioactivity. The synthesized bioceramics exhibited particle sizes ranging from approximately 265.28 nm (HAP) to 560.5 nm (β-TCP), with polymer-containing samples between 228.5 and 340.7 nm. X-ray diffraction confirmed pure HAP and β-TCP phases, while polymer incorporation induced BCP formation by modulating nucleation and growth showing tunable biphasic ratios. The material demonstrated excellent biocompatibility and effectively promoted osteogenic differentiation of mesenchymal stem cells by supporting adhesion and proliferation. The one-pot synthesized biphasic calcium phosphate with tunable HAP/β-TCP ratios and nanoscale particle size demonstrates controlled bioactivity and degradation. This novel material offers a promising, multifunctional scaffold with superior potential for advanced bone regeneration.

Keywords: Biphasic bioceramics, Hydroxyapatite, Tricalcium phosphate, Bone regeneration

[OP003] Antifreeze Protein Mimetics: Self-Healing Coatings for Ice-Free Optical and Photonic Surfaces

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Although ice may appear harmless, it silently disables the technologies that we rely on. A thin layer of ice can weaken aircraft and drones, blind sensors, freeze moving parts, and make vital systems unreliable in areas with a lot of snow or the polar regions. Our standard fixes, such as heaters, chemical de-icing agents, and protective coatings, only function while they remain intact and continuously consume electricity. But nature has a different tale to tell. Since they contain antifreeze proteins that gently attach to ice crystals and prevent them from growing out of control, many cold-dwelling organisms can survive. Our work investigates a bio-mimetic, self-healing ice-phobic film that mimics the actions of these antifreeze proteins, motivated by this quiet

resilience. The film prevents ice from attaching or spreading by manipulating the energy between surfaces and interfering with lattice matching at the surface, as opposed to using physical force. Additionally, the film may reconstruct itself and regain its protective function when it is damaged or scratched, just like nature would. Without using up valuable energy, such a coating could safeguard aircraft, drones, optics, communication systems, and remote-operation equipment. This gentle, nature-inspired approach may provide a safer and more sustainable way to keep technology alive in the world's coldest regions in military, rescue, and aerospace settings where every gram and every watt counts.

Keywords: Antifreeze proteins, Self-Healing Kinetics, Ice-phobic films, Energy Manipulation, Lattice Matching

[OP04] Studies on Photo-Modulated Insulin Secretion from Optogenetically Modified β-Cells

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Diabetes mellitus is a chronic metabolic disorder characterized by either impaired insulin secretion or insulin resistance. Current diabetes management predominantly relies on exogenous insulin administration, which often compromises quality of life and is associated with complications such as hypoglycemia. Cell-based therapies offer a promising alternative, however, achieving precise and user-controlled insulin release remains a major challenge. Optogenetics offers a powerful tool for precise modulation of cellular functions through light, thus its integration bears potential for user controlled hormonal release. In this study, we expressed Channelrhodopsin-2 (ChR2), a light-sensitive cation channel, in MIN6 cells (mice pancreatic β-cells) and investigated photo-modulated insulin secretion. Initial investigations were carried out in monolayer cultures to systematically study the effect of blue-light irradiation on intracellular calcium dynamics and insulin secretion. Results demonstrated that a maximum increase in insulin secretion (~ 25%) was observed with continuous irradiation for 10 seconds compared to unirradiated controls. Notably, introducing an intermittent irradiation protocol (5 seconds on, 10 seconds off) significantly enhanced insulin secretion by 35%. To better mimic the native islet microenvironment, ChR2-expressing MIN6 cells were subsequently cultured as 3D multicellular spheroids and their growth was monitored over time through microscopic analysis. The light-induced insulin secretion from spheroids exhibited size-dependent behavior, with smaller spheroids demonstrating improved cell viability and higher insulin secretion compared to larger spheroids. Additionally, the enhanced cell–cell and cell–extracellular matrix interactions within spheroids resulted in greater photo-stimulated insulin secretion relative to monolayer cultures. Overall, these findings demonstrate the potential of optogenetics to provide precise, light-mediated control over insulin secretion, with 3D cell models being more promising than 2D cell cultures. This integrated approach holds significant potential for next-generation cell-based therapies for diabetes management.

Keywords: Optogenetics, diabetes management, cell-based therapy, MIN6 cells, spheroids

[OP05] Characterizing Metabolic Signatures in Colon Tissues using Autofluorescence Imaging

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Metabolic signatures are critical biomarkers for distinguishing cancerous from non-cancerous tissues. In this study, we focus on metabolic changes in colon tissues, specifically comparing healthy samples to malignant tissues. NADH and FAD are endogenous autofluorescent cofactors that function as essential electron carriers in metabolic pathways, including glycolysis and oxidative phosphorylation. In this study, we employed fluorescence microscopy to quantify the autofluorescence of NADH and FAD in colon

tissues. By calculating the optical redox ratio (FAD / [NADH + FAD]), we established a quantitative marker of cellular metabolic state of tissue without need for external dyes. Our findings demonstrate that this label-free imaging approach provides diagnostic insights that complement or exceed the information gained from conventional Hematoxylin and Eosin (H&E) staining. This research highlights the potential of autofluorescence imaging as a powerful diagnostic tool for real-time metabolic assessment in colon cancer diagnostics.
Keywords: energy metabolism, fluorescence microscopy, tissues, endogenous

[OP06] A Portable LED-Based Autofluorescence Platform for Label-Free Detection of Protein Misfolding and Aggregation

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Protein misfolding and aggregation are central to numerous pathological conditions, including neurodegenerative diseases; however, their detection typically depends on complex and high-cost instrumentation, limiting accessibility in routine and resource-constrained settings. In this work, we report the development of a portable and cost-effective optical platform based on light-emitting diodes (LEDs) and custom metal-coated cuvettes to enhance intrinsic protein autofluorescence for label-free detection of protein unfolding and aggregation. The performance of the device was evaluated using bovine serum albumin (BSA) and human serum albumin (HSA) subjected to controlled thermal stress and characterized through a multimodal biophysical approach. Conventional assays, including UV–visible absorbance, Thioflavin T fluorescence, ANS (8-anilino-1-naphthalenesulfonic acid) binding, and Congo red assays, confirmed protein destabilization, β-sheet enrichment, and amyloid-like fibril formation. Scanning electron microscopy and fluorescence microscopy revealed pronounced morphological transitions into ordered fibrillar assemblies. Dynamic light scattering showed significant increases in hydrodynamic diameter ($p < 0.05$), while Fourier-transform

infrared spectroscopy and circular dichroism spectroscopy demonstrated α-helix loss accompanied by β-sheet gain, with these effects being more prominent in HSA. X-ray diffraction further verified the presence of ordered β-sheet packing in aggregated proteins. Across all analyses, HSA exhibited a higher aggregation propensity than BSA, reflecting intrinsic sequence-dependent stability differences. Overall, the results demonstrate that the proposed LED-based platform reliably detects protein misfolding in strong agreement with established biophysical techniques, while offering advantages of portability, affordability, and scalability. This approach provides a promising route for routine protein stability monitoring and accessible amyloid diagnostics.

Keywords: Protein aggregation; Autofluorescence; LED-based optical device; Amyloid detection; Protein misfolding

[OP07] Automated Image Stitching for Large-Field Microscopy Using GPU-Accelerated Serpentine Scanning

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Automated image stitching is critical in optical microscopy to overcome the limited field of view and enable quantitative analysis over extended regions of interest without manual intervention. In motorized-stage systems employing serpentine as well as raster scanning, nonuniform tile spacing, variable overlap, and mechanical backlash introduce alignment uncertainties that challenge conventional stitching pipelines. Prior works on microscopy mosaicing has demonstrated accurate stage-model–based stitching and scalable performance for large tile grids, hybrid CPU–GPU implementations for large-scale optical microscopy images, and robust feature-based algorithms for whole-slide microscopic data. These prior studies highlight the need for accurate overlap estimation, seamless fusion, and high computational throughput to support real-time or near–real-time imaging workflows. We present an automated, GPU-accelerated stitching pipeline tailored for serpentine-scanned tile acquisitions in an *in-house* built microscope. The method comprises three stages: (1) pre-processing, where horizontal flipping corrects the serpentine scan direction using CUDA-accelerated operations, reducing pre-processing time by a factor of 2.8; (2) overlap detection, where normalized cross-correlation–based template matching serves as the primary alignment mechanism, estimating pairwise overlaps independently to accommodate variable tile spacing; and (3) blending, where linear alpha blending with configurable blend width generates visually seamless transitions between adjacent tiles using GPU arithmetic operations. A sequential composition strategy accumulates tiles without pre-allocating the full mosaic, enabling memory-efficient reconstruction of arbitrarily long rows and full-field images of the region of interest in near real time as the stage scans. Future work will incorporate quantitative stitching metrics, including structural similarity index (SSIM), feature localization error, edge continuity across tile boundaries, and intensity variance along seams, and will leverage these metrics to jointly optimize both acquisition and reconstruction parameters, complementing and extending existing microscopy stitching frameworks.

Keywords: Image stitching, Serpentine scanning, GPU acceleration, Normalized cross-correlation, Microscopy imaging.

[OP08] Non-Invasive Point-of-Care Detection of *Staphylococcus aureus* Based on Volatile Metabolite Analysis

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Multidrug-resistant *Staphylococcus aureus* (MRSA) is a serious global health concern. Rapid identification and treatment of these infections remain challenging in clinical settings. Conventional laboratory methods, although accurate, are time-consuming (24–72 hours), costly, and require specialized equipment and trained personnel. These limitations lead to delayed treatment, increased transmission, and overuse of broad-spectrum antibiotics. There is an urgent need for simple, affordable, non-invasive point-of-care tools that can detect the pathogen quickly. A low-cost, disposable paper-based patch was developed as a passive wearable sampler to collect volatile organic compounds (VOCs) emitted by *S. aureus*. The patch was tested under controlled laboratory conditions with bacterial growth medium. The extracted VOCs were analysed using gas chromatography–tandem mass spectrometry (GC–MS/MS). Later, the practicality and environmental sustainability of the method were evaluated using the Blue Applicability Grade Index (BAGI). The patch successfully captured and identified a characteristic VOC profile specific to *S. aureus*, including heptadecane, allene derivatives, cyclopropane-containing compounds, and glaucic acid. The method received a BAGI score of 62.5, indicating good practicality, low environmental impact, minimal sample preparation, and suitability for resource-limited settings. The patch is inexpensive, easy to manufacture at scale, disposable, and requires no technical expertise for sampling. This study demonstrates that a simple wearable paper patch can detect *S. aureus* non-invasively by sensing its volatile metabolites. Due to its low cost, ease of use, and eco-friendly design, the patch shows strong potential for point-of-care diagnostics, infection surveillance, and antimicrobial resistance monitoring, particularly in low-resource healthcare settings and within the One Health framework.
Keywords: Point-of-care diagnostics, non-invasive sensors, volatile organic compounds, antimicrobial resistance, *Staphylococcus aureus*

[OP09] Deep Feature–Driven Tumor Tissue Classification Using Label-Free Multiphoton Imaging

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Conventional histopathology relies on chemical staining and manual interpretation, making it time-consuming, labor-intensive, and prone to inter-observer variability. To address these limitations, we present **a** label-free multimodal multiphoton imaging framework integrated with a lightweight machine learning (ML) pipeline for automated tumor tissue classification. Two-photon fluorescence (TPF) and second harmonic generation (SHG) images were acquired from tissue microarray cores to capture complementary biochemical and structural information without exogenous labels. Quantitative features were extracted using both traditional texture descriptors based on gray-level co-occurrence matrices (GLCM) and deep features derived from a pre-trained MobileNetV3-Small network, with dimensionality reduction performed using principal component analysis (PCA). Multiclass support vector machine (SVM) classifiers were trained and evaluated to discriminate normal and tumor tissues. Comparative analysis demonstrates that deep feature–based models significantly outperform conventional texture features, achieving higher accuracy of 91% and sensitivity. The proposed integrated approach enables rapid, robust, and stain-free tumor tissue classification, highlighting its potential for real-time digital pathology and clinical decision support.

Keywords: Label-free imaging; Two-photon fluorescence; second harmonic generation; tumor tissue classification; digital pathology

[OP10] Fabrication of a Silver-Decorated Aluminium-Based Array for SERS-Based Detection of Harmful Chemical Compounds

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Surface-enhanced Raman spectroscopy(SERS) is a powerful analytical technique for the ultra-sensitive detection of a wide range of chemical analytes relevant to environmental monitoring, consumer safety, and chemical hazard assessment. However, widespread implementation is often restricted by the limited availability of inexpensive, reproducible, and scalable SERS substrates. Aluminium-based substrates present a promising alternative due to their low cost, mechanical flexibility, and inherent plasmonic properties. In this work, an aluminium-based SERS substrate array was fabricated as a cost-effective sensing platform and subsequently decorated with silver nanostructures synthesised via the Lee-Meisel method to enhance electromagnetic field localization. The resulting silver-decorated aluminium array was evaluated for the detection of harmful chemical compounds commonly encountered in complex formulations. Many such compounds, including aromatic amines, phenolic derivatives, and oxidative intermediates, are associated with adverse health effects upon prolonged or repeated exposure. The developed substrate enabled sensitive identification of characteristic Raman signatures of target analytes, demonstrating its capability as a rapid and reliable analytical platform for chemical screening. This approach highlights the potential of aluminium-silver SERS arrays for on-site monitoring and safety assessment of hazardous or regulated chemical substances.

Keywords: Raman spectroscopy, Surface-enhanced Raman spectroscopy, Aluminium, Lee–Meisel method, Chemical detection

[OP11] Polarization Sensitive Imaging for Surface Roughness Study

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Mueller matrix polarimetric imaging provides quantitative contrast mechanisms for biomedical tissue characterization by probing polarization-dependent scattering and depolarization. In this work, a compact 3 3 × 3 Mueller matrix polarimetric imaging system implemented using a polarization –sensitive camera, enabling spatially resolved polarization measurements with reduced system complexity. The system uses a rotating linear polarizer in the illumination path to generate linearly polarized states at 0°, 45°, and 90°.Reflected light is detected by a polarization-sensitive camera incorporating a micro-polarizer array with orientations of 0°, 45°, 90°, and 135° within each binned pixel. Images acquired for all illumination – detection polarization combinations are used to reconstruct 3 × 3 Mueller matrix element images. Polar decomposition is applied to extract depolarization and retardance parameters. Intial validation is performed using adhesive tapes with varying surface roughness as tissue mimicking phantoms. The measured average depolarization index increases from approximately 0.25 to 0.55 with increasing roughness, with corresponding spatial fluctuations of 0.03 to 0.08. Retardance maps exhibit spatial variations in the range of 5 to 20, indicating anisotropic scattering effects. Intensity difference images between horizontal and vertical polarization components further enhance contrast for rougher samples. These results demonstrate the feasibility of simplified Mueller matrix imaging for biomedical Surface and tissue characterization, providing a foundation for future extension to in-vivo diagnostic applications.

Keywords: Polarization sensitive imaging, Muller matrix, Polar decomposition, Difference image.

[OP12] Segment Anything Microscopy (SAM) enabled Optical Tweezer for assessment of Optically driven Oscillations

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Optical Tweezers use tightly focused light to trap microparticle under optical confinement. In ray optics regime, momentum transfer via. reflection and refraction of light bring about stable trapping. Hence the shape and size of trapped microparticle dictate the trajectory evolution. Tracking temporal evolution of trapped microparticle trajectory is crucial task in analyzing dynamic behavior. In particular axisymmetric anisotropic particles like oblate discoid can exhibit optically driven oscillation when at least one of their axes is comparable to the spot size. In this work we use a custom-made optical tweezer system that uses 532nm wavelength with spot size ~450nm to trap in house synthesized oblate discoid that can show optical oscillations. Due to its flat disc shape the intensity profile of trapped microparticle is not uniform but rather have a streak. Thus, anisotropic intensity gradient with low contrast and SNR makes traditional thresholding-based and edge-detection algorithms incapable of generating a consistent mask. Whereas existing deep learning models rely on labeled datasets which are both time-consuming and costly. To overcome this, we propose a single-shot hybrid shape aware segmentation model, that combines Segment Anything Microscopy (SAM), a vision foundation model and elliptical contour fitting. The pipeline is evaluated on experimental video dataset, containing 2960 frames captured at 120 fps. The model is evaluated against temporal Intersection over Union (IoU) yielding a score of 0.7825 ± 0.0672. These results highlight the importance of SAM enabled optical tweezer tracking approach to enable deeper exploration of trapped dynamics in optical confinement.

Keywords: optical tweezer, shape-aware segmentation, temporal dynamics, SAM, optical oscillations

[OP13] Detection of toxic glycols in paediatric syrups using ATR-FTIR Spectroscopy

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Diethylene glycol (DEG) and ethylene glycol (EG) are highly toxic glycols that have been frequently responsible for fatal poisoning incidents when mistakenly or intentionally substituted for pharmaceutical grade propylene glycol (PG) in paediatric syrups. Conventional pharmacopeial methods used for the detection of DEG and EG are tedious, requires extensive sample preparation, use carcinogenic solvents and limits their use for rapid, large-scale screening. In the present study, potential of attenuated total reflectance Fourier transform infrared (ATR-FTIR) spectroscopy as a rapid screening tool was investigated for the identification and determination of DEG and EG, in PG based paediatric syrups. ATR-FTIR measurements were performed on neat PG, a key excipient in paediatric syrups, as well as on three commercial paediatric syrups spiked with DEG and EG over a concentration range of 0.5–50 % (v/v). For quantitative determination of DEG contamination, characteristic ether C–O–C stretching bands in the 1250–1100 cm^{-1} region was used, while EG estimation was based on the dominant primary alcohol C–O stretching band at ~1050 cm^{-1}. Using these characteristic bands, ATR-FTIR spectroscopy technique was able to detect DEG and EG at contamination levels of ~ 0.5 % (v/v) in neat PG. In commercial syrup formulations, the detection limits were ~1 % (v/v) for both DEG and EG in Cetirizine and Levodropropizine. For Paracetamol, higher detection limits were observed, ~2 % for EG and 5 % for DEG, likely due to stronger matrix interference from excipients. These measurements demonstrate that ATR-FTIR technique can be used for excipient & raw material identification to

prevent mislabelling during pre-production stages, as well as for rapid screening across pharmaceutical supply chain to detect major deviation from acceptable limits (0.1 % v/v). This approach will help prevent serious adverse outcomes, such as acute renal failure and deaths. Further studies are in progress to decrease the limit of detection.

Keywords: DEG, EG, Paediatric syrup, ATR-FTIR and Excipient

[OP14] Evaluation of Exosome-Encapsulated Curcumin for Enhanced Photodynamic Cytotoxicity in Breast Cancer Spheroids

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Breast cancer remains a predominant global malignancy, where the efficacy of conventional treatments is often compromised by drug resistance and systemic toxicity. Photodynamic therapy (PDT) offers a promising, targeted alternative; however, the clinical utility of potent natural photosensitizers like curcumin is severely restricted by their hydrophobicity, instability in physiological fluids, and rapid systemic clearance. This study explores the capacity of breast cancer cell-derived exosomes to encapsulate and deliver curcumin specifically to breast cancer cells by leveraging their intrinsic biocompatibility and homing capabilities, thereby enhancing its stability and photodynamic therapeutic efficacy of this formulation. Exosomes were isolated from MCF-7 conditioned media via ultracentrifugation and phenotypically validated by flow cytometry for tetraspanin surface markers CD9, CD63, and CD81. Curcumin was encapsulated via passive diffusion. Fluorescence spectroscopy revealed that encapsulation significantly improved curcumin's stability in aqueous solution; while free curcumin displayed rapid degradation and fluorescence loss, curcumin encapsulated within exosomes (Exo-Cur) maintained superior molecular integrity. PDT

efficacy was assessed in both 2D monolayers and 3D spheroid models irradiated with blue light. *In-vitro* cytotoxicity assays revealed a significant, dose-dependent therapeutic advantage for the nanoformulation; treatment with Exo-cur resulted in superior cell killing compared to equivalent doses of free curcumin. In 3D spheroids, fluorescence microscopy utilizing Propidium Iodide (PI) and CFDA-SE staining confirmed that Exo-cur facilitated extensive cell death and deep tissue penetration. These findings indicate that tumor-derived exosomes effectively stabilize hydrophobic photosensitizers, presenting a robust bio-photonic platform for enhanced oncological interventions.

Keywords: Curcumin, Exosome, PDT, Breast Cancer, Breast Cancer Spheroids

[OP15] Label-Free Quantitative Phase Imaging for Objective Oocyte Evaluation

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Oocytes are the fundamental building blocks of life and play a crucial role in embryo development and successful outcomes in reproductive medicine. In modern medical imaging, non-invasive and objective evaluation of oocytes remains a significant challenge for embryologists. In this work, we present a quantitative phase imaging framework based on digital holographic microscopy for label-free, three-dimensional assessment and grading of oocytes. Off-axis holograms are numerically reconstructed using the angular spectrum method to retrieve quantitative phase maps. From the reconstructed phase, key morphometric and biophysical parameters including oocyte diameter, circularity, optical volume, zona pellucida thickness and uniformity, granulation variance, and phase-based texture metrics are extracted. Representative results demonstrate near-spherical oocyte morphology with high circularity (0.96), an outer diameter of 118.1 µm, and

a symmetric zona pellucida with a mean thickness of 5.9 µm and low non-uniformity (0.098). Granulation analysis reveals moderate cytoplasmic heterogeneity, reflected by a phase variance of 110.9 and phase entropy of 3.83. Based on comparison with established quantitative ranges, a grading scheme is proposed to classify oocytes into Grade A, B, and C categories. This study highlights the potential of quantitative phase-derived parameters for objective, scalable, and non-invasive oocyte quality grading.

Keywords: Quantitative phase imaging, Digital holographic microscopy, Oocyte grading, Optical thickness, Label-free imaging.

[OP16] From Single Species to Co-Cultures: Raman Spectroscopy with Ensemble Learning and MCR-ALS

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Rapid identification of bacteria in both pure cultures and co-culture systems is important for understanding microbial behaviour and improving diagnostic decision-making, yet conventional culture-based methods are often time-consuming and labour-intensive. In this study, Raman spectroscopy along with ensemble machine-learning and multivariate curve resolution-alternating least squares (MCR-ALS) was applied to address both single-species identification and co-culture analysis. Raman spectral fingerprints collected from nine bacterial species were analysed. The ensemble learning algorithm combines feature selection with stacked neural network models and provides a reliable discrimination between species and highlighting key spectral features associated with biochemical differences. To extend the approach toward more realistic biological systems, Raman spectra from bacterial co-cultures were examined using MCR-ALS. This analysis allowed separation of overlapping spectra and provided estimation of how individual species contributions changes over time, including in cases involving closely related organisms. The MCR-ALS results consistently reduced complex co-culture spectra into a limited number of chemically interpretable components,

highlighting how dominance between species changed during the microbial growth. Together, these findings demonstrate potentials of Raman spectroscopy combined with ensemble learning and chemometric decomposition for label-free analysis of bacterial species and offers a promising direction for culture-independent applications in healthcare, pharmaceutical research, and environmental monitoring.

Keywords: Raman Spectroscopy, Label-Free Diagnostics, Chemometrics, Ensemble Learning, Multivariate Curve Resolution (MCR-ALS)

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