Scientific Program & Book of Abstracts

IESL Science Days 2022

15-16 December 2022

INSTITUTE OF ELECTRONIC STRUCTURE AND LASER

Scientific Program

Thursday 15 December 2022

9:00-9:15	S. H. Anastasiadis	Welcome from the Director of IESL
	Chair: S. H. Anastasiadis	
9:15-9:40	P. Tzallas	Strong laser fields in Attosecond science and quantum optics
9:40-10:05	M. Vamvakaki	Dual-functional antimicrobial polymers
10:05-10:30	K. Makris	Exceptional points: robustness versus sensitivity in non-Hermitian Photonics
10:30-10:55	B. Loppinet	Soft Matter Dynamics by Design
10:55-11:20	A.Lappas	Tweaking Nanoscale Functionalities by Correlated Disorder
Coffee-break		
	Chair: M. Konstantaki	
11:45-12:10	D. Papazoglou	Optics for Space Applications
12:10-12:35	P. Samartzis	Chirality explored with Photoelectron Circular Dichroism
12:35-13:00	M. Farsari	Non-Linear Lithography Group Activities
13:00-13:25	M. Chatzinikolaidou	Advances and challenges in bioengineering bone grafts
13:25-13:50	P. Rakitzis	Applications of Cavity Ring-down Polarimetry and of High-density Spin-Polarized Hydrogen Isotopes
Lunch-break		
	Chair: V. Pouli	
14:45-15:10	M. Kafesaki	Metamaterials for advanced electromagnetic wave control
15:10-15:35	D. Petrosyan	Quantum simulations and interfaces with Rydberg atoms
15:35-16:00	G. Deligeorgis	Electronics using 2D and 1D nano materials; reality, possibility or utopia?
16:00-16:25	L. Lymperakis	Ab-initio based computational materials in synergy with experiment
Coffee-break		
	Chair: E. Aperathitis	
16:45-17:10	A.Mitraki	Self-assembly of minimal dipeptide building blocks through simulations and experiments
17:10-17:35	P. Loukakos	Femtosecond Laser Spectroscopy in Solid State
17:35-18:00	S. Pissadakis	Transducers and Designs for Optical Fiber Sensors
18:00-18:25	V. Binas	Advanced Materials and Devices for Environmental and Energy applications
18:30-20:00	**Poster Session**	

Friday 16 December 2022

	Chair: E. Pavlopoulou	
9:30-9:55	E. Iliopoulos	Aspects of III-Nitride semiconductors research: Towards energy production and quantum technologies applications
9:55-10:20	S. Tzortzakis	UNIS group: Taming strong laser and THz fields
10:20-10:45	K. Chrissopoulou	Polymer Nanocomposites: Correlating Structure with Properties
10:45-11:10	G. Filippidis	Non-linear optical microscopy for biological applications
11:10-11:35	G. Vasilakis	Precision measurements at the quantum interface between light and atomic spin ensemble
Break for the Physics Department Event		
	Chair: D. Gray	
15:00-15:25	W. von Klitzing	Matter-Waves Lensing in Dynamic Wave-Guides
15:25-15:50	S. Sotiropoulou	Light and colour on Heritage objects: Analytical approach to retracing the original appearance and projecting it into the future
15:50-16:15	E. Filippidi	Unravelling associations of proteins with large intrinsic disorder
16:15-16:40	G. Zaharakis	Looking and listening to complex biological systems with novel biophotonics
Coffee-break		
	Chair: D. Anglos	
17:00-17:25	G. Kopidakis	Atomic-scale modeling of 2D nanostructures
17:25-17:50	E. Stratakis	The research activities of the Ultrafast Laser Micro- and Nano- Processing Lab of IESL-FORTH
17:50-18:15	A.Ranella	Approaches to studying cellular responses under the effect of extracellular signals
18:15-18:40	A. Klini	Nanostructured materials for optosensing applications
18:45-19:30	**Special Session- Discussion -Closing**	

List of Posters

1	**Development of a portable, hybrid analytical instrument combining LED-Induced Fluorescence, Laser-Induced Breakdown Spectroscopy and Diffuse Reflectance for an integrated analysis of materials on monuments and objects of archaeological interest** A. Giakoumaki, V. Piñon, M. Andrianakis, K. Hatzigiannakis, K. Melessanaki, D. Anglos and P. Pouli
2	**Development of a fully automated micro-LIBS system for 2D elemental analysis of archeological shells** V. Pinon, N. Hausmann, P. Siozos and D. Anglos
3	**Generation and Characterization of Energetic Highly-Elliptical Extreme Ultraviolet Radiation** E. Vassakis, S. Madas, L. Spachis, I. Orfanos, S. Kahaly, M. Upadhyay Kahaly, P. Tzallas, D. Charalambidis and E. Skantzakis
4	**Optical spectroscopy and microscopy of 2D materials** G. Kourmoulakis, E. Katsipoulaki, I. Demeridou, G. M. Maragkakis, D. Katrisioti, K. Mourzidis, G. Merianis, L. Mouchliadis, S. Psilodimitrakopoulos, I. Paradisanos, G. Kioseoglou and E. Stratakis
5	**Ultrafast Laser Micro/Nano Processing Laboratory Lasers in Optoelectronics** I. Konidakis, A. S. Sarkar, E. Serpetzoglou, K. Tsimvrakidis, A. Karagiannaki, M. Adamidis, H. Goniotakis, E. Stratakis
6	**Photonics Application in Agrofoods and Environment** E. Orfanakis, R. Kontzedaki, E. Boumpoulaki, M. Vlasiadi, N. Fragkoulis, K. Stamataki, A. Zoumi, A. Philippidis, P. Siozos, G. Psyllakis, P. Samartzis and M. Velegrakis
7	**Fe-based Superconductors: Structural Phase Transitions Tuned by Electronic Fluctuations** M. Kaitatzi, A. Deltsidis, A. Missiul, E. S. Bozin and A. Lappas
8	**Control of Femtosecond Laser Filamentation and Supercontinuum Generation in Liquids Using Neural Networks** P. Konstantakis, P. E. Dufour, M. Manousidaki, A. D. Koulouklidis and S. Tzortzakis
9	**Designing new perovskite nano/micro- particles for energy storage and sensing applications** A. Kostopoulou, K. Brintakis, K. Alexaki, A. Argyrou, M. Splinaki and E. Stratakis
10	**Hyper expanded molecule intercalated iron selenides with robust superconducting response** A. Deltsidis, M. Kaitatzi and A Lappas

11	**Biomimetic pattern formation via the employment of ultrashort pulsed lasers: from theory to experiment** G. D.Tsibidis, F. Fraggelakis, S. Maragkaki, P. Lingos, I. Sakellari, D. Mansour, L. Mouchliadis, M. Vlahou, M. C. Velli, C. Siogka and E. Stratakis
12	**Engineering Laser Wavefronts for Advanced Materials Processing** M. Manousidaki, A. Kyriakakis, K. Misdanitis, D. G. Papazoglou, M. Farsari and S. Tzortzakis
13	**Applications of non-linear imaging in low dimensional materials and in living biological systems** S. Psilodimitrakopoulos, L. Mouchliadis, D. Xydias, G. M. Maragkakis, M. Kefalogianni, R. Zafiri, E. Babaliari, and E. Stratakis
14	**Tilted fiber Bragg grating with Graphene nanohybrids overlayer for Ammonia detection** E. Grantzioti, N. Samartzis, K. Bhrokar, S. Pissadakis, S. N. Yannopoulos and M. Konstantaki
15	**Miniature optical fiber sensor with photopolymerizable resin cavity for VOC vapor sensing** E. Grantzioti, S. Pissadakis, M. Konstantaki
16	**Intense THz sources and applications** A. D. Koulouklidis, V. Yu. Fedorov, Ch. Daskalaki and Stelios Tzortzakis
17	**Direct Laser Fabrication and 4D printing of Biomimetic, 3D Scaffolds for Tissue Regeneration** E. Kanakousaki, A. Parlanis, P. Daskalakis, Ch. Ntoulias, K. Alexaki, L. Papadimitriou, E. Babaliari, P. Kavatzikidou, A. Ranella and E. Stratakis
18	**Femtosecond Lasers for Hydrogen Production** M. Pigiaki, N. Papakosta, M. N. Polychronaki, E. Nikoloudakis, I. A. Poimenidis, S. D. Moustaizis, D. Anglos, A. G. Coutsolelos, A. Klini, M. Farsari, P. A. Loukakos
19	**Additive manufacturing laser processing techniques in Biotechnology, Energy, Food and Automotive Industry** M. Pervolaraki, K. Savva, A. Pylostomou, K. Tsimvrakidis and E. Stratakis
20	**Cavity Enhanced Microscopy (CEMIC)** V. Pareek, D. Papazoglou, W. von Klitzing, G. Deligeorgis, G Kourmoulakis and G. Kioseoglou
21	**Altering the Surface Properties of Flexible Substrates by Utilizing Nanostructured Coatings** Th.–M. Chatzaki, F. Krasanakis, K. Chrissopoulou and S. H. Anastasiadis
22	**Development of Functional Materials Surfaces** F. Gojda, L. Papoutsakis, M. Loulakis, S. Tzortzakis, K. Chrissopoulou, and S. H. Anastasiadis

23	**Development of Polyurethane/r-GO Nanocomposites with Reinforced Self-healing Properties** E. Giannakaki, K. Giannaris, M. M. Stylianakis, A. Fidelli, P. Krassa, K. Chrissopoulou and S. H. Anastasiadis
24	**Polymer / Graphene Oxide Nanocomposites: Investigating the Effect of the Interfacial Interactions on Structure and Properties** I. Karnis, F. Krasanakis, A. N. Rissanou, K. Karatasos and K. Chrissopoulou
25	**Acetylene Photochemistry Near its Ionization Energy** I. C. Giannakidis, A. Mpanoutsos, N. Findrilis and P. Samartzis
26	**Detection of Gasoline Adulteration with Spectroscopic Methods** N. Fragkoulis, E. Koliou and P. Samartzis
27	**Mechanotransduction: the effect of mechanical properties, topography and shear stress on cell response** L. Papadimitriou, P. Kavatzikidou, E. Babaliari, G. Flamourakis, A. Kordas, M. Papageorgiou, E. Kanakousaki, A. Parlanis, S. Skrepetos, Ch. Andrianakis, A. Vlachopoulou, S. Karagiannakis and Anthi Ranella

Book of Abstracts

Oral Presentations

Recent progress on:
A) The development of high power ultra short XUV pulses and applications in non-linear XUV optics.
B) The generation and characterization of optical Schrödinger "cat" and entangled states.

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Abstract

I will present the progress made the last 2 years in the two research directions of the Attosecond Science and Technology (AST) lab. of IESL.

Attosecond science (Direction #A): After a brief introduction on the attosecond beam lines of AST lab., I will present the recent development on the generation of intense 10-fs and isolated attosecond pulses [1-5] and the applications in non-linear XUV optics.

Quantum optics in strong laser-fields (Direction #B): Here, after a brief introduction on fundamentals of the optical Schrödinger "cat" states, I will present you our recent findings on the optical Schrödinger "cat" and entangled state engineering [1-8].

References

Direction #A:

[1] I. Orfanos et al., *Phys. Rev. A* **106**, 043117 (2022)
[2] I. Orfanos et al., *J. Phys. B: At. Mol. Opt. Phys.*, **54**, 084002 (2021).
[3] I. Makos et al., *High Power Laser Science and Engineering*, **8**, e44 (2020).
[4] I. Orfanos et al., *J. Phys. Photonics*, **2**, 042003 (2020).
[5] I. Makos et al., *Sci. Rep.* **10**, 3759 (2020).

Direction #B:

[1] M. Lewenstein, et al., *Nature Phys.*,**17**, 1104 (2021).
[2] P. Stammer, et al., *Phys. Rev. Lett.* **128**, 123603 (2022).
[3] J. Rivera-Dean, et al., *Phys. Rev. A* **105**, 033714 (2022) [Editors' suggestion].
[4] J. Rivera-Dean, et al., *J Comput. Electron.* **20**, 2111-2123 (2021).
[5] Th. Lamprou, et al.,, *Photonics* **8**, 192 (2021).
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[7] J. Rivera-Dean, et al., *Phys. Rev. A* (accepted).
[8] P. Stammer, et al., *PRX Quantum* (accepted).

Dual-functional antimicrobial polymers

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Abstract

Antimicrobial surfaces have attracted great attention lately for use in medical devices, food processing and water purification systems. Among the different approaches employed, antimicrobial polymer surfaces that possess either antifouling or bactericidal properties have been shown to effectively inhibit the spreading of microbial infections [1, 2]. Herein, functional polymer coatings exhibiting controllable antimicrobial properties were developed. Two types of polymeric materials were synthesised comprising (i) antifouling-bactericidal polymer brushes and (ii) self-polishing cross-linked polymer films. The solvent responsive behavior of the polymer brushes and their bactericidal activity for both Gram-positive and Gram-negative bacteria strains were evaluated. On the other hand, the ability of the cross-linked polymers to kill both bacteria strains and their self-polishing properties to renew the biocidal surface, were studied [3]. Overall, these dual-functional polymer surfaces exhibit unique antifouling-bactericidal and bactericidal-self-renewal properties, which render them promising for antimicrobial applications.

References

[1] Zander, Z. K.; Becker, M. L. *ACS Macro Lett*. **2018**, *7*, 16-25.
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[3] Manouras, Th.; Koufakis, E.; Vasilaki, E.; Peraki, I.; Vamvakaki, M. *ACS Applied Materials and Interfaces,* **2021,** *13*, 17183.

Exceptional points: robustness versus sensitivity in non-Hermitian Photonics

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The scattering and diffraction of waves through complex media is a paradigmatic phenomenon that has captured the attention of various communities of physics for quite some time now. Recently, there is a lot of interest in composite media that contain spatial distributions of gain and loss materials. Due to the plethora of novel applications, like ultrasensitive sensors and gyroscopes, topological insulator lasers, non-reciprocal ring cavities and single mode nanolasers, such ideas have led to the new area of non-Hermitian photonics.

In this talk we are going to present some recent results regarding the interplay between topological protection and ultra-sensitivity around higher order exceptional points and their relation to the underlying theory of pseudospectra. Connection of the above topics to recent experiments will also be examined.

Soft Matter Dynamics by Design

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Abstract

Ability to control or predict the macroscopic properties of soft materials is a formidable task.
I will present efforts of the polymer and colloid science group in that direction.
The presentation follows the one given at the evaluation committee last June.

Tweaking Nanoscale Functionalities by Correlated Disorder

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Abstract

The quest for nanoscale crystals that surpass the performance of a single core is motivated by the design-concept of controlling the spatial distribution of chemical composition within a single motif. In that respect, colloidal nanocrystals designed for important biomedical applications [1], such as magnetic hyperthermia treatment of tumors, occasionally require defect-free, large entities (>20 nm) due to their high capacity to dissipate heat in their near vicinity.

Disorder though, is an inherent component of real nanoscale materials, with significant implications for their application in functional devices. Here, we discuss the evolution of size and shape mediated structural disorder in core-shell iron-oxide nanocrystals and learn how their imperfections couple to properties relevant to nanobiotechnology [2]. In this endeavor, especially valuable are nanocrystals with subcritical sizes (<20 nm), which occasionally display the desired magnetic properties and some other times they don't, making it rather challenging to comprehend their diverse responsiveness. X-ray total scattering methods, utilizing ultra-bright, high-energy photons offered at a synchrotron facility, attest that their differences arise primarily due to metal cations missing from particular lattice sites. The emerging local symmetry breaking owing to correlated defects, changes the nanocrystal's magnetic anisotropy. In effect, the emerging competition amongst the elementary magnets (spins) out of which the nanocrystals are composed, allows a remarkable magnetically mediated heating power generation for potential hyperthermia and related theranostic applications.

The investigations advocate the broader implications of atomic-scale defects, but also enquire how prevalent correlated disorder effects, combined with alternative pathways to remedy the atomic-scale defects, may drive interactions and enable optimized nanomaterials functionality.

References

[1] D. Yoo et al., *Acc. Chem. Res.* **44**, 863 (2011).
[2] A. Lappas et al., *Phys. Rev. X* **9**, 041044 (2019).

Optics for Space Applications

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Abstract

Optics is a discipline focused on understanding and manipulating light. We are all familiar with our eyes and our visual system as one important and complex imaging and sensor system that enables us to operate in a complex environment. A spacecraft, in a similar way to our visual system, employs many different types of optical imaging and sensing systems to observe and measure. An enabling, essential capability to develop, build, test and use optical instrumentation in space is optical engineering.

In this talk we will discuss about novel technologies developed by the Space Optics Group in collaboration with ESA. These include precise and robust optical beam steering on compact optical bread boards. This technology aims to simplify existing approaches, whilst increasing stability and scalability, in an effort to develop optical technologies for the next generation of spacecraft. Furthermore, we will discuss on the ongoing effort to establish a fully operational optical ground station (OGS) at Skinakas Observatory so that, besides astronomical observations, the observatory can become a center for secure satellite communications.

Chirality explored with Photoelectron Circular Dichroism

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Abstract

Photoelectron Circular Dichroism (PECD) was predicted theoretically in the 1970s [1] and implemented experimentally in the 2000s [2, 3]. It is based on the forward-backward asymmetry of photoelectron distribution produced when a chiral molecule is ionized by circularly polarized light. Synchrotron and ultrafast laser radiation, and, more recently, nanosecond lasers have been used in PECD measurements of chiral molecules [4]. I will present recent advances in the field and show how PECD can be useful in studying different aspects of chirality and in solving the problem of isolating enantiomers in mixtures [5].

References

[1] B. Ritchie, *Phys. Rev. A* **13**, 1411 (1976).
[2] N. Böwering, T. Lischke, B. Schmidtke, N. Müller, T. Khalil, and U. Heinzmann, *Phys. Rev Lett.* **86**, 1187 (2001).
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Advances and challenges in bioengineering bone grafts

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Abstract

Bone is a highly dynamic tissue that undergoes continuous remodeling through lifetime. During this process, osteoblasts and osteoclasts are responsible for bone formation and bone resorption respectively [1]. Mechanical forces physiologically applied on bone tissue during body movements control the balance between these two cell populations. The mechanical stimuli applied to the cells are recognized as regulators of the cell fate and functionality, since cells sense and transmit them to their interior or to other cells and translate them to biochemical signals that affect their cellular responses. These processes of mechanotransduction within bone cells have been reported to be dramatically affected by the characteristics of the in vivo bone environment including the 3D lacunocanalicular network architecture and extracellular matrix composition [2].

Pre-osteoblastic cells are well established to evaluate in vitro osteogenic responses, and they can differentiate into mature osteoblasts under appropriate culture conditions, allowing for the validation of bone tissue formation. In this talk, the application of uniaxial compression on pre-osteoblastic cells seeded onto 3D printed polymeric and composite scaffolds, and the in vitro osteogenic differentiation assessment in co-culture of different cell populations will be discussed. Cell viability, proliferation and differentiation markers have been evaluated to show the effect of the mechanical stimulation on cellular responses.

In addition, new technologies for bioengineering complex bone grafts including bioprinting of biocompatible hydrogels and cells, as well as electrospinning to resemble the nanofibrous extracellular matrix network morphology will be discussed, with emphasis on their challenges towards functional bone tissue fabrication.

References

[1] Wang, L., et al., Mechanical regulation of bone remodeling. Bone Res, 2022. 10(1): p. 16.

[2] van Tol, A.F., et al, The mechanoresponse of bone is closely related to the osteocyte lacunocanalicular network architecture. PNAS, 2022, www.pnas.org/cgi/doi/10.1073/pnas.2011504117

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Applications of Cavity Ring-down Polarimetry and of High-density Spin-Polarized Hydrogen Isotopes

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Abstract

We discuss the development of Cavity-Ringdown polarimetry [1] into a precommercial instrument, with optical rotation sensitivity of at least 50 μdeg $Hz^{-1/2}$ [2], which is about 100 times more sensitive than current commercial polarimeters. We demonstrate the measurement of chiral microsamples, and discuss present and future measurement capabilities [3].

We also discuss the production of ultrahigh-density spin-polarized hydrogen isotopes from hydrogen halide photodissociation [4], and plans for the use of these atoms at laser facilities for the production of polarized electron and proton beams with record fluxes, and for demonstrations of polarized laser fusion (for which the cross section is expected to be enhanced by 50%) [5].

References

[1] D. Sofikitis *et al.*, "Evanescent-wave and ambient chiral sensing by signal-reversing cavity-ringdown polarimetry" *Nature* **514**, 76 (2014).

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Metamaterials for advanced electromagnetic wave control

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Abstract

Metamaterials are artificially structured materials with engineerable electromagnetic properties, arising mainly from the shape and distribution of their subwavelength-scale building blocks (known as meta-atoms). Arranging properly those building blocks one can achieve novel and uncommon properties, such as negative permeability in the optical region, negative refractive index, extreme permittivity and permeability values, giant chirality, unusual anisotropy etc. All these properties are associated with unique capabilities in the control of electromagnetic waves, exploitable in a large variety of applications, including imaging, sensing, telecommunications and information processing, etc.

In this talk I will review some of the recent metamaterials-related activities of our group, emphasizing on (a) chiral metamaterials and their possibilities in parity-time symmetric systems (see, e.g. [1]), (b) multifunctional metasurfaces (i.e. thin metamaterial layers) with programmable (software controllable) response [2] and metasurfaces with broad-band operation [3], (c) metamaterials suitable for perfect absorption and sensing applications [4], and (d) photonic structures for solar-cell radiative cooling applications [5]. All these metamaterial types have been examined in detail, in many cases both theoretically and experimentally, their rich physical response has been analyzed and their great capabilities in applications have been evaluated.

References

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Quantum simulations and interfaces with Rydberg atoms

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Abstract

Atoms in the highly excited Rydberg states possess unique properties, including long lifetimes and huge dipole moments, which facilitate their use in various quantum technology applications. I will discuss recent progress in quantum simulations of many-body physics with strongly-interacting Rydberg atoms and coherent interfaces of Rydberg atoms with superconducting microwave resonators and optical photons, presenting some of our results and collaborations with experimental colleagues [1-5].

References

[1] A. F. Tzortzakakis, D. Petrosyan, M. Fleischhauer, K. Mølmer, *Microscopic dynamics and an effective Landau-Zener transition in quasiadiabatic preparation of spatially-ordered states of Rydberg excitations*, Phys. Rev. A **106**, xxx (2022)

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Ab-initio based computational materials in synergy with experiment

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Abstract

Ab-initio-based computational materials co nstitute nowadays a working horse in state-of-the-art materials science and technology. A great advantage of computational materials is that they can provide information not straightforwardly accessible by experiment, and they can identify the dominant mechanisms at the atomistic and nanoscale governing the properties of materials.

In this talk, we will discuss how computational materials can be applied in synergy with characterization and growth experiments to investigate the atomistic mechanisms governing the properties of technologically important materials. Examples will be drawn from the field of materials for optoelectronic applications. Specifically, based on ab-initio calculations, we will demonstrate how the interplay between chemistry, strain, and quantum mechanics at surfaces and in bulk governs the electronic and structural properties of semiconductor alloys. Based on these insights, recent experimental findings will be explained, and routes to optimize the synthesis and growth of these alloys will be presented.

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Self-assembly of minimal dipeptide building blocks through simulations and experiments

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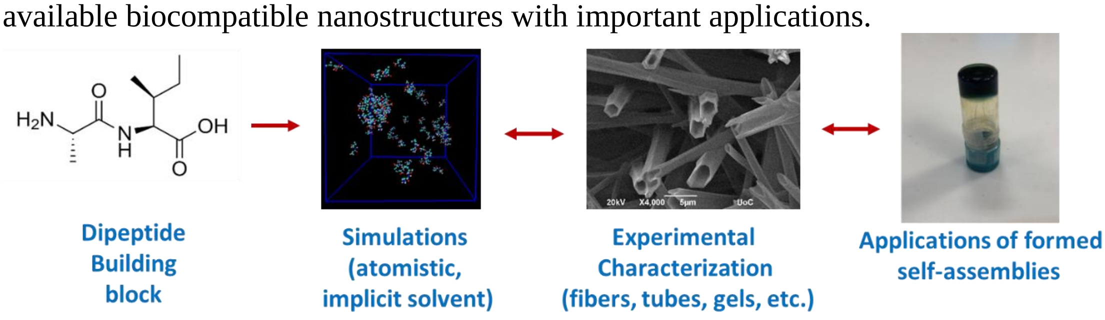
Abstract

The quest for “bottom-up” fabrication that can take place under mild conditions has brought up biomimetic procedures as innovative routes towards nanoscale biomaterial fabrication, with expected and foreseen use in environmental and biomedical applications. There are far more advantages in being able to fabricate and integrate water-soluble but resistant biological materials, without the use of high temperatures and harsh solvent conditions. Furthermore, protein and peptide-based nano-bioassemblies are highly suited for flexible functionalization procedures, since chemical groups can be readily incorporated at the sequence level. Merging theoretical and experimental approaches is becoming necessary in order to explore these possibilities.

In the last few years we have been involved in a studying minimal dipeptide building blocks that self-assemble into fibrils, tubes, and sometimes form hydrogels. Our approach involves their theoretical study in collaboration with Drs. Anastasia Rissanou and Vangelis Harmandaris. All-atom Molecular Dynamics simulations using an Explicit solvent model for each system, followed by a number of simulations where an Implicit solvent model is applied, shed light on the driving forces behind the self-assembly process responsible for each structure. In order to experimentally study the various self-assembling structures, techniques such as Transmission and Scanning Electron Microscopy, Atomic Force microscopy and X-ray fiber diffraction are used. So far, we focused on self-assembly studies of aromatic [1] and aliphatic [2]dipeptides. Ultimately this combined approach of theory and experiment will further advance the understanding of peptide self-assembly benefitting various fields while also providing a way to obtain cheap, readily available biocompatible nanostructures with important applications.



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Femtosecond Laser Spectroscopy in Solid State

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Abstract

In this talk we will present several examples of the application of ultrashort laser pulses and time-resolved laser spectroscopy that demonstrate the capabilities of the method in the understanding of basic physical mechanisms in various materials that are triggered by ultrashort optical excitation and associate these dynamics in the microcosmos with their macroscopic properties.

Moreover, we will present a few examples of the use of ultrashort laser pulses in the manipulation of the morphology of hard solid surfaces and their use towards solutions in global goals pertinent to the green energy transition.

Transducers and Designs for Optical Fiber Sensors

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Abstract

The realization of highly functional optical fiber sensors relies on the parallel investigation of transduction mechanisms/materials and optical designs for interrogating those. Herein, results will be presented on the development of optical fiber sensors while employing new transduction materials, combined with suitable optical interrogation platforms, for demonstrating devices that can find application in industrial instrumentation, agriculture, safety/security and environmental monitoring.

Advanced Materials and Devices for Environmental and Energy applications

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Abstract

The global concerns in the development of human civilization, the scientific and technological issues of energy utilization and environment protection are currently facing challenges. Nowadays, enormous energy demands of the world are mainly met by the non-renewable and environmental unfriendly fossil fuels. The substitution of the conventional energy platform has become extremely urgent, in the pursuit of the renewable and clean energy sources and carriers. Additionally, long-term industrial and agricultural activities induce serious environmental pollution problems (such as greenhouse and toxic gases, pharmaceuticals and organic micro-polutants) in air and water to deteriorate the ecological balance and the daily human health.

Advanced materials (metal oxides, perovskite type nanomaterials, 2D materials etc) are of great technological importance in energy and environmental applications because if their capability to generate charge carriers when stimulated with a required amount of energy. The promising arrangement of electronic structure, light absorption properties, and charge transport characteristics of most of oxides render them potential candidates particularly for effective environmental and energy applications. Moreover, these materials can be synthesized with low cost, high yield, through easily controlled solution-based techniques.

Here we discuss our recent advances on photocatalytic nanomaterials for improved air, water and health quality and to produce hydrogen from water. We also discuss our recent advances on gas sensors to control the air quality and to detect toxic gasses. Finally, we will also be discussing our recent advances on thermochromic materials for smart windows and heat regulation coatings which are suitable for reduced energy consumption in Buildings.

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Aspects of III-Nitride semiconductors research: Towards energy production and quantum technologies applications

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Abstract

In this presentation a brief overview of aspects of III-Nitride semiconductors research activities will be presented. The aim is to introduce these activities in the broader IESL researcher's community in light of exploring possible future synergies. The relevant activities concern:

(i) Material and device aspects of III-N alloys, in particular Indium Gallium Nitride (InGaN) heterostructures for applications in energy production devices: While InGaN have enormous potential for very high efficiency photovoltaic cell operation, a number of bottleneck challenges need to be overcome in epitaxy control, heterostructure design and device processing. Apart for describing recent understanding and progress, info on possible future synergetic research directions will be presented.

(ii) A new research activity concerning application of III-N nanostructures for high temperature operating quantum processors: A brief overview of current qubit technologies imitations will be given, along with recent research trends to overcome those, using semiconductor spin qubits approaches. Our research activities and aims, within the IQubits FET program will be introduced.

UNIS group: Taming strong laser and THz fields

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The UNIS group of IESL-FORTH is focusing on 3 major research areas: i) Nonlinear optics and propagation phenomena of high intensity ultrashort laser pulses, ii) THz science and technology, iii) Advanced photonic structuring of dielectrics and semiconductors.
In this presentation I will overview some recent topics of research that can be of interest for collaboration opportunities with other members of the IESL. Examples of discussion topics:

1. Can artificial intelligence be used to predict and control highly nonlinear optical phenomena?
2. Challenges in ultrashort laser engineering of bulk Silicon, electron dynamics in semiconductors.
3. How strong THz fields induce nonlinear self-action effects in 2D and bulk media.
4. Status and challenges of active THz optical devices for the next generation of wireless communications.
5. Taming light propagation for future free space optical telecommunications.

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Polymer Nanocomposites: Correlating Structure with Properties

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Abstract

Polymer materials are often filled with inorganics to improve their properties. The cases in which the additive exists in the form of a fine nm-sized dispersion within the polymeric matrix, thus producing a *nanocomposite,* allow the investigation of basic scientific problems. At the same time, the behavior of polymers restricted in space or close to surfaces/interfaces can be very different from that in the bulk.

The investigation of the structure, morphology, chain conformations and dynamics of hydrophilic polymers in nanohybrids containing either layered materials or spherical nanoparticles will be presented. [1,2] Mixing polymers with layered additives can lead to intercalated hybrids when the interactions between the constituents are appropriate; these can serve as model systems for the investigation of the static and dynamic properties of macromolecules in nano-confinement. On the other hand, using nanoparticles of largely different sizes provides the opportunity to vary the confining length as well the chain adsorption capacity. The polymer thermal and rheological properties are correlated with the obtained structure in an attempt to understand the relationship between the physicochemical attributes of the constituents and the final properties of the hybrids which is of great importance for the design of new materials, whereas polymeric nanohybrid coatings can lead to optimized surface properties [3] which may possess enhanced self-healing properties, as well.

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Non-linear optical microscopy for biological applications

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Abstract

Non-linear microscopy techniques are at the forefront of biomedical research over the last decade. These non destructive modalities offer improved resolution, high contrast images with increased penetration depth and complementary information while minimizing phototoxicity and photodamage effects on the biological samples. These properties characterize them as perfect imaging tools for revealing valuable and unique information of the specimen under investigation. These techniques are not limited to visualization since they also permit precise quantitative analysis and testing of specific mechanisms and biological processes. In this talk, the imaging modalities of MPEF, SHG, PSHG and THG will be presented as novel diagnostic tools for providing new insights to fundamental biological problems such as cell activation and differentiation, fat metabolism during aging and cancer [1-4]. Moreover, recent applications of non-linear imaging microscopy techniques to Cultural Heritage objects will be discussed [5,6].

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Precision measurements at the quantum interface between light and atomic spin ensembles

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Abstract

Quantum features of atom-light interaction have been among the central issues in physics since the early days of quantum mechanics. Recent technological breakthroughs have transformed the light-atom quantum interface to a powerful tool for performing measurements with unprecedented accuracy. In this talk I will describe current activity in our group that aims to harness quantum features of the light interaction with warm atomic ensembles for precision magnetometry.

I will discuss a setup which can address and simultaneously reduce all sources of quantum noise that limit the performance of atomic-optical magnetometers. The operating principle of this setup is based on the Faraday interaction of stroboscopically modulated light with polarized atoms contained in a glass cell. A novel source of polarization squeezed light will be introduced, which can be engineered to decouple its quantum noise from the measured spin observable. Spin-squeezed atomic states will be generated as a result of the measurement. We will present preliminary studies on the spin-noise spectrum, which shows an unusual deviation from the expected spectrum of a simple harmonic oscillator.

Matter-Waves Lensing in Dynamic Wave-Guides

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Abstract

We have demonstrated smooth and controllable matter-wave guides by transporting Bose-Einstein condensates (BECs) over macroscopic distances without any heating or decohering their internal quantum states [1]. We then use a novel magnetogravitational matter-wave lens to collimate and focus matterwaves in ring-shaped time-averaged adiabatic potentials. This "Delta-kick cooling" sequence of Bose-Einstein condensates reduces their expansion energies by a factor of 46 down to 800 pK [2]. Compared to the state-of-the-art experiments, requiring zero gravity or large free-flight distances, the ring-shaped atomtronic circuit has a diameter of less than one millimetre and exhibits a high level of control, providing an important step toward atomtronic quantum sensors and the investigation of very low energy effects in ultra-cold atoms.

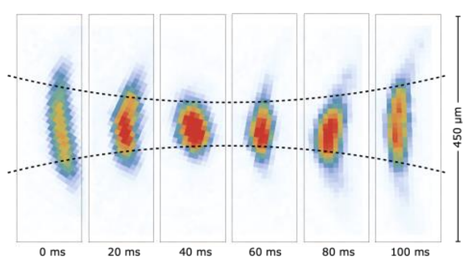

Figure: The focus of a BEC in a matter wave guide based on Time-Averaged Adiabatic Potentials

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Light and colour on Heritage objects: Analytical approach to retracing the original appearance and projecting it into the future

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Abstract

Analytical approach contributes significantly to the investigation of the materiality of colour in heritage objects and to detect and trace its possible change, fading or loss over time, with the intention of reconstructing the original appearance of the objects as conceived by their creators and appreciated at the time of their creation. However, in the case of fragmentary remnants of colour on originally polychrome objects, the exact identification of the materials on the object's surface provides only a partial understanding and gives only limited hints to build theories for the original appearance of the objects. More importantly, colour constitutes an interdisciplinary research topic involving material science and provenance studies, but requiring a broader approach to colour perception, addressing sensorial, cognitive and psychological responses to colour, as well as getting insight into its semantic content with respect to the context in which the coloured artworks belong. Light is our tool for investigating colour, to identify the materials and elucidating the techniques of its application with various media and on different substrates. It is equally the means to display, to communicate colour and enhance its perception in exhibitions by museum visitors. However, light is on the same time the insidious enemy of colour, threatening the most sensitive aspect of the artwork. Museum lighting design is in consent with Preventive conservation and research has significantly contributed to solve the "The Dilemma: seeing vs saving", responding to the twofold needs of better preserving and communicating colored artworks.

The first and main part of the talk is dedicated to this topic, presenting an overview of recent developments and our group's involvement in a number of collaborative research frameworks, namely: PROTEAS - ΠΡΩΤΕΑΣ - Advanced System for collection and management of analytical data for documentation and conservation of large-scale paintings in an open laboratory, ΕΣΠΑ - ΕΡΕΥΝΩ-ΔΗΜΙΟΥΡΓΩ-ΚΑΙΝΟΤΟΜΩ, Α.Π. 5069984, (2020 – 2023); IPERION-HS, Integrating Platforms for the European Research Infrastructure ON Heritage Science, H2020-INFRAIA-2019-1, GA 871034, (2020-2023) and PERCEIVE, Perceptive Enhanced Realities of Colored collEctions through AI and Virtual Experiences, HORIZON-CL2-2021-HERITAGE-01-04, GA 101061157 (2023-2026).

At the end of this talk, an update will be presented relating to a bunch of action lines and respective National or EU framework projects aiming at the establishment of the European Research Infrastructure for Heritage Science (E-RIHS). Our group is actively involved in the final preparative Implementation Phase towards E-RIHS as ERIC legal entity, according to the ESFRI framework, in E-RIHS IP, HORIZON-INFRA-2021-DEV-02-02, GA 101079148 (2022-2024).

Unravelling associations of proteins with large intrinsic disorder

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Abstract

One may consider a protein as a monodisperse macromolecule with a sequence consisting of negatively and positively charged, as well as hydrophilic and hydrophobic side groups, therefore producing a sequence of increased complexity compared to typical homopolymers or block copolymers. Many proteins, in isolation, are predicted to have large regions of intrinsic disorder equivalent to extended chain, swollen polymers. It is also known that many proteins both *in vivo* and *in vitro* can undergo liquid-liquid phase separation in a dense and a dilute phase under the control of temperature, pH or intra cellular stress.

The question we would like to address is how the conformation of such proteins is altered as the proteins undergo phase separation [1], how that depends on their sequence [1], and how their conformation changes and possibly compacts as they interact with association partners. As a next step, we would like to transfer the acquired knowledge to biological relevant systems and pathology.

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Looking and listening to complex biological systems with novel biophotonics

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Abstract

Modern advances in photonic technologies and their applications in biomedical research and clinical practice offer new avenues for exploration of biological function, detection and treatment of disease in living organisms and systems. It is indeed only recently that the Nobel Prize was awarded for the invention of Nanoscopy enabling us to observe and quantify biology with resolutions down to the nanometer scale [1]. For imaging larger samples methods that provide three dimensional microscopic images such as Optical Projection Tomography (OPT) and Light Sheet Fluorescence Microcopy (LSFM) [2] have been widely used. Furthermore, advances in optoacoustic imaging have allowed to image in so far non-accessible regimes with unprecedented resolutions, based on the use of light for the production of ultrasonic waves [3]. However, the use of photonic technologies still comes with significant disadvantages associated with the diffusive transport of light in biological tissue. Radically new technologies are being developed for the production, manipulation and delivery of light radiation, based on adaptive wavefront control [4, 5]. These very exciting discoveries and advances in biophotonic technologies have now starting to revolutionize the way biological research is performed, providing the ability to perform in vivo imaging in scales ranging from microscopy to macroscopy at depths from a few micrometers to several centimeters.

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Atomic-scale modeling of 2D nanostructures

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Abstract

Triggered by graphene, research activity on two-dimensional (2D) materials is still growing at an explosive rate. Single layers of atomic thickness often display very different properties from their 3D counterparts. Ranging from insulators and semiconductors to conductors, some 2D crystals exhibit exciting low-dimensional physics and show great promise for optoelectronics, catalysis, and energy applications. Semiconducting transition metal dichalcogenide (TMD) monolayers have direct bandgaps, striking excitons, and, in addition to charge and spin, their electrons possess a valley degree of freedom. Robust metallic states at the edges of TMD nanostructures are observed. These unique properties depend on composition, dimensionality, strain, defects, chemical modification and nanostructuring, and may be engineered for specific applications. When combined in heterostructures, with graphene and/or other materials, TMDs offer new opportunities in nanotechnology. Great progress in the field in a short time period has raised great expectations and, at the same time, many fundamental and practical issues. Theory, accurate modeling, and simulation, contribute decisively to efforts to resolve them. Detailed theoretical understanding, besides interpreting and guiding experiments, provides predictions and guidelines for improved design and functionality of 2D materials. We discuss theoretical and computational approaches used in our "Quantum Theory of Materials" group and present some results which are mainly based on first principles calculations for TMDs and other nanostructured materials, including from our recent collaborations with experimental groups in our local research ecosystem [1-6].

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The research activities of the Ultrafast Laser Micro- and Nano-Processing Lab of IESL-FORTH

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Abstract

This presentation provides an overview of the activities performed by the researchers of the Ultrafast Laser Micro- and Nano- Processing laboratory (ULMNP) of IESL-FORTH and their collaborators within or outside funded projects. The ULMNP lab follows a multidisciplinary research approach and comprises 7 subgroups focusing on distinct scientific topics. In particular:

The *Laser Processing of Materials* subgroup follows a combined experimental/theoretical approach to understand and control the formation of complex hierarchical bioinspired topographies on artificial materials.

In the *Laser Materials Synthesis* subgroup the activities are focusing on the chemical free one-step laser based manufacturing techniques for the fabrication of nanomaterials, thin films and complex nanostructures for applications in automotive, energy, biology and food industry.

The *Lasers in Optoelectronics* subgroup focuses on the implementation of laser spectroscopy and diagnostics for the characterization of materials for advanced energy harvesting and catalysis applications as well the development of advanced composite glasses for optoelectronic and photonic applications.

The *2D Materials* subgroup applies optical spectroscopy methods to access and control key information of monolayers and novel 2D heterostructures such as the optical gap, absorption and emission strength, exciton formation and crystallographic orientation.

The *Nanomaterials* subgroup focused on the synthesis of stable all-inorganic metal halide perovskite colloidal nanocrystals to be used as efficient energy storage and gas sensing elements. Special focus is dedicated to the conjugation with 2D materials.

In the *Direct Laser Biofabrication of Tissue Scaffolds* subgroup research is focused on the development of ultashort direct laser, 3D, as well as hybrid, 4D, biofabrication methods for tissue engineering and other biomedical applications.

The *Imaging* subgroup is developing state of the art linear and non-linear imaging modalities for application in materials and devices diagnostics as well in biology and bioengineering.

Besides presenting recent research progress, the future perspectives will also be analysed and discussed.

Approaches to studying cellular responses under the effect of extracellular signals

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Abstract

Understanding the mechanisms by which the topographical cues of extracellular matrix (ECM) affect cellular responses such as proliferation, adhesion, growth, orientation, and differentiation is fundamentally important for tissue engineering / regenerative medicine applications. However, the complexity of the hierarchical micro/nano topography of ECM renders extremely difficult the investigation of cell-substratum response; revealing, thus, the need for the development of in vitro experimental models with defined surface topography.

Towards this scope research efforts have been focused on lasers as tools for 2D and 3D structuring materials as they do not require harsh processing conditions (chemicals or high temperature). These technologies can help the generation of well-controlled three-dimensional structures in a precisely predictable manner where it is easy to modulate the chemistry and the underline topography. Such 3D structures are valuable tools as model scaffolds in tissue engineering and regenerative medicine approaches.

In spite of what has been achieved so far in the Engineering and Materials fields, a complete understanding from a biological point of view is missing. The questions that are inquired are “how do cells interact with their micro/nano environment?” “How do they respond to the extracellular stimuli?” These are the questions that the field of Mechanobiology deals with. A field at the interface of biology, physics, and bioengineering, which focuses on how cell/tissue mechanics and physical forces influence cell behavior, cell and tissue morphogenesis, and diseases related to these processes. Mechanotransduction refers to the ability of the cell to actively sense and respond to mechanical cues of its microenvironment by adapting its behavior accordingly. In the TERMIm (Tissue engineering, Regenerative medicine & Immuno-engineering) group we study the activation of mechanotransduction mechanisms in response to the mechanical properties of a scaffold, the topography and the shear stress.

Nanostructured materials for optosensing applications

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Abstract

Semiconducting metal oxides are known to undergo changes in their properties electrical, optical, or mechanical in response to an external stimulus. This behavior makes oxide semiconductors highly promising materials for a number of chemical sensor applications and sensing schemes.

In this context, new type of sensors based on the laser-induced photoluminescence (PL) emission of nanostructured materials (e.g. ZnO/polymer hybrids [1][2], titanates $MTiO_3$ (M = Ni, Co) [3]) and their capacity regarding their sensing properties will be presented. Their sensing behavior has been investigated at different surrounding atmosphere (ethanol [1], oxygen [2], ozone [4]), exploring both weak and strong laser excitation. For the optical characterization and the study of the PL emission the samples were optically pumped with laser sources of proper wavelength and pulse width (Nd:YAG laser, λ=355nm, τ=8 ns; KrF laser, λ=248 nm, τ = 450 fs).

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Development of a portable, hybrid analytical instrument combining LED-Induced Fluorescence, Laser-Induced Breakdown Spectroscopy and Diffuse Reflectance for an integrated analysis of materials on monuments and objects of archaeological interest

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The present work describes the technical and performance characteristics of a newly developed portable hybrid instrument, which is used for the analysis of a wide range of materials encountered on monuments and objects of archaeological interest. As is widely known, archaeological objects may be composed of different types of stones, ceramics, metals and metal alloys and present paint overlayers (e.g. wall paintings, ceramics etc.). Moreover, the impact from numerous anthropogenic and environmental factors leads to the formation on the monuments' surface of crusts and deposits of varying composition; inorganic pollution crusts and biodeterioration are only few of the different deposits. Prior performing any type of conservation procedure, it is of vital importance to fully characterise the materials present on the object/monument, as a different treatment will be required depending on their composition. The portable, hybrid analytical device developed in the frames of the project CALLOS (Conservation of Athens antiquities with Laser and Lidar technologies Open to Science and public, NSRF-EPAnEK, MIS-5056208) is performing three spectroscopic techniques: LED-Induced Fluorescence for the detection and identification of biodeterioration, Laser-Induced Breakdown Spectroscopy for the elemental analysis of inorganic materials (pigments, metals and metal alloys etc.) and Diffuse Reflectance Spectroscopy for the molecular analysis of pigments. LED-IF and Diffuse Reflectance are completely non-destructive. LIBS is micro-invasive, giving thus the opportunity of stratigraphic analysis of multi-layered objects. The instrument consists of a portable analysis head connected with an umbilical with the power supply and spectrometers unit and the whole system can be easily transported on site for an integrated study of a monument. The preliminary analytical results from experiments conducted in the lab are promising and the authors believe that the developed system will be proved a valuable tool at the hands of conservators and heritage scientists towards a more efficient preservation of our cultural heritage.

Development of a fully automated micro-LIBS system for 2D elemental analysis of archeological shells

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Abstract

Chemical analysis of mollusc shells can offer valuable information in paleo-climatic studies. Information about past environmental conditions, including the sea surface temperature, can be obtained. In addition, from the analysis of shells collected from archaeological sites, the season in which they were harvested can be inferred, helping to understand the settlement life, gathering practices and seasonality of occupation. Stable isotope analysis of shells is usually employed to obtain the sea surface temperature however, this analysis is time-consuming, destructive and expensive. Information about the sea surface temperature can also be estimated from the ratio between Mg and Ca concentration [1-2]. Mollusc shells are mainly composed of calcium carbonate however, in a process dependent on the sea surface temperature, magnesium is also incorporated, replacing the calcium ions. Unfortunately, the ratio of these two elements can be affected by endogenous mechanisms. The analysis of a large number of samples is recommended to avoid a possible misinterpretation of the results and increase the statistical value of the obtained information.

In this work, we present a micro-LIBS system able to obtain 2D elemental maps of shell samples. This system uses a laser working at a repetition rate of 100 Hz, completely synchronized with the sample stages' movement that allows the scanning of a whole shell (approx. 5000 points, 10 shots per position) in around 15 minutes. The scanning process (sample movement, auto-focus, spectra acquisition, etc.) is controlled by custom-made software specifically developed for this work. The LIBS instrument developed and built at IESL was delivered to the Römisch-Germanisches Zentralmuseum (Germany) research museum and it is being employed to analyze thousands of archaeological shells. This high-quantity and high-resolution approach will produce a combined natural and societal archive that because of its size can more easily and robustly reveal links between society and climate change, extreme events and natural hazards experienced.

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Generation and Characterization of Energetic Highly-Elliptical Extreme Ultraviolet Radiation

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Abstract

We report the generation of tunable energetic coherent extreme ultraviolet (XUV) radiation with controlled polarization. The XUV radiation results from the process of high harmonic generation (HHG) in a gas phase atomic medium, driven by an intense two-color circularly polarized counter-rotating laser field, under loose focusing geometry conditions. The output spectrum of the highly-elliptical HHG radiation can be tuned for a energy range of $\Delta E \approx 150 meV$ in the spectral range of $\approx$ 20 eV with energy per pulse $E^{XUV} \approx 400\ nJ$ at the source. The demonstrated energy values (along with tight XUV focusing geometries) are sufficient to induce nonlinear processes. Our results challenge current perspectives regarding ultra-fast investigations of chiral phenomena in the XUV spectral region.

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Optical spectroscopy and microscopy of 2D materials

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Abstract

The strong light-matter interaction and ultimate thinness of two-dimensional (2D or layered) materials makes them promising for applications in nanophotonics. The optical properties of monolayer transition metal dichalcogenides (TMDs) are governed by excitons, Coulomb-bound electron–hole pairs, while their unique electronic structure and symmetry gives access to new degrees of freedom such as the valley index. Additional functionalities emerge as these materials are stacked to form heterostructures and combine the unique properties of the constituent monolayers. Besides the materials currently being investigated, about 1800 materials are predicted to be stable in monolayer form [1]. Tools for investigating and controlling the optical properties of these emerging layered materials are therefore of critical importance.

We use optical methods to access key information such as the optical gap, absorption strength and exciton complexes in TMD monolayers [2]. We combine spatial and polarization resolution in photoluminescence experiments to examine spin and valley physics in monolayers and in heterostructures [3]. Furthermore, effective tuning and control of the electron density and valley polarization degree is achieved by pulsed laser irradiation doping techniques [4]. Combining Raman with photoluminescence spectroscopy and nonlinear microscopy techniques we evaluate the impact of strain and dielectric environment on the electronic structure of these materials. The structural symmetry of monolayers, as well as the twist angle in heterostructures[5] are revealed by polarization-resolved second harmonic generation microscopy [6]. In addition, novel structures with atomically-sharp 1D interface such as lateral heterostructures are investigated for exciton transport and formation of interlayer excitons. As the emission efficiency of 2D semiconductors can be further improved, we incorporate monolayers and heterostructures on dielectric nanoresonators to enhance and direct light emission via near-field interactions.

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Ultrafast Laser Micro/Nano Processing Laboratory

Lasers in Optoelectronics

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Abstract

Lasers in Optoelectronics (LiOn) is a subgroup within the Ultrafast Laser Micro/Nano Processing Laboratory (ULMNP). The research orientation of LiOn is divided in two main activities. The first consists of the implementation of laser spectroscopy and diagnostics for the characterization of materials for advanced energy harvesting and catalysis applications. Namely, ultrafast laser time-resolved transient absorption spectroscopy (TAS) is employed in perovskite [1-3], and organic photovoltaic devices [4]. The main objective of this approach is to study the physical origins of charge generation and free carrier exciton dynamics with the photovoltaic devices, towards improving their power conversion efficiency and stability [1-4]. Along similar lines, TAS is used to study thermoelectric composite polymers [5,6]. In thermoelectric materials, TAS allows to solve the challenge of correlating exciton dynamics of single and hybrid carbon nanotubes (CNTs) composite polymers with thermoelectric performance, so that superior materials can be used in advanced energy scavenging devices. Finally, plasmonic photocatalysts are studied by means of TAS, in order to provide insights into their action mechanism. Sustainable copper-iron-sulfide ($CuFeS_2$) photocatalysts were studied, to reveal that their excellent performance in the reduction of nitroarenes is attributed to the generation of hot electrons and heat in both the conduction and the intermediate bands [7]. The second research activity of LiOn subgroup involves the development of advanced composite glasses for optoelectronic and photonic applications. Laser processing of transparent inorganic oxide glasses is performed for the fabrication of erasable periodic surface patterns on silver phosphate ($AgPO_3$) glasses [8], whereas erasable waveguides are generated with the bulk of the same material [9]. Moreover, the recently developed post-melting encapsulation protocol, allows the growth of ultrastable and highly luminescent perovskite patterns within glasses [10,11]. On a similar manner the incorporation of two dimensional (2D) materials within transparent glasses was achieved, for the tailoring and enhancement of photoluminescence [12]. The developed composite glasses appear promising towards next-generation optoelectronic applications. Finally, the post-melting approach is employed for the feasible development of photochromic glasses with superior photo-switching response times.

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Photonics Application in Agrofoods and Environment

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Abstract

At the Photonics for Agrofoods and Environment Laboratory of IESL, we exploit our expertise in the field of the interaction of light with matter to develop and demonstrate specialized optical spectroscopic analysis methods in the field of agrofoods and the environment.

AGROFOODS

Specifically, we record the optical spectrum (from Absorption, Fluorescence, FT-IR and Raman Spectroscopy) that is the characteristic "fingerprint" and reflects the chemical composition of an agrofood sample. The optical spectrum is used to determine the agrofoods origin and to assess their quality and authenticity. Furthermore, we employ an innovative approach based on the combination of optical spectroscopy with machine learning algorithms for

a) Classification: The comparison of samples for investigation of similarities or differences and their grouping leads to conclusions for geographical origin [1], variety [2], age etc.

b) Regression: The correlation of optical spectroscopy results with results measured from other methods (e.g., classical analytical techniques) of the same samples allows the prediction of properties of a new unknown sample without any chemical analysis.

ENVIRONMENT

Greenhouse gas (GHG) emissions locally produced from small-scale human activities and natural phenomena have a massive environmental impact and thus require continuous monitoring. To that end, developing robust, accurate and cost-effective GHG monitoring instruments is critical. A ground-based, integrated path, differential absorption (IPDA) device is presented equipped with two low optical power DFB diode lasers for the detection of CO_2 and CH_4[3]. The atmospheric background concentration of these two GHG was measured with an accuracy of 5 ppm and 90 ppb, respectively. The calculation of the GHG concentration is performed using the differential absorption lidar (DIAL) equation which requires the spatial extent of the laser beam.

The device comprises a sealed waterproof case containing the components of the device, which is placed onto a 3.5m long pole. Moreover, it operates autonomously and can be rotated to a selected angle horizontally.

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Fe-based Superconductors: Structural Phase Transitions Tuned by Electronic Fluctuations

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Abstract

Among unconventional superconductors, the exceptional FeSe exhibits the simplest structure accompanied with intriguing behaviors, arising from structural modifications and electronic correlations upon intercalation. Intercalation of the binary 8 K FeSe superconductor with pyridine molecules leads to the hyper-expansion of the lattice with a concomitant 5-fold enhancement of the critical temperature (T_c) up to 42 K [1]. Subsequently, local distortions are introduced in the nanoscale environment which induce modifications on the average level, too. A global rotational symmetry-breaking structural transition called electronic nematicity [2], is believed to be the precursor of superconductivity, in such correlated systems. Our team has developed solvothermal synthesis pathways for $Li_x(C_5H_5N)_yFe_{2-z}Se_2$ intercalated samples which were probed at state of-the-art synchrotron facilities. In one hand, high Q-resolution X-ray diffraction, over a broad temperature range (10-300 K) is utilized to shed light on possible structural phase transitions, taking place at the average level when the materials across the T_c. Rietveld analysis suggests that their high-T_c relates to the tetragonal $ThCr_2Si_2$-type structure. On the other hand, complementary high-energy synchrotron X-rays enable a wide-Q field of view, appropriate for total scattering insights [3]. When combined with pair distribution function (PDF) analysis, correlated local distortions, pertaining to the electronic active Fe-selenide layers, are identified as the outcomes of the electron donor moieties, accommodated in the interlayer space. Meticulous studies in such superconductors will elucidate the correlation between structure, magnetism and superconductivity, in an effort to draw materials-design principles that help to optimize the electronic structure for attaining even higher T_c.

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Control of Femtosecond Laser Filamentation and Supercontinuum Generation in Liquids Using Neural Networks

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Abstract

Supercontinuum generation induced by laser filamentation has been a field of study of great interest since first demonstrated back in 1970 [1]. The control of laser filamentation and spectral shaping of supercontinuum generation are challenges by themselves because subtle changes in experimental parameters such as the pulse duration, or energy, result in great differences in the generated supercontinuum spectrum. This is where machine learning and especially neural networks come into play since they are robust against experimental noise with excellent pattern recognition capabilities [2].

Here we show that neural networks can be applied for the control of complex nonlinear phenomena, like laser filamentation. We demonstrate control of the spectral shaping of supercontinuum generation inside ethanol through filamentation of femtosecond laser pulses at 1030 nm [3]. For controlling the filaments length, we employ Bessel beams of tunable Bessel zones. Changes in supercontinuum generation were recorded by fine-tuning three experimental parameters: pulse energy, pulse duration and the Bessel zone range. A feedforward neural network was trained using these experimental data.

Our results show great promise for the control of complex nonlinear phenomena that are impossible to describe analytically and too difficult to simulate numerically. Examples include all laser filamentation phenomena and applications, like weather control, and strong THz emission.

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Designing new perovskite nano/micro- particles for energy storage and sensing applications

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Abstract

The past decade, metal halide perovskites have attracted great scientific and technological interest due to their promising application in diverse fields. Despite the great success of organic-inorganic metal halide perovskite materials mainly in photovoltaics, several challenges remain to be addressed such as their moisture, oxygen, light and heat intrinsic sensitivity. Low-temperature re-precipitation-based colloidal protocols will be presented for the synthesis of stable all-inorganic metal halide perovskites of centrosymmetric or non-centrosymmetric in nano- and micro-particles form. Morphological and structural features, as well as their physicochemical properties of these materials will be discussed and their potential utilization as energy storage and gas sensing elements. Furthermore, photo-induced processes in liquid dispersions will be introduced as efficient methods to induce shape and crystal structure transformations of the perovskites or even to conjugate them with 2D materials to improve their properties for these specific applications [1].

Perovskite-based, high-performance and stable anodes for Li- and Zn-air energy storage devices as well as stable, ultra-sensitive gas sensors will be presented [2]. Special focus will be dedicated to the role of the shape and size of these materials in the performance of both applications. Moreover, focus will be given to the synergistic effects emerging from the conjugation of them with 2D materials which endow enhanced properties and improved performance. Important to notice, that these materials showed a specific discharge capacity of 549 mAh g^{-1} and stability up to 1500 scans and can detect O_3 and H_2 down to 5 ppb and 1 ppm respectively.

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Hyper expanded molecule intercalated iron selenides with robust superconducting response

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Abstract

Iron-chalcogenides along with the copper oxides constitute two families of 2D materials that exhibit high superconducting critical temperature (T_c). In these, magnetism and superconductivity typically coexist, and the superconducting state emerges when antiferromagnetic (AFM) order is suppressed by carrier doping, structural modifications under external pressure, or chemical pressure via isovalent substitutions. Since the parent materials of Fe-based superconductors have layered structures, doping by intercalation offers a facile avenue to suppress the AFM state with concomitant enhancement of the T_c. Electron donor molecules co-intercalated with alkalis in the β-FeSe allow to study the impact on the electronic structure of the host, as the intercalation increases the interlayer separation and leads to a five-fold rise of the T_c (44 K). We have developed low-T solvothermal routes, for such high-T_c $Li_x(C_5H_5N)_yFe_{2-z}Se_2$ [1] in order to study their structure-property relations by high-resolution synchrotron-based tools. In particular, insights were sought on the way interlayer guests [Li-PyH5] impact (a) the evolution of the $FeSe_4$ building blocks in the FeSe electronically active layers and (b) the magnitude of T_c. For this, element-specific, synchrotron X-ray absorption (XAS, at the Fe and Se K-edges) spectroscopy has been chosen to uncover local structure correlations with evolving electronic properties as a function of doping (x) across T_c (~44 K) [2]. Local structure assessments through the Extended X-ray Absorption Fine Structure (EXAFS) region of the XAS spectra, reveal a systematic increase of the intralayer bond lengths (cf. Fe−Se and Fe−Fe) with an increased amount of doping (x). The nature of the Fe−Se bond remains highly covalent and stiff. However, the Fe−Fe distance evolves to become significantly softer at high Li content, as conferred by the reduced lattice force constant of the Fe−Fe network. The local bond fluctuations infer larger in-plane configurational disorder arising from some Fe-site deficiency. Density functional theory (DFT) guided modification of the isolated $Fe_{2-z}Se_2$ (z, vacant sites) planes, resembling the host layers, identify that Fe-site deficiency occurs at low energy cost, giving rise to stretched Fe sheets, in accordance with experiments. The robust high-T_c in $Li_x(C_5H_5N)_yFe_{2-z}Se_2$, arises from the interplay of electron-donating spacers and the iron selenide layer's tolerance to defect chemistry, a tool to favorably tune its Fermi surface properties [2].

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Biomimetic pattern formation via the employment of ultrashort pulsed lasers: from theory to experiment

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Abstract

The capability to produce an abundance of complex bioinspired surfaces exhibiting hierarchical structuring at length scales ranging from hundreds of nanometers to several micrometers unveils the advantage of the employment of the laser technology. An efficient control of the complexity of the fabricated topographies on artificial materials (i.e. metals, dielectrics, semiconductors, polymers) requires appropriate tuning of various laser parameters such as the wavelength, fluence, energy dose, polarization states, pulse duration [1]. The research activities of the Laser Processing of Materials Subgroup at Ultrafast Laser Micro- and Nano- Processing group (ULMNP) focus on tailoring submicrometer periodic surface structuring on various materials through the modulation of the laser parameters [2-5] or through the application of more advanced methodologies such as direct laser interference patterning [6]. Experiments were performed on both bulk and thin films.

In addition to the experimental methods developed to fabricate biomimetic structures, several laser-driven underlying phenomena including multiscale physical processes are investigated on a theoretical basis to determine the conditions for surface patterning. Rigorous theoretical approaches have been developed to be used to investigate the energy absorption (including surface waves and surface plasmon excitation) [7], electron excitation (use of Density Functional Theories, investigation of formation of population of out-of-equilibrium electrons) [8] phase transitions and pattern formation [9-10]. Theoretical studies have been conducted in a wide range of conditions including irradiation with pulses between the visible and the mid-IR [4,11] spectral region of duration between 10 fs to several ps. Simulations were performed on both thin films and bulk materials and optical parameter evaluation and damage thresholds estimation was performed as well as the exploration of excited electromagnetic modes [7, 12]. Another direction of the theoretical research activities is the employment of advanced machine learning-based approaches towards determining the laser conditions for the fabrication of biomimetic structures with specific features. The aim is to reduce the number of expensive experiments (i.e. via trial and error schemes) and time consuming simulations [13].

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Engineering Laser Wavefronts for Advanced Materials Processing

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Abstract

Processing of materials or 3D additive manufacturing by ultrashort laser pulses has evolved significantly over the last decade and is starting to reveal its scientific, technological and industrial potential with numerous applications in mechanics, optics, and the life sciences. Its configuration is to assemble small material building blocks, referred to as three-dimensional (3D) volume elements or voxels (volume pixels), into complex 3D functional architectures with increasing flexibility in geometry designing. Multiphoton Polymerization (MPP) by Direct Laser Writing (DLW) is a well-established technique for the fabrication of 3D micro- or nano-structures with high resolution. Although this technique has been regarded as a powerful method for many practical applications like photonics, metamaterials, micro-optics, scaffolds for tissue engineering or biomedical implants, this conventional single point by point, high spatial resolution writing routine is highly time-consuming when is combined with demands for parallel processing, large area or volume fabrication, long scale structuring, massive production or high aspect ratio structures.

Here, in order to surpass these limitations and accelerate the production of complex large scale and high-resolution 3D printed structures, we have developed a variety of 3D laser wavefronts engineering methods using a Spatial Light Modulator (SLM), for Advanced Laser Materials Processing. Firstly, exotic radially symmetric Airy beams are employed for the first time, for the advanced multiscale DLW of high aspect ratio structures [1]. Next, a holographic focal volume engineering technique is proposed and employed for the direct fabrication of 3D Chiral microstructures. In this case, discretized holograms in motion obtain the all-optical fabrication of 3D structures using a SLM [2]. In addition, Multi-beam Interference Lithography is proposed for parallel materials processing and the fabrication of 3D porous photocatalysts by MPP. This approach found to offer more than 100 times faster fabrication in comparison with the conventional DLW technique. Finally, Multi-Foci Lithography is employed for the fabrication of high porosity 3D printed media for photocatalysis, as well as the generation of THz chiral metamaterials.

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Applications of non-linear imaging in low dimensional materials and in living biological systems

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Abstract

At the Ultrafast Laser Micro and Nano Processing Laboratory (ULMNP) we employ a high-power (6W, 80MHz), 30fs oscillator followed by an optical parametric oscillator and a frequency doubler to generate a wide range of excitation wavelengths (760nm-1850nm) and perform combined polarization-resolved second harmonic generation (P-SHG), polarization-resolved third harmonic generation (P-THG) and two- and three- photon excited Fluorescence (2pF and 3pF) non-linear imaging. This is based on a fully motorized Zeiss microscope equipped with an incubator (37°C, 0,5% CO_2) and a pump (μl/min) providing the conditions and the supporting medium for long lasting live-imaging of cells and tissues. Our platform can record simultaneously the non-linear signals in both transmission (forward) and reflection (epi-) detection, using 5 simultaneous channels (based on PMT detectors) and presents dual beam, dual galvanometric mirrors dual raster-scanning imaging. The polarization of the excitation fs pulses and the polarization of the detected non-linear signals are controlled using motorized retardation plates and polarizers, while the samples can be studied in cryogenic conditions (78K) by utilizing a cryostat at the sample plane of our microscope.

We develop theory based on non-linear optics and we image at the nanometer level the quality, the twist angle, the valley population imbalance, the in-plane anisotropy and the strain in low dimensional materials and devices, while in parallel we study epilepsy and myelin related diseases in living brain slices [1-6]. Additionally, we study the adhesion, proliferation, and differentiation of live cells (e.g. fibroblasts, mesenchymal stem cells, N2a cells) cultured on polymeric substrates. Finally, we study the cytotoxicity of nanoparticles under static and flow conditions.

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Tilted fiber Bragg grating with Graphene nanohybrids overlayer for Ammonia detection

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Abstract

Ammonia in gas (NH_3) or aqueous (Ammonium hydroxide-NH_4OH) phase is used in a variety of applications including fertilizers, explosives, agriculture and cleaning fluids. It is a toxic substance, corrosive to tissues upon contact and exposure to sufficient, concentrated, quantities can be fatal. Herein, we report on the development of an Ammonia sensor based on a tilted fiber Bragg grating (TBFG) with graphene nanohybrids over layer.

A 4º TFBG was inscribed in a photosensitive fiber utilizing a 193 nm excimer laser and a standard phase mask setup. Employing laser-mediated explosive synthesis and transfer (LEST) a few microns thick film of few-layer turbostratic graphene flakes doped with F atoms (5%) were deposited on the fiber at the location of the grating. The response of the sensor in increasing vapor pressure of NH_4OH (28.0-30.0% NH_3 basis) was investigated by studying the shift of the characteristic spectral features of the TFBG spectrum (Fig 1a). For reference, the effect of H_2O was also monitored at identical conditions. As shown in Fig 1b, in saturated atmosphere of H_20 vapors, not only the cladding modes but also the fundamental Bragg mode exhibit a blue shift, of comparable value, indicating that the effect is not solely due to changes in the optical parameters of the overlayer. Similarly, in the case of NH_4OH, all modes exhibit a wavelength shift but in this case the shift is initially negative turning to positive when vapor saturation is reached (Fig 1c). Furthermore, there is a distinct difference in the magnitude of the monitored shifts with the higher order mode exhibiting 2.5x higher values compared to the Bragg mode. The study is ongoing and will also include fibers with pure graphene and graphene doped with SiO_x nanoparticles overlayers.

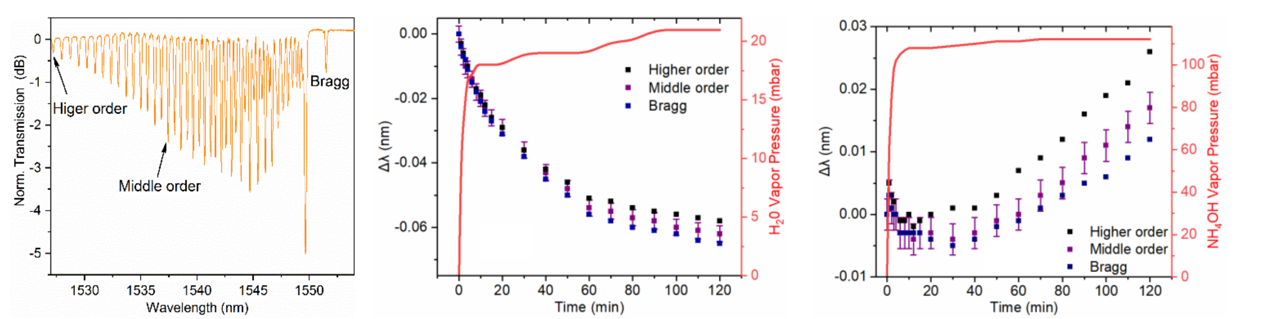

Fig. 1 (a) Typical TBFG transmission spectrum and TFBG wavelength shift versus time for increasing pressure of (a) H_2O vapors (c) NH_4OH vapors.

Miniature optical fiber sensor with photopolymerizable resin cavity for VOC vapor sensing

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Abstract

Volatile Organic Compounds, (VOCs), are organic chemicals that have a high vapor pressure under typical ambient conditions and can potentially create toxic conditions for humans, imposing the need for the development of accurate and reliable alcohol vapor sensors. Herein we report on the design and development of compact, easily produced and of low cost, Fabry Perot optical fiber sensor that exhibits distinct wavelength shift response in the presence of methanol, ethanol and isopropanol vapors at saturation pressure.

Commercially available UV photopolymerizable resin (NOA 65) is used to form a 60 μm length cavity at the end face of a single mode optical fiber (SMF28e) (Fig 1a inset). Upon exposure of the sensor to increasing vapor pressure of VOCs, in a testing chamber, the characteristic sinusoidal spectrum of the Fabry Perot shifts to higher wavelengths. Under prolonged exposure of the sensor to saturated alcohol vapors the wavelength shift continuous to increase and saturation is reached with different time delays for each VOC examined as shown in Figure 1 (a to c) for Methanol, Ethanol and Isopropanol respectively. The characteristic time required for the wavelength shift to stabilize is reached in 20, 50 and 120 min, respectively, for the aforementioned alcohols. Preliminary results indicate that the total wavelength shift is higher for ethanol (64.5 nm) followed by isopropanol (56.2 nm) methanol (52.8 nm). However these values depend on the size and geometry of the cavity and even higher shifts have been recorded (e.g 83 nm for MeOH) so further studies are required before concluding on the sensitivity of the sensor to each VOC.

Upon purging of VOC vapors, the sensor recovers back to its pre-exposed status albeit at a show rate, evident by an exponential decay trend of the FP wavelength shift corresponding to a mean lifetime of over an hour, for the case of methanol, due to the slow out diffusion properties of the resin. However, the low cost and ease of fabrication of the sensor makes it suitable for applications where single use sensing devices are favored.

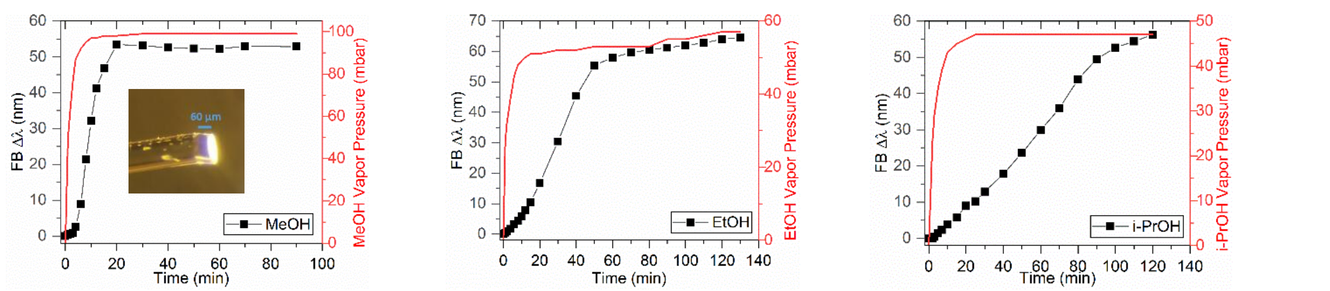

Figure 1 Sensor response to increasing vapor pressure of (a) Methanol, (b) Ethanol (c) Isopropanol. Inset: Microscope image of a typical sensor.

Intense THz sources and applications

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Abstract

Terahertz (THz) radiation, located in-between microwave and infrared frequencies, belongs to one of the most interesting and less explored regions of the electromagnetic spectrum. Currently, the interaction of powerful THz pulses with matter is a major frontier in strong field laser physics and nonlinear optics. A plethora of scientific challenges and applications are presently under study, like table-top electron acceleration, THz-enhanced attosecond pulse generation and strong electric and magnetic THz field interactions with matter. Nevertheless, despite the rapid development of THz science during the last two decades, most available table-top THz sources remain rather weak limiting the interactions of THz radiation with matter mostly in the realm of linear optics.

Here we present our advances towards the generation of intense, broadband THz fields. We focus on the generation scheme based on two-color filamentation in air, under which the fundamental and the second harmonic of an ultrashort pulsed laser are combined and focused into air forming a filament, which produces intense THz pulses in the far field. Novel approaches to enhance the THz emission and further upscale the efficiency of these sources will be presented [1,2]. These, among others, include the use of mid-infrared two-color laser pulses to drive the filamentation in air, resulting in an unprecedented THz conversion efficiency of a few percent, exceeding by far any previously reported experimental values for plasma-based THz sources [3]. Moreover, due to the large bandwidth of the generated THz radiation (~ 20 THz) the peak THz electric and magnetic fields exceed the 100 MV/cm and 33 Tesla, respectively. Finally, we discuss on the utilization of intense THz fields for the excitation of non-linear phenomena on various materials platforms [4-6].

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Direct Laser Fabrication and 4D printing of Biomimetic, 3D Scaffolds for Tissue Regeneration

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Abstract

The Direct **La**ser Fabrication of **Bio**mimetic, 3D Scaffolds for Tissue Regeneration (LaBio) Subgroup focuses on the following research topics:

i) Direct Laser Micro/Nano Fabrication of Biomimetic Scaffolds: Ultrafast pulsed laser irradiation is a simple microfabrication method to produce structures controlling their geometry, wettability and pattern regularity[1]. Such structures with an anisotropy discontinuous topography could enhance cellular growth and alignment (e.g. neuronal[2-4]). Soft lithography is used to transfer well-defined micropatterns to polymeric surfaces allowing the study on cell behavior[4,5].

ii) 3D Scaffolds Hosting Neurons and Neural Stem Cells: Topography is capable of inducing different effects on NSCs, such as changes in cell morphology, alignment, adhesion, migration, proliferation, cytoskeleton organization and also differentiation[1,2,6]. Embryonic neural stem cells that are cultured on ECM-based foams and hydrogels with differences in their architecture and their mechanical properties sense and respond to these substrate cues allowing us to develop tailor-made scaffolds for specific applications.

iii) Development of microfluidic systems for cell studies under dynamic culture conditions: Flow-induced shear stress can be applied to cells, in-vitro, using specially designed microfluidic systems. A precise flow-controlled microfluidic system with specific custom-designed chambers, incorporating laser-microstructured polymeric substrates with microgrooves[4], was developed to assess the combined effect of shear stress and topography on Schwann cells' behavior (adhesion, orientation, cell length) complemented with computational flow simulations to calculate accurately the shear stress values. The wall shear stress gradients may be acting either synergistic or antagonistic depending on the substrate groove orientation relative to the flow direction[7].

iv) 4D Printing of Biomaterials Scaffolds for Tissue Engineering: 4D printing is an emerging field of additive manufacturing enabling printing devices to mimic the sophisticated dynamics of native tissues. The developed 4D hybrid system combines a fused-deposition and a fluid-deposition mechanism in order to print hierarchically polymeric structures for cell ingrowth e.g. bone. Precision in creating micro-holes and topographical patterning are the main advances of the proposed 4D printing system. The ability of our techniques to control the cellular behavior and create cell patterns could be potentially useful in understanding disease pathogenesis and for the development of patient-specific applications.

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Femtosecond Lasers for Hydrogen Production

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Abstract

Femtosecond lasers are in the spotlight of research the last few decades, offering high research impact. In our laboratory femtosecond laser pulses are utilized to investigate the photophysical paths of effective donor-acceptor systems in photocatalytic hydrogen production, as well as to construct new nanostructured surfaces that will lead to more efficient electrocatalytic hydrogen production.

In detail, ultrafast time-resolved spectroscopy has been used to detect the subnanosecond electron dynamics in the tin-porphyrin and cobaloxime donor-acceptor system. The electron dynamics in the isolated porphyrin, presented constant behaviour at the framework of the detected time window. In contrast, in the presence of the cobaloxime catalyst the electron dynamics in the porphyrin ring have been found to drastically accelerate. This observation was attributed to an oxidative mechanism between the two components, interpreting the effect of enhanced hydrogen production in the system [1].

Femtosecond laser pulses have been also employed to irradiate metallic (Ni, Fe) and semiconducting (Si) surfaces. These have been subsequently used as electrodes in alkaline electrolysis for Hydrogen production. The laser-nanostructured electrodes presented a significantly increased (×5+) Hydrogen production efficiency, when compared to the flat ones. The H_2 production enhancement has been confirmed by current-time measurements during electrolysis. This significant enhancement has been attributed to the enlargement of the electrochemically active surface as a result of the laser irradiation and the concomitant laser-induced periodic surface nanostructures, [2][3][4], which have been characterized by scanning electron microscopy.

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Additive manufacturing laser processing techniques in Biotechnology, Energy, Food and Automotive Industry

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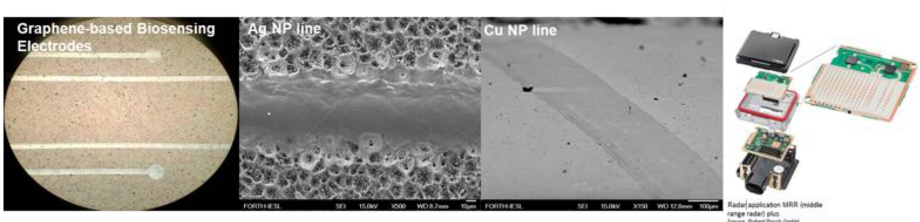
Abstract

Biotechnology: Brain function relies upon a complex, coordinated function of neurons, glial cells and blood vessels, which in neurological disorders such as epilepsy, Alzheimer's, and Parkinson's disease is disrupted. Via EPIGRAPH project we proposed the design and development of graphene biomolecular sensors, with graphene organic electronic ion pump (OEIP) neurotransmitter delivery, and electrophysiological electrodes integrated in an "all-in-one or single device/platform" for the prediction and control of epileptic seizures (towards a general intervention tool for most brain disorders). Ultimately, the Laser Materials Synthesis (LMS) activity, has developed a graphene based electrodes using laser reduction method, resulting to the desirable optical and electrical properties used in a biomolecular sensor for glucose and/or lactate detection.

Energy, Food and Automotive Industry: Digital printing of nanoinks complemented by direct laser sintering enables the mass production of digital conductive and dielectric patterns, which is advantageous for the performance of existing additive manufacturing technologies, leading to products with lower resistivities, improved adhesion, high aspect ratios and high-resolution line patterns on flexible and temperature sensitive substrates. To this end, the LMS activity of the Ultrafast Laser Micro and Nano Processing Laboratory has developed game changing cost effective technologies that enable higher aspect ratios and narrower patterning, following the popular trend towards sustainability and environmental friendliness. LMS efforts on laser sintering focus on printed electronics in the energy sector, namely photovoltaic grid electrodes. The aforementioned additive manufacturing techniques along with adaptive laser ablation and drilling are employed for new generation compact automotive sensor packages for autonomous cars. We focused on the design and optimization of fabrication processes, at speeds up to 7000mm/sec, for implementation into the RADAR/LIDAR TINKER pilot line. Finally, food industries, such as resourcing, production, processing, packaging and marketing of edible goods, are some of the most vital sectors of the global economy. Global efforts related to food safety and security have led to a rising interest in smart, "active" food packaging technologies. In SMARTPACK we report on the development of intelligent food packaging CO_2 gas sensors able to monitor gasses released during food shelf life realized via localized photonic processing using a homemade prototype laser sintering station.



Cavity Enhanced Microscopy (CEMIC)

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Abstract

Much of the knowledge in research comes from some form of light matter interaction. Traditionally, light passes through matter only once before being detected for any matter induced changes like adsorption or scattering etc, making measurements difficult when the light-matter interaction becomes weak. A solution for this problem is by placing the matter inside an optical cavity where light bounces back and forth several times thus increasing the light matter interaction by the number of passes. It is well-known that using an optical cavity can increase the sensitivity by several orders of magnitude [1]. However, most optical cavities do not retain the spatial variations occurring from the interaction. As a result this technique is predominantly used in spectroscopy measurements for example, Cavity Ring Down Spectroscopy. [1]

We have found a novel configuration of the optical cavity, where any spatial variation is sustained inside the cavity and gets enhanced due to the multiple passes of light. Thus we are now able to image the matter inside the cavity along with measuring any interactions. This technique opens the door to previously inaccessible or difficult to obtain images and measurements for optically thin samples in various research fields.

In this poster I discuss a proof of concept by imaging 2D optically transparent materials and discuss potential future applications.

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Altering the Surface Properties of Flexible Substrates by Utilizing Nanostructured Coatings

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Abstract

In recent years, the development of amphiphobic surfaces has attracted considerable interest due to their broad range of applications. Simultaneously, the properties of polymers can be tuned by the incorporation of nanoadditives in a polymer matrix, forming a composite material. In this study, we report on the development of superhydrophobic and highly oleophobic nanocomposite coatings, utilizing nanoparticles of different size added in a low surface energy polymer. The coatings were deposited on Low Density Polyethylene (LDPE) substrates appropriately modified by Corona treatment. The surface properties of the films were evaluated via Contact Angle (CA) measurements, indicating they highly depend on the kind of polymer matrix (silane/siloxane mixture, fluoropolymer), its concentration in aqueous solution, as well as on the content and size of the incorporated inorganic nanoparticles. Moreover, the CA values for the organic solvents were affected by their surface tension (Glycerol, Ethylene Glycol and Dimethyl Sulfoxide), with none of them surpassing that of water. The surface topology and roughness of the coatings were studied by Scanning Electron Microscopy (SEM) providing complementary information towards the interpretation of the results. The coated films exhibited the same transmittance and thermal properties as the original ones, as proven by UV-Vis spectroscopy and Differential Scanning Calorimetry (DSC), respectively, making them potential candidates in applications for the coverage of greenhouses.

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Development of Functional Materials Surfaces

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Abstract

Superhydrophobic surfaces have attracted significant scientific interest due to their importance in both fundamental research and practical applications [1, 2]. In this work, the development of a superhydrophobic and in certain cases water repellent surface is reported utilizing a simple, fast and economical way [3]. The material used was a smooth Ti6Al4V metal alloy that is widely utilized in several applications however its surface is considered hydrophilic. The surface of the material was initially irradiated by a femtosecond (fs) laser, without following a specific pattern, in order to acquire the necessary roughness. Following the irradiation, the effect of different parameters like temperature, pressure as well as residence time under heating or vacuum on the surface properties was investigated and the results were compared to the respective ones of a smooth surface. Contact angle and contact angle hysteresis measurements were performed to evaluate the wetting properties. The surface morphology was imaged by scanning electron microscopy (SEM) whereas the surface chemical composition was evaluated by energy dispersive X-Ray spectroscopy (EDS). A just-irradiated surface exhibits superhydrophillic behavior, nevertheless its residence in an oven at different temperatures results in an alteration of its surface characteristics and in the manifestation of a hydrophobic behavior especially for temperatures higher than 120°C. A similar effect was observed in the case that an irradiated surface was placed in a vacuum chamber (pressure 10^{-2} mbar); after a minimum of 3 hours the surface was converted to a superhydrophobic one, which additionally possessed water repellent properties, exhibiting very high contact angle and very low contact angle hysteresis. The observed behavior can be understood if one considers the change in the surface morphology and surface chemical composition.

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Development of Polyurethane/r-GO Nanocomposites with Reinforced Self-healing Properties

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Abstract

In recent years, self-healing coatings have been the subject of increasing research interest due to their ability to self-repair local damages caused by external forces. Polymeric materials comprise one of the most promising materials to use towards this direction [1]. Waterborne polyurethane dispersions (WPUD) have attracted broad attention due to their advantage of low release of volatile organic compounds (VOCs). WPUD have a wide range of commercial applications in coatings, adhesives, and other consumer products. On the other hand, graphene derivatives are widely used to reinforce the mechanical and thermal properties of WPUDs. In the current work, reduced graphene oxide (r-GO) was incorporated within a waterborne polyurethane dispersion based on polycarbonate polyol to develop nanocomposites in different compositions and investigate its effect on the self-healing properties. Initially, the graphene oxide (GO) was synthesized via a modified Hummers method and was subsequently reduced using hydroiodic acid (HI) as a reducing agent to prepare the r-GO. The self-healing ability of the polyurethanes was found enhanced in the nanocomposites and the healing rate was found much higher compared to that of the pure polymer, as confirmed by microscopic and thermal analysis techniques, mainly due to better heat dissipation. The superior heat conductivity of r-GO allowed for the optimization of the self-healing ability with the incorporation of just a small amount of the additive, whereas its presence enhanced the mechanical properties of the nanocomposites after healing, as well.

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Polymer / Graphene Oxide Nanocomposites: Investigating the Effect of the Interfacial Interactions on Structure and Properties

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Abstract

Polymer nanocomposites have been in the focus of interest of the research community due to their improved properties compared to the ones of the pure polymers. In this work, nanohybrids which consist of hyperbranched polymers of different generation and graphene oxides (GO) with different degree of oxidation were developed in a broad range of compositions to investigate the effect of the varying polymer/GO interactions on the final material structure and properties. Initially, the change of the GO oxidation degree was achieved by altering either the oxidation time or the mass of the oxidation agent, however it is only the latter that is found to play a role on the hybrid structure. Subsequently, nanohybrids were synthesized utilizing hyperbranched polyester polyols and the GOs with varying oxidation degrees. A gradual change from a phase separated to a fully intercalated structure was obtained using X-ray diffraction (XRD). Moreover, Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA) measurements revealed that the nanohybrids thermal properties were affected by the nanocomposite structure as well as the composition since there is a significant effect on the thermal transitions, the thermal stability of the polymer and on the reduction temperature of the GO.

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Acetylene Photochemistry Near its Ionization Energy

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Abstract

Acetylene is of fundamental importance in the fields of organic photochemistry [1], astrochemistry [2] and organic synthesis [3]. Matthiasson *et al.* [4] recorded REMPI spectra of acetylene following seven two-photon resonant transitions to low lying 3p and 4p Rydberg states in the 73000-83000 cm^{-1} region. They observed that parent ion formation dominates at low energies, while fragments such as H^+, C^+, CH^+, CH_2^+, C_2^+ and C_2H^+ become significant at higher energies. Using Velocity Map Imaging (VMI), we recorded photoelectron and ion (parent and H^+, C^+, CH^+, CH_2^+, C_2^+ and C_2H^+) images at the same seven 2-photon Rydberg transitions. We present here these results and what they reveal about acetylene photochemistry mechanisms near the ionization energy of the molecule.

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Detection of Gasoline Adulteration with Spectroscopic Methods

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Abstract

Gasoline adulteration is a major problem to both the economy and the environment. Optical spectroscopy methods, such as UV and NIR absorption, Raman, fluorescence and others, have been exploited in detecting adulteration in fuels. In this work, we compare the performance of three spectroscopic techniques, UV, FTIR and NIR absorption, in detecting two common types of gasoline adulteration: (1) fuel-in-fuel and (2) solvent-in-fuel. Premium (high octane) gasoline adulterated with regular (lower octane) gasoline and premium gasoline adulterated with non-fuel chemical solvents such as ethanol, toluene and white spirit were studied as prime examples of fuel-in-fuel and solvent in fuel adulteration respectively.

The UV, NIR and FTIR spectra were analyzed using Partial Least Squares (PLS) regression. Fitting coefficients (R^2) exhibit values between 87% and 99.5% for the premium-regular gasoline mixtures and above 96% for the solvent adulterations. Root-Mean-Square Error for Cross Validation (RMSECV) ranges from 4-14% in fuel-in-fuel and from 0.5-6.4% in solvent adulterations, which is sufficient to detect real-life gasoline adulteration.

This study signifies the potential of optical spectroscopy, combined with chemometrics, as a fast and reliable alternative technique for fuel quality studies.

Mechanotransduction: the effect of mechanical properties, topography and shear stress on cell response

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Abstract

Mechanotransduction refers to the ability of the cell to actively sense and respond to mechanical cues of its microenvironment by adapting its behavior accordingly. For such a response the cell activates a series of mechanisms to receive mechanical stimuli from the surrounding extracellular matrix (ECM) or from neighboring cells. These mechanical stimuli are converted intracellularly to biochemical ones which after being transferred into the nucleus they orchestrate the cell response by regulating gene expression.

The responses to these mechanical cues play key roles in many important cell functions such as the adhesion, survival, migration, proliferation and differentiation, and are therefore of interest in connection with the fabrication of improved biomimetic materials for tissue engineering applications. In the TERMIm (Tissue engineering, Regenerative medicine & Immuno-engineering) group we study the activation of mechanotransduction mechanisms in response to the mechanical properties of a scaffold, the topography and the shear stress.

Mechanosensing of ECM/substrata stiffness is mediated primarily by focal adhesions (FAs) which influence cell adhesion, spreading, and remodeling of the actin cytoskeleton. The FAs in turn modulate signaling pathways that control cell proliferation and differentiation through the YAP/TAZ molecules. Generally, with a stiffer substrate, there is an increased cytosol to nuclear translocation of the YAP/TAZ substrate, which can be attributed to the increased number of FAs per cell, as well as the increased tensile force on the stress fibers connecting the FAs that cause the cell to spread over a larger surface area. In the case of bone marrow derived mesenchymal stem cells (BMSCs), increased YAP/TAZ activation on a stiff substrate leads to enhancement of osteogenic differentiation. Laser made micro- and nano-topographies or 3D scaffolds of auxetic metamaterials offer an invaluable non-invasive means of investigating cell responses to mechanical cues, and greater understanding of mechanotransduction at the cell-material interface offering the potential to advance development of tailored topographical substrates and new generation implantable devices. In addition, the investigation of the mechanotransduction in dynamic cultures by introducing shear stress using microfluidic platforms can better recapitulate the complex cellular mechanosensing milieus in vivo. Moreover, shear stress combined with substrate topography can provide biomimetic cell growth environments for the improved understanding of cellular mechanotransduction behaviors accounting biomimetic mechanophysical conditions.