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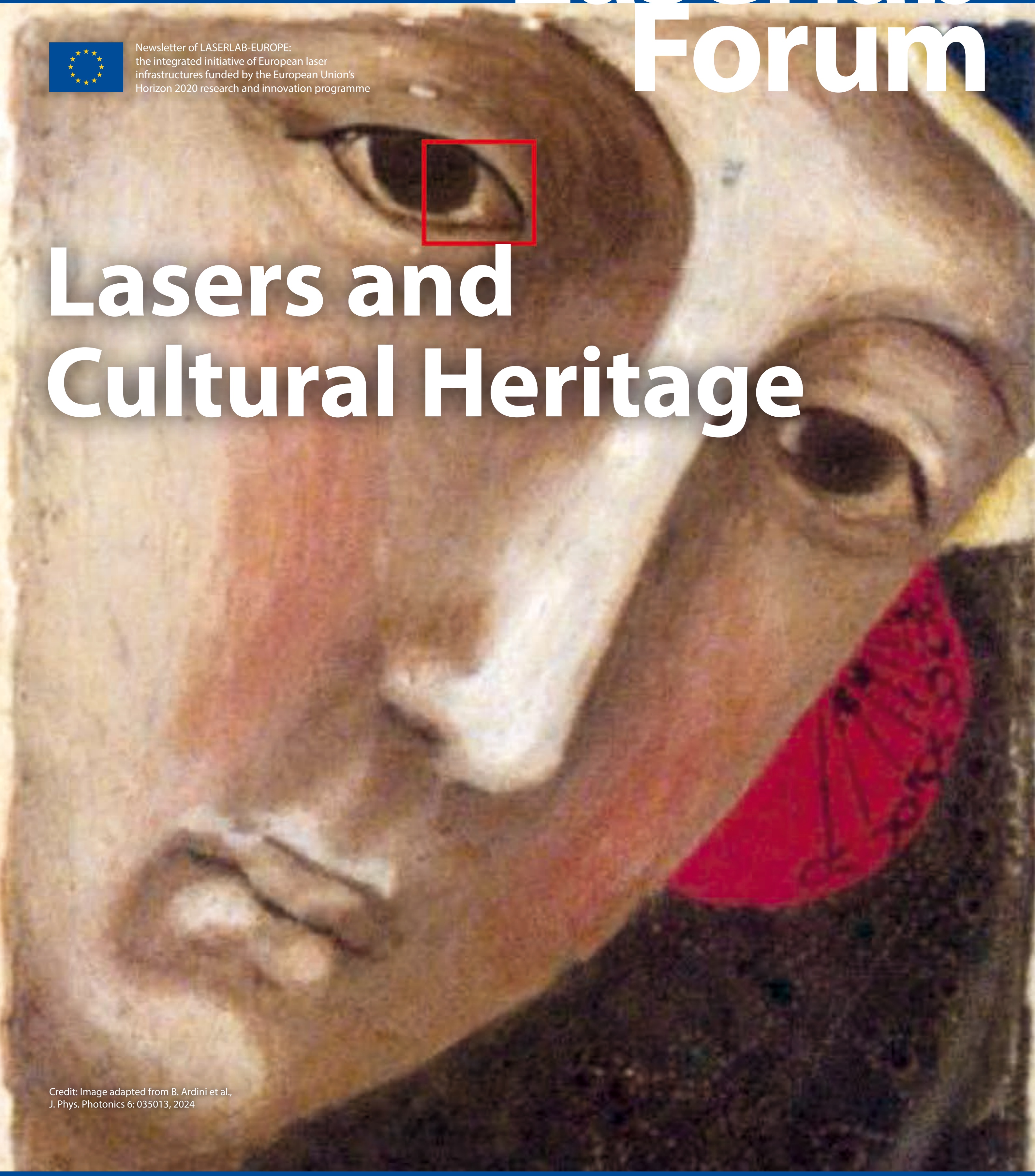
Laserlab Europe

Laserlab Forum

Newsletter of LASERLAB-EUROPE:
the integrated initiative of European laser infrastructures funded by the European Union's Horizon 2020 research and innovation programme



Lasers and Cultural Heritage

Credit: Image adapted from B. Ardini et al., J. Phys. Photonics 6: 035013, 2024

In this Issue

Editorial

Sylvie Jacquemot

In an era of fast technological advances, preserving the past is more important than ever. Laser-based technologies are revolutionising this effort, offering new ways to uncover, understand, and protect our cultural heritage for future generations. The ensuing articles highlight current studies of Laserlab-Europe's researchers, demonstrating the unique power of laser technologies in this field.

Additionally, I would like to update you on recent developments at Laserlab-Europe. Lasers4EU, the successor of the Laserlab-Europe V project, was launched in October with a fruitful kick-off meeting in Crete (Greece), and will offer transnational access and comprehensive training opportunities over the next four years. The RIANA project, with a focus on access in nanoscience and nanotechnology, has recently opened its call for proposals, with many Laserlab-Europe infrastructures offering access to their laser-related techniques.

With these exciting new developments, we look forward to using the power of lasers to link the past, present, and future, opening up new research possibilities every day.

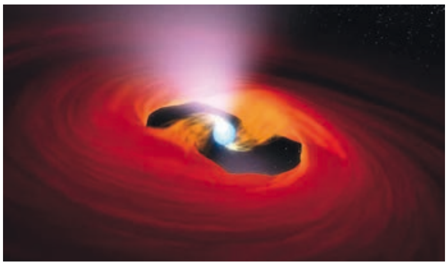
I wish you an interesting reading and a safe, happy New Year!

Sylvie Jacquemot

News

First-ever lab creation of electron-positron pair plasmas marks breakthrough in plasma physics

NASA



Researchers from the Central Laser Facility (CLF), operated by the Science and Technology Facilities Council, in collaboration with international institutions, have successfully generated electron-positron pair plasmas in the laboratory for the first time. These plasmas, commonly found in extreme astrophysical environments like black holes and neutron stars, have been challenging to replicate due to the difficulty in producing sufficient positron densities.

After decades of effort, scientists from the CLF and their colleagues finally succeeded in producing electron-positron pair plasmas robust enough for testing. Using CERN's Super Proton Synchrotron (SPS), they managed to generate sufficiently high numbers of electrons and positrons by bombarding a specialised target with a proton beam traveling near the speed of light. This resulted in a flood of positrons and electrons dense enough to create electron-positron pair plasmas displaying collective effects suitable for testing.

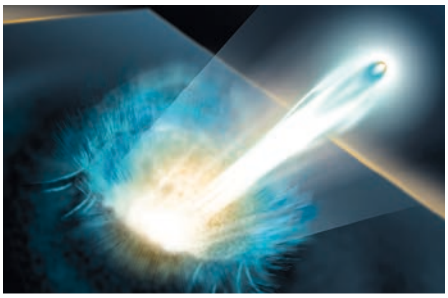
This breakthrough allows scientists to study cosmic phenomena in detail and opens new possibilities for future research using advanced laser facilities like Vulcan 20-20.

https://doi.org/10.1038/s41467-024-49346-2

New energy record for next generation proton accelerators

The Helmholtz-Zentrum Dresden-Rossendorf (HZDR) has made a significant advance in laser plasma acceleration. By employing an innovative method, a research team managed to substantially exceed the previous record for proton acceleration, nearly doubling the proton energy from 80 MeV to 150 MeV.

To achieve this record, the team conducted a series of experiments to refine key interaction parameters, including the optimum target thickness and laser contrast settings. When



HZDR / Blaurock

analysing the measurement data, the research group discovered that the accelerated particle beam had another pleasing property: the high-energy protons exhibit a narrow energy distribution, meaning that, figuratively speaking, they are all about equally fast – an advantageous feature for later applications – for which high, uniform proton energies are extremely beneficial.

This advancement could lead to more compact and energy-efficient accelerators compared to conventional systems. Potential applications include cancer treatment and materials analysis, as the method enables higher precision and energy efficiency.

https://doi.org/10.1038/s41567-024-02505-0

What is Laserlab-Europe?

Laserlab-Europe, the Integrated Initiative of European Laser Research Infrastructures, understands itself as the central place in Europe where new developments in laser research take place in a flexible and co-ordinated fashion beyond the potential of a national scale. The Consortium currently brings together 35 leading organisations in laser-based inter-disciplinary research from 18 countries. Additional partners and countries join in the activities through the association Laserlab-Europe AISBL. Its main objectives are to maintain a sustainable inter-disciplinary network of European national laboratories; to strengthen the European leading role in laser research through Joint Research Activities; and to offer access to state-of-the-art laser research facilities to researchers from all fields of science and from any laboratory in order to perform world-class research.

Novel universal light-based technique to control valley polarisation in bulk materials

ICFO

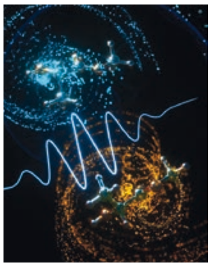
A team of researchers at ICFO, in collaboration with international partners, has developed a new universal technique to control valley polarisation in centrosymmetric bulk materials, marking a significant breakthrough in the field. This method uses specially tailored light pulses to manipulate the "valleys" – a local minimum or maximum in a material's electronic band structure – without being restricted by the specific properties of a material.

Previously, valley polarisation, which is key to advancing technologies like quantum computing and information processing, had only been achieved in 2D monolayer materials, which are difficult to produce and scale. The ICFO team's discovery overcomes these limitations by successfully inducing valley polarisation in bulk materials. This universal approach opens the door to broader applications in controlling electron behaviour, enabling more detailed material characterisation and advancing low-energy, high-speed devices.

https://doi.org/10.1038/s41566-024-01436-9

Scientists decipher the contribution of electrons to molecular chirality

A new experimental approach has advanced the understanding of the role of electrons in the molecular chiral reactivity and offers a way to control physical and chemical properties that result from chiral interactions. The study was led by University of Hamburg and DESY as part of a collaboration with the Centre Lasers Intenses et Applications (CELIA) and the Laboratoire de Chimie et Physique Quantiques (LCPQ) in France and the Max Born Institute (MBI) in Berlin.

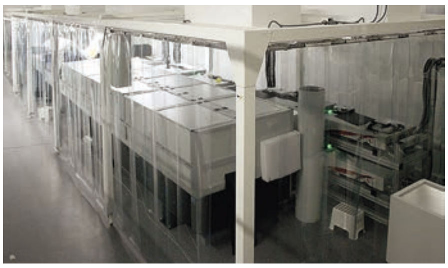


Ella Maru Studio, Inc.

Molecular chirality, crucial for interactions between enantiomers – molecules that are mirror images of each other –, plays a significant role in drug design. The static and dynamic properties of chiral molecules can be shaped by using light. So far, only the light-activated structural dynamics have been considered to affect the chiral response of molecules. Using ultrashort ultraviolet light pulses, the team initiated ultrafast electron migration in neutral chiral molecules. They discovered that the activated coherent electronic motion can modulate the molecular chiral response and even induce a sign reversal, on a timescale below 10 femtoseconds.

https://doi.org/10.1038/s41586-024-07415-y

Advancements in ultra-short laser technology: The petawatt system VEGA at CLPU



CLPU 2023

The Spanish Center for Pulsed Lasers (CLPU) has successfully completed a project aimed at optimising its unique petawatt laser system, VEGA, after three and a half years of work. Funded by the Ministry of Science and Innovation, the project called "Reorganisation of the VEGA system lines for pump and probe experiments" has significantly enhanced the functionality of the equipment and increased the versatility of the experimental environment of the facility.

Key achievements include, among others, the commissioning of a new uncompressed petawatt laser line, the construction and commissioning of a delay line for the synchronisation of VEGA outputs, and the improvement of space-time synchronisation through optimisation and characterisation of stability in the pre-amplification of the system.

These developments have enabled the provision of a new diagnostic system for users known as the pump and probe, in which two laser beams are used: one to interact with a target (the object where the laser impacts) and the other to perform an analysis of the results of that interaction.

In memoriam: Karel Jungwirth

René Volfík

Laserlab-Europe mourns the loss of Karel Jungwirth, former director of the Institute of Physics of the Czech Academy of Sciences and the PALS Research Centre, who passed away on 9 October 2024 at the age of 82.

Karel Jungwirth played a pivotal role in establishing and leading the PALS (Prague Asterix Laser System) Research Centre, facilitating the transfer of the high-power iodine laser system from the Max Planck Institute to the Czech Republic. As PALS director for nearly 20 years and a 15-year representative in the Laserlab-Europe Consortium, he made a significant mark on the scientific community.

The Laserlab-Europe community will remember him as an outstanding scientist whose contributions to Czech science leave a lasting legacy.

ERC Grants

The European Research Council (ERC) promotes frontier research by awarding prestigious grants to outstanding researchers for projects of ground-breaking nature. Laserlab-Europe researchers have again been successful in the ERC's highly competitive selection process. Congratulations to the five scientists who were recently awarded ERC grants, four receiving a Starting Grant, and one receiving an Advanced Grant.

Kasra Amini (MBI): Complete characterisation of photochemical reactions by time- and energy-resolved electron scattering

Kasra Amini will use his ERC Starting Grant to develop a ground-breaking technique called time- and energy-resolved electron scattering (TERES). This method will add an energy dimension to existing ultrafast electron scattering measurements, allowing the exploration of interactions between electrons and atomic nuclei in molecules and thin films. Amini's project combines ultrafast electron diffraction (UED), which tracks molecular structural changes, with electron energy loss spectroscopy (EELS), providing insights into electronic states. The TERES approach could revolutionise our understanding of molecular reactions by creating "quantum molecular movies" that reveal detailed, real-time changes at the quantum level.

Jad C. Halimeh (MPQ): Quantum simulation of far-from-equilibrium gauge theories


MCQST / C. Hohmann

The ERC Starting Grant will fund Jad C. Halimeh's project aimed at advancing quantum simulation, particularly in the challenging field of far-from-equilibrium gauge theories. These theories are crucial for understanding fundamental physics but are difficult to probe due to quantum entanglement in their non-perturbative dynamics. The project "QuSiGauge" employs a two-pronged approach: a technological pillar focused on developing large-scale quantum simulators of non-Abelian gauge theories in higher spatial dimensions and a phenomenological pillar aimed at uncovering exotic far-from-equilibrium quantum dynamics. The results could shed light on the nature of equilibration in isolated quantum many-body systems, with potential applications in quantum sensing and metrology.

Marco Piccardo (IST): Space-time and vectorial meta-optics for high-power structured laser-matter interactions

Plasma, an extreme state of matter, is central to numerous advanced applications such as fusion energy and particle acceleration. High-power lasers, operating at terawatt or petawatt levels, are essential for the creation and control of plasma. However, a significant challenge in plasma science and engineering is the need for advanced beam control at these high-power levels. Marco Piccardo's ERC Starting Grant project metaPOWER addresses this challenge by developing high-damage-threshold metasurfaces, a cutting-edge nanotechnology in structured light, for high-power lasers. The team will mold plasma using structured lasers as sculpting tools, unlocking an unprecedented control over laser-plasma interactions and enabling new possibilities in fusion energy, particle acceleration, and radiation sources.


Carolina | Instituto Superior Técnico

Guillermo González-Rubio (CLUR): Timescale-controlled transformations for colloidal multielemental nanocrystal design

Multielemental colloidal nanocrystals represent an exciting material class where surface and finite-size effects result in prominent physicochemical phenomena. Unfortunately, these nanomaterial features and their technological impact remain largely unexplored due to the high energy barriers and kinetic conditions often associated with the required synthesis process. With his ERC Starting Grant, Guillermo González Rubio will develop in the project Time4Nano a novel colloidal methodology to create highly out-of-equilibrium conditions required for multielemental nanomaterial creation. The major challenge is to combine pulsed laser irradiation and wet-chemical strategies to control chemical composition, elemental distribution, and lattice defects.

Andrei Kirilyuk (FELIX): Interaction of light with matter via control of terahertz phonons


Bert Beelen

With the ERC Advanced Grant project INTERPHON, Andrei Kirilyuk and his group challenge the existing ideas and understanding of the interactions between light and matter, creating a whole new research area at the junction of nonlinear optics, phononics and ultrafast magnetism. Light will be made to communicate with matter in an interactive way, so that matter reciprocates by changing the very resonance used for excitation. To realise this, INTERPHON will develop novel research methods using short and intense pulses of infrared-to-THz-range free electron laser FELIX. The aim is energy-efficient and ultrafast manipulation of materials.

Focus: Lasers and Cultural Heritage

From decoding ancient secrets to preserving iconic masterpieces, laser-based technologies continue to transform our understanding of cultural heritage. The laser experts from Laserlab-Europe have played a vital role in uncovering, understanding, and preserving Europe's rich history. In this issue, we highlight remarkable projects that demonstrate the unique power of laser technologies to examine and preserve Europe's cultural treasures for generations to come.

Seeing the invisible (CLF, United Kingdom)

A collaborative team from STFC's Central Laser Facility, UK, and ISPC-CNR, Italy, has gained a detailed understanding of the performance of spatially offset Raman spectroscopy (SORS) in the boundary region accessible through macro- and micro-SORS techniques. This knowledge will enable more effective and wider deployment of the techniques in cultural heritage (CH) applications.

Macro-SORS, usually simply referred to as SORS, was developed at the CLF for probing larger, diffusely scattering objects, such as opaque plastic bottles, pharmaceutical products or human tissue at depth, and has been deployed in various applications, for example at airports for scanning liquid samples within unopened bottles. Micro-SORS is an adaptation of this technique and was originally developed in partnership with ISPC-CNR in Milan to facilitate the non-invasive probing of objects of CH, to reveal the chemical composition of hidden layers of paint in frescoes, paintings and statues. Such information is required, for example, for the effective and safe restoration of objects of art, or when studying artist's techniques.

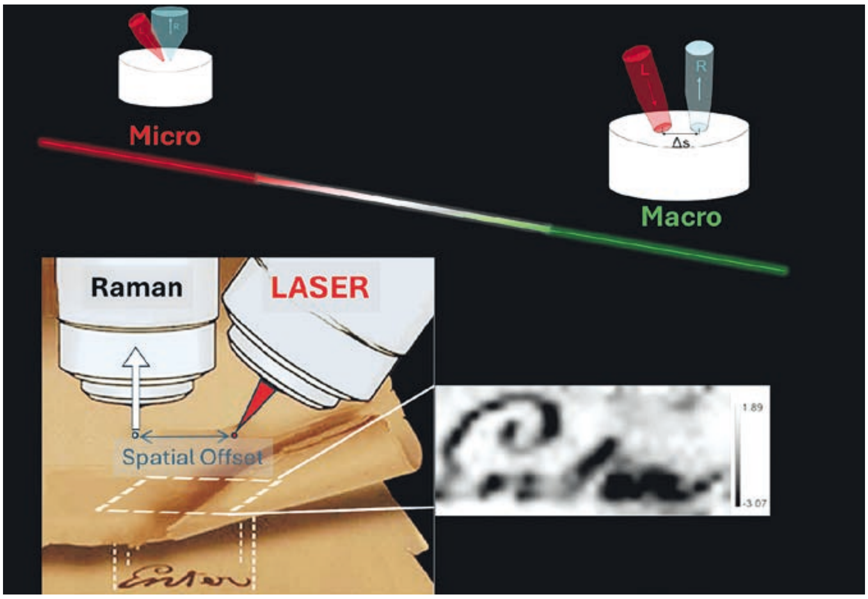
Until recently, there was little understanding of the interface between the macro- and micro-SORS regimes, posing a challenge for applications at mesoscale (for example, to probe samples with ~1 millimetre-thick overlayers). This recent study [1] has clarified when micro- and macro-SORS techniques are better suited to a particular set of samples and has provided a simple set of rules for selecting the optimum sampling approach.

In further work, the above teams have partnered with The National Archives, UK, to apply micro-SORS to read 18th century historic documents and letters [2], including letters seized on ships that were never delivered and remain sealed. This study was carried out at The National Archives premises using an open geometry Horiba Raman microscope adapted for micro-SORS sampling. Using the optical properties of the sample, such as absorption and fluorescence emission, in conjunction with photon diffusion effects enabled the team to recover hidden texts through paper, in a non-invasive way.

Claudia Conti, Alessandra Botteon and Alberto Lux (CNR-ISPC); Pavel Matousek and Sara Mosca (Central Laser Facility); Marc Vermeulen (The National Archives, UK)

[1] A. Lux et al., Appl. Spectrosc. 1–14, 2024
[2] A. Botteon et al., Anal. Chem. 96: 4535–4543, 2024

Figure adapted from A. Lux et al., Appl. Spectrosc. 1–14, 2024, and A. Botteon et al., Anal. Chem. 96 (11): 4535–4543, 2024



Schematic of the micro-SORS configuration used to retrieve the sub-surface imaging of concealed texts

Multi-scalar and multi-modal hyperspectral imaging of artworks with the TWINS-based camera (POLIMI, Italy)

Hyperspectral imaging (HSI) is a powerful non-contact tool for studying artworks [1]. Traditionally, HSI is performed using push-broom line-scanning cameras, which offer excellent spectral resolution. However, these systems require spatial scanning of the object or of the detection module, making it difficult to analyse large or complex artworks efficiently.

An innovative hyperspectral camera, based on the Fourier transform (FT) approach, offers a more flexible alternative. This method involves coupling a high-throughput interferometer – such as the Translating Wedge-Based Identical Pulses Encoding System (TWINS) – to a monochrome camera [2,3]. Studies performed so far have demonstrated the versatility of this method and how it can be configured for multi-modal and multi-scale imaging [4,5]. The system's high collection efficiency allows for rapid, sequential detection of multiple signal types, including diffuse reflectance, transmittance, photoluminescence, and Raman. Moreover, by using different optical configurations in the collection path, the system allows for the investigation of areas of different size, spanning from wide field of view (FOV) imaging to macro- and micro-imaging, as detailed in the following.

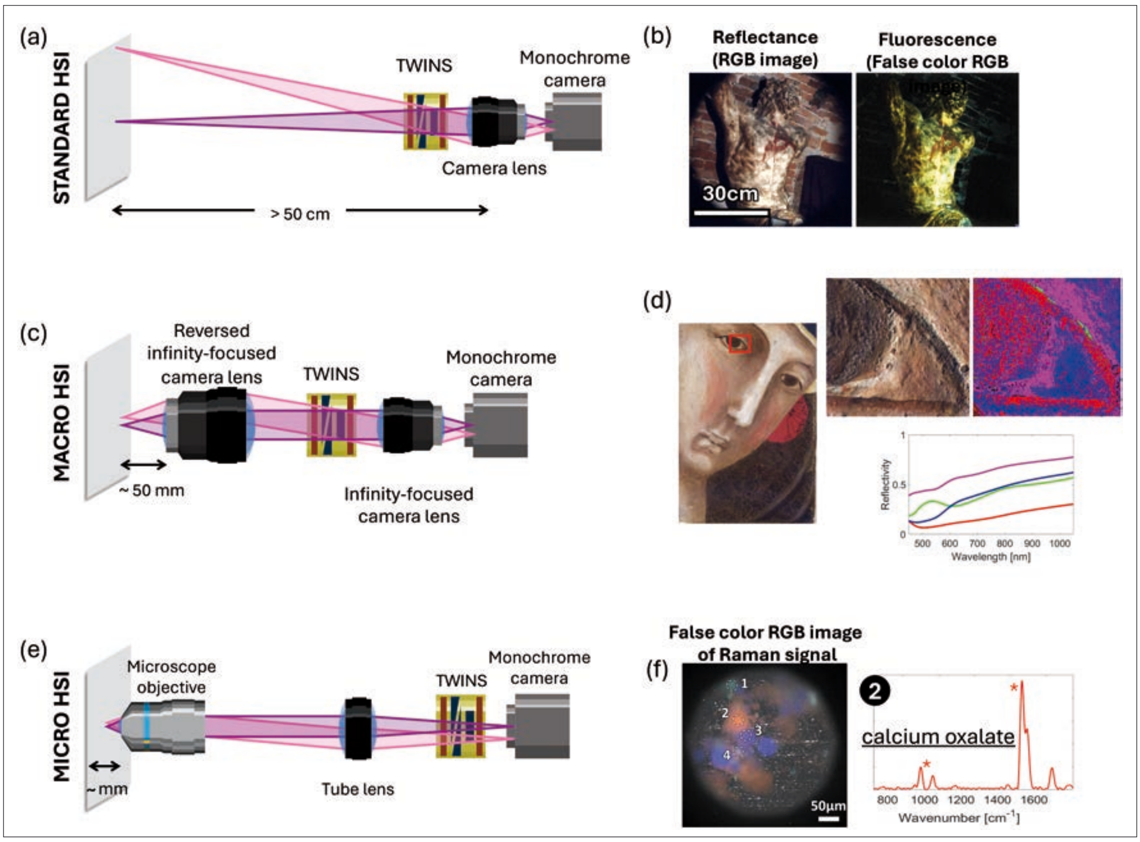
By coupling the TWINS-based HSI system to a camera lens (focal length 25 mm, angular FOV 15.4°), it can be used to study large artworks (from tens of centimetres to several metres in size) in situ (Figure a). For example, UV-excited photoluminescence measurements of a statue at the Accademia di Belle Arti di Brera revealed distinct colourants and surface contaminants left by an act of vandalism (Figure b).

For more detailed analysis, the TWINS-based HSI system can be configured for macro imaging [4], providing a FOV of approximately 20 mm and a spatial resolution of about 30 µm (Figure c). By focusing on a small area of a painting, this setup allows the precise identification of pigments with different spectral reflectivity, and thus, different chemical compositions (Figure d).

Finally, the TWINS interferometer can be paired with an optical microscope to conduct hyperspectral studies at an even smaller scale (Figure e) [5]. With this set-up, it proved possible to distinguish and spatially map different white mineral grains in a powder sample, based on the grains' unique Raman shifts (Figure f).

Daniela Comelli, Benedetto Ardini, Alessia Candeo (POLIMI); Giulio Cerullo, Gianluca Valentini (POLIMI, IFN-CNR) and Cristian Manzoni (IFN-CNR)

[1] C. Cucci et al., Accounts of chemical research 49: 2070-2079, 2016
[2] A. Perri et al., Optics Express 27: 15956-15967, 2019
[3] A. Candeo et al., The European Physical Journal Plus 137: 1-13, 2022
[4] B. Ardini et al., J. Phys. Photonics 6: 035013, 2024
[5] B. Ardini et al., Optica 10: 663-670, 2023



The TWINS-based HSI camera, comprising the TWINS interferometer and a monochrome 2D sensor, coupled with different optical systems to inspect scenes and samples at different FOVs. (a-c-e) Schematics showing the set-ups for imaging of large surfaces, macro- and micro-imaging, respectively. (b-d-f) Illustrative examples of system application on different types of samples to assess the spectral behaviour of different optical phenomena, such as diffuse reflectance, photoluminescence and Raman.

Emerging photonics technologies for remote and/or on-site monitoring of cultural heritage monuments and artefacts (IESL/FORTH, Greece)

Innovative non-invasive diagnostic technologies can be used to acquire vital information on cultural heritage (CH) artefacts and monuments. This information can provide advanced warning of risks related to material degradation and structural integrity, and is key to devising optimal conservation strategies that will prolong the lifespan and preserve the aesthetic value of CH objects.

High-resolution structural and chemical analysis of different types of CH objects has been carried out using two emerging photonic technologies, non-linear optical microscopy (NLOM) and optoacoustic (OA) imaging, with promising results [1]. In particular, NLOM has been used for stratigraphic analysis and detailed material profiling, and to detect degradation processes in various materials, including varnish, paint, glue, wood, parchment and metal, without causing damage [2-4]. Employing several NLOM modalities, such as multi-photon excitation fluorescence (MPEF), second harmonic generation (SHG), and third harmonic generation (THG), has enabled compositional analysis, sub-micron morphological imaging, and mapping of non-centrosymmetric materials to be carried out simultaneously.

NLOM modalities are based on the detection of optical signals following excitation with femtosecond laser sources, whereas the OA imaging technique uses the high-frequency acoustic waves generated by the strong absorption of pulsed optical radiation in a material sample. Recent studies at IESL/FORTH have looked at ways of applying OA methods to CH diagnostics [5]. OA signal recordings have successfully been used to detect invisible restoration operations in artworks, measure the thickness of opaque paint layers, and reveal hidden underdrawings in paintings and murals and hidden text in multi-layered documents. These results have demonstrated that OA techniques offer enhanced imaging depth to spatial resolution ratios coupled with high optical absorption sensitivity, overcoming the light scattering limitations associated with several pure optical techniques.

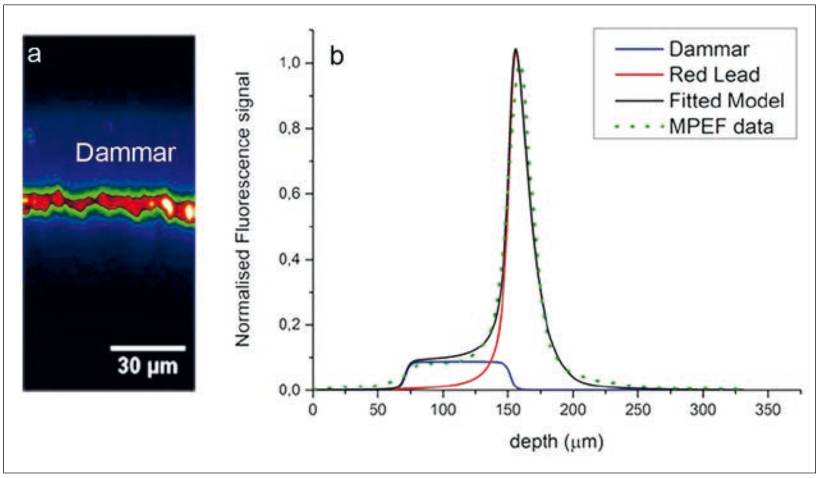


Figure 1: a) MPEF cross-sectional image of a model multi-layer sample, consisting of a red lead pigment paint layer and a dammar resin varnish layer. b) MPEF signal deconvolution in a z-scan profile.

The potential of NLOM and OA techniques to help safeguard CH monuments and artefacts is being further investigated within the ongoing *iPhotoCult* project. Funded by *Horizon Europe*, this project aims to develop, demonstrate and validate advanced, safe and non-invasive photonics and 'smart' software tools for on-site and/or remote monitoring and diagnostics. IESL/FORTH is coordinating *iPhotoCult*, which involves 14 European research, technology, CH and modern culture organisations from six EU member-states. A key project activity will involve adapting a transportable OA system such that it is capable of supporting NLOM measurements, thereby enabling the extraction of complementary chemical information from the same region by applying both techniques. Such an OA-NLOM system will bring about progress in CH diagnostic capabilities, beyond the current state-of-the-art.

George Filippidis, George J. Tserevelakis, Meropi Mari, Giannis Zacharakis, Kristalia Melessanaki, Eleanna Pirgianaki and Costas Fotakis (IESL/FORTH)

[1] G. Filippidis et al., Applied Physics A 128: 982, 2022
[2] M. Mari et al., Sustainability 12: 1409, 2020
[3] M. Schmeltz et al., Sci Adv 7: 29, 2021
[4] M. Martínez-Weinbaum et al., J. of Cultural. Heritage 62: 170, 2023
[5] G.J. Tserevelakis et al., Heritage Science 8: 98, 2020

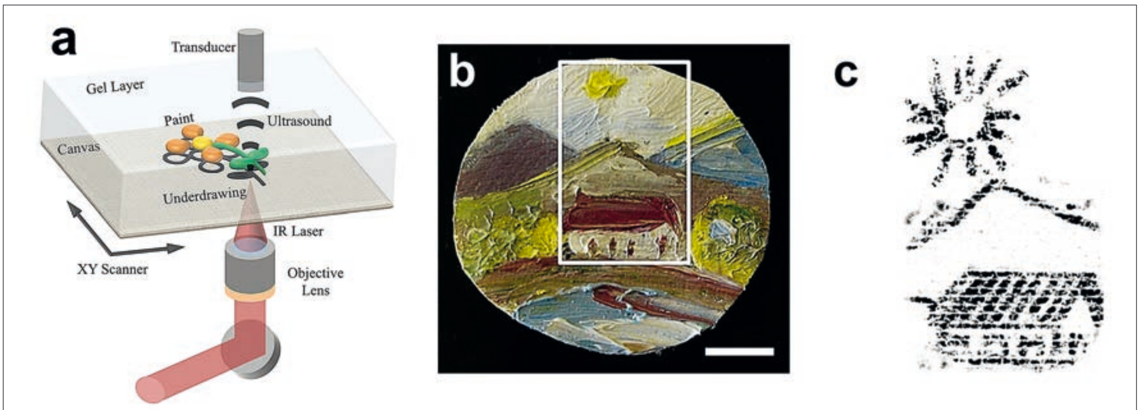


Figure 2: a) Schematics of the OA imaging setup for uncovering hidden pencil underdrawings in painted artworks. b) Image of a miniature painting portraying a rural landscape. The white rectangle indicates the investigated region. Scalebar is equal to 1 cm. c) OA amplified image of the painting's hidden sketch.

Studying light-induced degradation mechanisms of dyes using a liquid-core waveguide (LaserLaB Amsterdam, Netherlands)

Colour change or discolouration due to photodegradation is a major problem in cultural heritage. A well-known example is the painting by Vincent Van Gogh of his own bedroom, which he describes in a letter to his brother as having purple walls. However, in the Van Gogh Museum in Amsterdam today, the painting shows blue walls (see Figure 1). It is now known that this colour change has arisen because of the red eosin-based component of the purple paint being more sensitive to light-induced degradation than the blue component.

Figure 1: Vincent Van Gogh: The Bedroom. Right its current appearance, left a digital reconstruction of its original appearance

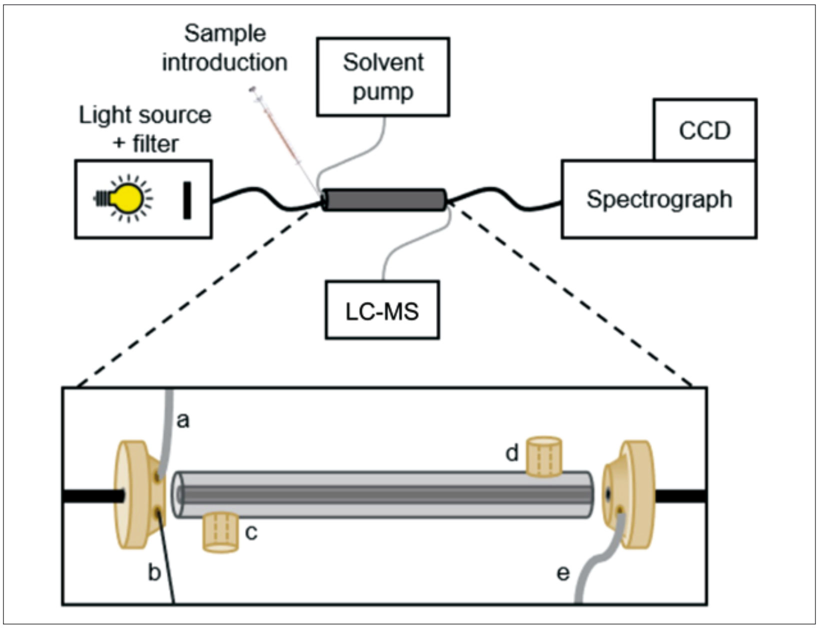


Figure 2: Schematic overview of the design of the LCW cell: (a) connection with solvent pump; (b) sample delivery; (c) gas inlet; (d) gas outlet; (e) coupling to LC-MS

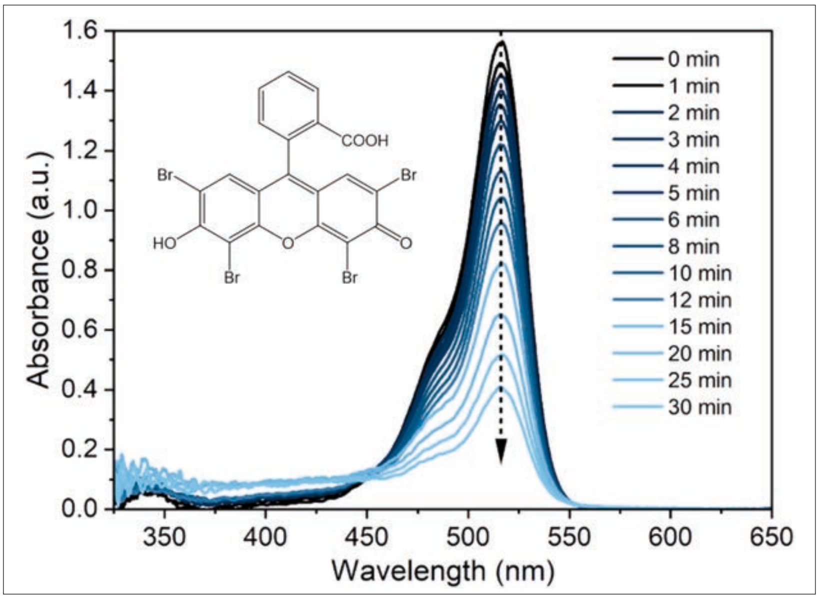


Figure 3: Photodegradation of Eosin Y under oxic conditions, measured in situ

A team of scientists from the University of Amsterdam, the Vrije Universiteit Amsterdam and several partner organisations, including the Van Gogh Museum and the Netherlands Cultural Heritage Agency, set out to develop instruments and approaches to study the chemistry of light-induced degradation in a more systematic manner. One of the systems developed (see Figure 2) is based on a liquid-core waveguide (LCW) flow cell, a thin hollow tube made of a special type of Teflon that has a lower refractive index than that of water. As a result, light entering the core of the LCW at one side is transported over its full length because of total internal reflection, and can thus irradiate a liquid sample inside the cell both efficiently and homogeneously.

For this study, a dye solution was injected into the LCW (internal volume 60 µlitre) and irradiated with a Xenon lamp, used to mimic the solar spectrum. A spectrometer at the other end was used to monitor the changes in UV-Vis absorbance during the irradiation process. The 100 µm thin LCW wall is air-permeable and by virtue of a tube-in-tube geometry, it was possible to monitor the degradation of dyes under oxic (air) or anoxic (nitrogen) conditions. After a specified irradiation time, the content of the LCW was transferred to a coupled liquid chromatography system with mass spectrometry detection (LC-MS system) for further analysis. The whole system was fully automated. Results obtained with Eosin Y under oxic conditions (see Figure 3) showed a gradual degradation over time with no change in the shape of the visible spectrum, indicating chemical breakdown into colourless products. A completely different mechanism, leading to faster breakdown into orange-coloured products, was found under anoxic conditions (not shown).

Current activities at LaserLaB Amsterdam include photodegradation studies of solid samples (including paintings) and the application of Raman imaging techniques for the subsequent non-invasive detection of chemical changes, at the surface and below.

Iris Groeneveld and Freek Ariese
(LaserLaB Amsterdam)

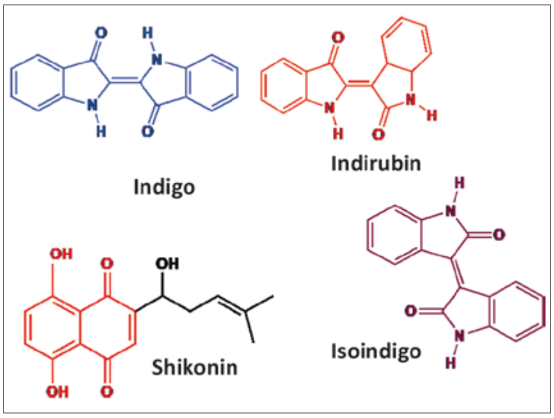
[1] I. Groeneveld et al., Analyst 146: 3197-3207, 2021
[2] I. Groeneveld et al., J Photochem Photobiol. 441: 114685, 2023

Fast reaction kinetics in the context of cultural heritage (CLL, Portugal)

Over the past 20 years, research in the field of cultural heritage (CH) has been conducted at the CLL, focusing on reaction kinetics involving what are known as "the molecules of colour," including historic dyes, such as indigo, indirubin and shikonin. These studies have highlighted the critical role of rapid excited-state decay processes in the stability of these molecules, and thus in the context of CH, since these molecules are present in numerous works of art, some dating back to the Egyptian civilisation. The longevity of these dyes is attributed to efficient excited state deactivation mechanisms, in particular excited state proton transfer (ESPT) and rotational isomerisation, which prevent photodegradation. In some cases, these processes can only be observed using fast time-resolved techniques (femtosecend-picosecond). For example, indigo exhibits remarkable photostability due to an efficient ESPT mechanism (with a rate constant of 9×10^{10} s^{-1}) [1,2].

Indirubin, a structural isomer of indigo, possesses both ESPT and rotational deactivation mechanisms [3]. Isoindigo (where ESPT is absent) has even shorter excited state lifetimes, on the order of a few picoseconds, which contributes to its high photostability [4]. Other dyes, such as naphto- and anthraquinone-based molecules, also exhibit significant photostability due to rapid ESPT. For example, shikonin undergoes ESPT that effectively reduces photodegradation, highlighting the influence of molecular structure on dye stability [5].

In the context of ancient works of art, and therefore CH, hybrid organic-inorganic materials such as Maya Blue – a stable indigo-palygorskite composite used by the ancient Maya civilisation – illustrate how inorganic matrices can significantly protect dyes. Indigo carmine in layered double hydroxides (LDHs) further demonstrates this approach by replicating the stabilising effects of Maya Blue [1,2].



Some of the chemical structures of the most representative molecules discussed in this text

Other less obvious works of art include old postage stamps, with molecules of colour present in the pigments or dyes used in them. Studies have been carried out using various techniques, including time-resolved fluorescence techniques as non-invasive analytical methods, to determine the chemical composition of the dyes used in some early Portuguese postage stamps and their authenticity [6].

Overall, these studies highlight the importance of fast kinetics in understanding the stability of organic natural dyes, and offer valuable insights into the conservation and preservation of important works of art.

João Sérgio Seixas de Melo (CLL)

[1] J.S. Seixas de Melo, Photochemistry 49: 31-52, 2022
[2] J.S. Seixas de Melo, Photochemistry 45: 68-100, 2018
[3] D.C. Nobre et al., Dyes and Pigments 212: 111116, 2023
[4] C. Cunha et al., Dyes and Pigments 229: 112307, 2024
[5] C. M. Pinto et al., J. Mol. Struct. 138898, 2024
[6] C. Pinto and J. S. Seixas de Melo, Pure and Applied Chemistry 90: 435–445, 2018

Launch of Lasers4EU: Proposals welcome

The successor of the Laserlab-Europe V project was launched in October 2024 with a fruitful kick-off meeting in Crete (Greece), and will offer transnational access and comprehensive training opportunities over the next four years.
By bringing together 29 leading laser research institutions across Europe, the EU co-funded project Lasers4EU offers a central platform with unprecedented access to cutting-edge laser technologies and services for external scientists from academia and industry. Whether seeking specialised laser facilities for groundbreaking research or looking to leverage cutting-edge laser technology for industrial innovation, Lasers4EU is the central hub for accessing Europe's laser research infrastructures.
To submit your access proposal, please visit *https://lasers4.eu/become-a-user/how-to-access/*

Simultaneous generation of high-frequency and high-pressure ultrasound waves through picosecond excitation of graphene-based materials

Advances in novel, efficient light-to-ultrasound conversion materials are opening the way for an increased number of applications in many different fields, including biology and medicine. Consequently, there is a growing need for high-amplitude and broadband ultrasound, which is driving the engineering of advanced photoacoustic materials and of device architectures. However, the opportunities for integrating miniaturised photoacoustic devices and minimally invasive tools in biomedical science can only be realised once the underlying phenomena are fully understood, and more efficient light-to-ultrasound conversion materials are available. To gain a better understanding of a new series of graphene-based materials and test their efficiency, researchers at the Coimbra Laser Lab (CLL, Portugal) used picosecond pulsed laser sources for photoacoustic excitation, and high-frequency sensors and needle hydrophones for ultrasound detection. It was experimentally shown that the photoacoustic waveform can be tailored by changing the temporal duration of the laser pulse, the geometry of the acoustic source, and the nature of the graphene absorber.

The increased interest in light-to-ultrasound conversion for biological and medical applications arises from the ability to generate ultrasound pulses characterised by high peak pressures (>1 MPa) and broad bandwidths (>50 MHz), using laser pulses with fluences typically below 100 mJ cm^{-2}. This combination of characteristics should enhance signal-to-noise ratios in high-resolution imaging, increase the depth of image acquisition, refine image resolution, and enhance mechanical interactions with microscopic objects and thin interfaces. The technique has vast potential in many applications, including diagnostic ultrasound imaging, therapeutic ultrasound, integrated micropumps based on photoacoustic streaming, and the capacity to make biological barriers, such as the skin or cell membranes, permeable for a short time, for example for drug delivery or gene transfection.

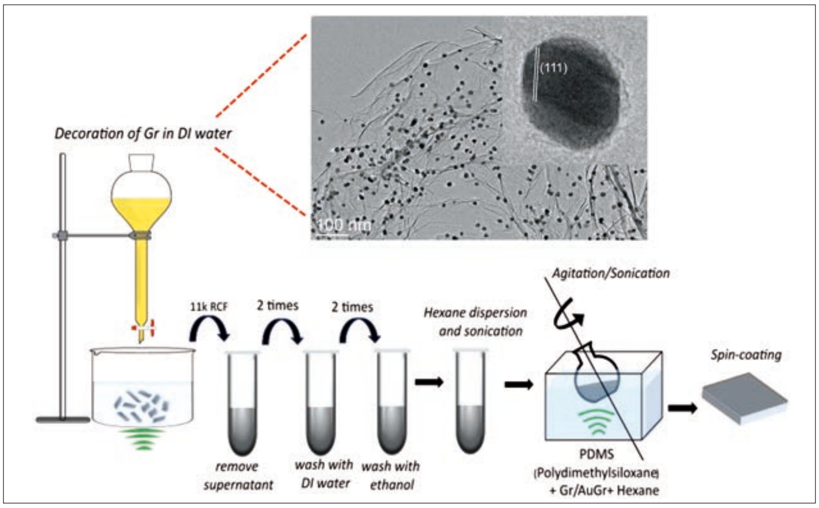


Figure 1: Illustration of the decoration process and an image of the decorated sample

Photoexcitation of films, made from a few layers of graphene (FLG) nanocrystals embedded in polymeric polydimethylsiloxane (PDMS) matrices, was proposed for efficient photoacoustic conversion. Due to the thermoelastic effect, when a short laser pulse is absorbed in such films, rapid heat transfer from the embedded graphene to the PDMS causes a rapid expansion of the polymer, resulting in the propagation of ultrasound in a liquid medium. Thin composite films were fabricated on a flexible support, with varying concentrations of graphene and gold-nanoparticle decorated graphene. Films containing 0.9 – 1.9 wt% of FLG, with thicknesses between 9.5 and 17 µm and light absorptions of up to 80%, were prepared and characterised at the University of Ljubljana (Slovenia). Decoration of graphene with gold nanoparticles was achieved by mixing the water dispersion of graphene with an aqueous solutions of gold(III)chloride at room temperature, without an additional reducing agent. Figure 1 shows a schematic of the decoration process and an image of the decorated sample. It was anticipated that the presence of gold nanoparticles would influence the shape and frequency response of the ultrasonic wave, enhancing the pressure peak due to improved light-matter interaction.

The experimental campaign associated with this Access project was proposed by Daniele Vella from the University of Ljubljana. With support from Laserlab-Europe, the experiments were performed at the Coimbra Laser Lab (CLL, Portugal), where short laser sources for photoacoustic excitation, high-frequency ultrasound detectors, and needle hydrophones were all available. Different laser pulse regimes were investigated to determine the thermal and stress confinement conditions needed for efficient light-to-ultrasound conversion. The thin films were excited with pulsed laser sources ranging from 30 ps to 8 ns pulse width, specifically to investigate the intensity, shape, and frequency distribution of the ultrasonic waves. A needle hydrophone and a broad bandwidth high-frequency (225 MHz) transducer in contact with the thin films were used to measure the ultrasonic waves (Figure 2). The contact transducer enabled the recording of all high-frequency ultrasound components that would otherwise be suppressed by strong attenuation in water.

The project set out to analyse the mechanisms involved in the optical generation of acoustic waves, by probing the photoacoustic response of graphene and gold-decorated graphene dispersed in a PDMS polymer matrix thin film, using different laser pulse durations for photoexcitation. The photoacoustic waveforms were tailored by modifying the geometry of the acoustic source and the composition of the graphene absorber.

It was found that the bandwidth of ultrasound waves generated via nanosecond excitation was limited by the excitation duration, but using picosecond excitation under stress confinement conditions broadened the frequency limit, generating intense and broadband photoacoustic waves. In experiments, picosecond excitation produced high-frequency waves with bandwidths of 6 dB and 20 dB around 70 MHz and 130 MHz, respectively, and peak pressures exceeding 5 MPa. Additionally, the presence of gold surface decoration improved the dispersibility of the graphene flakes within the polymer matrix, and led to a more uniform and efficient thermal interface. This improved the photoacoustic response, achieving a 6 dB bandwidth of 85 MHz. Notably, an increase in ultrasound frequency resulted from a decrease in film thickness, and was not affected by an increase in laser fluence to 150 mJ cm^{-2}, enabling the generation of stable high-pressure waves while keeping the same bandwidth. Some of the results obtained under picosecond laser excitation are shown in Figure 3.

This work has successfully demonstrated a flexible fabrication and decoration process for thin films, and offers a solution for the generation of high-frequency and high-pressure ultrasound waves. The results open promising new avenues for developing high-resolution photoacoustic imaging systems and for the use of physical methods to deliver more efficient permeabilisation of biological membranes.

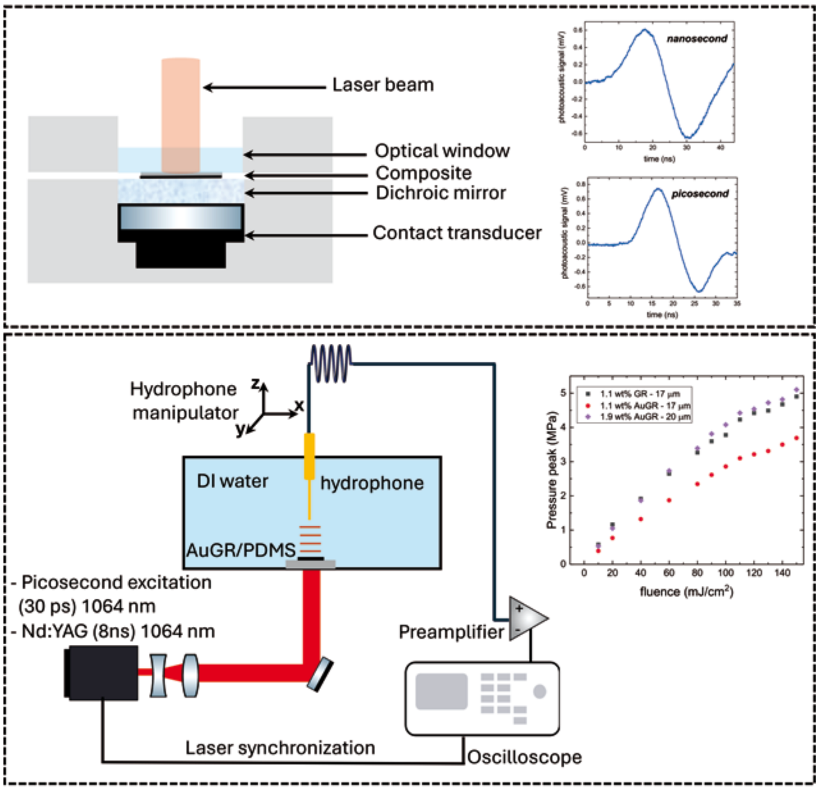


Figure 2: Experimental setup for high-frequency ultrasound detection (top panel), and absolute pressure measurements (bottom panel)

The results of this transnational Access project have recently been published in the journal Nano Energy.

Daniele Vella (University of Ljubljana, Slovenia) and Carlos Serpa (CLL, Portugal)

D. Vella et al., Nano Energy 131: 110236, 2024

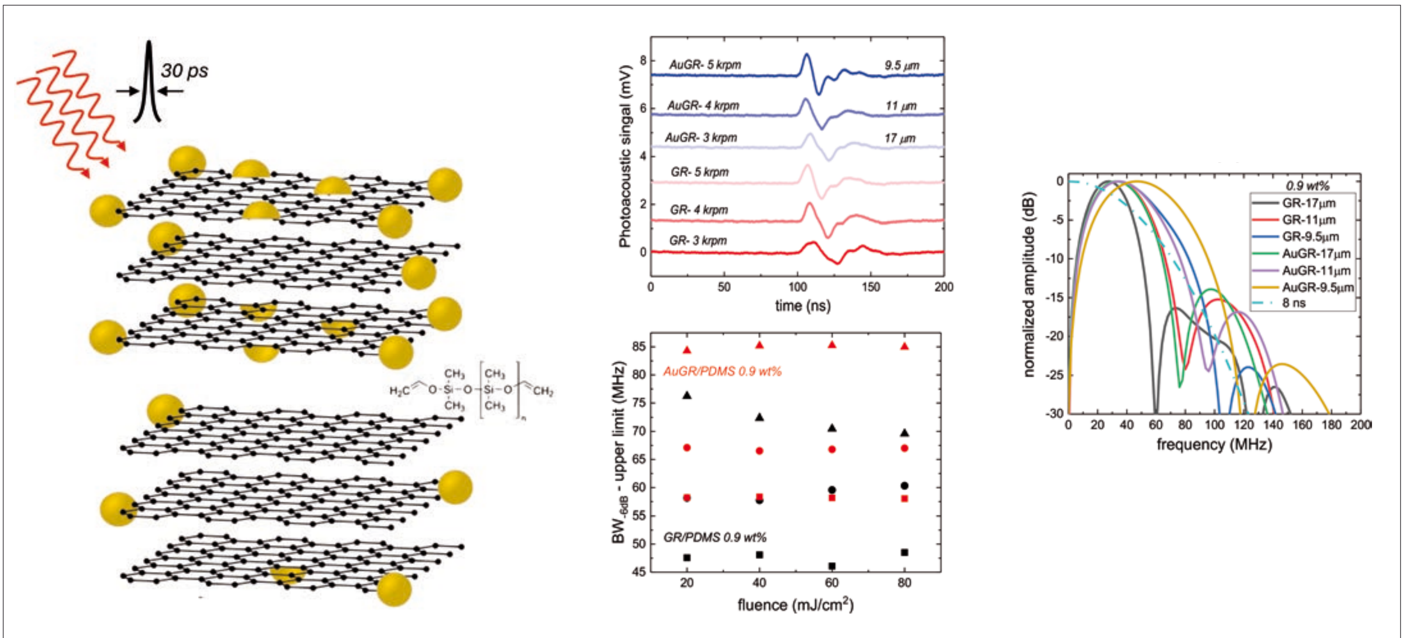


Figure 3: Results obtained under picosecond laser excitation

RIANA: Call for proposals is open

The hub for nanoscience and nanotechnology, RIANA (Research Infrastructure Access in Nanoscience & Nanotechnology), has opened its call for proposals. Academic researchers can apply for free access to at least two infrastructures from 69 leading nanoscience facilities across 22 European countries.

The project that has been officially launched on 1 March 2024 offers access to Europe's leading facilities in nanoscience and nanotechnology at the heart of the development of new materials for prosperity and sustainability. The facilities include synchrotron, electron microscopy, laser, ion beam, neutron, clean room, and soft matter research infrastructures as well as high performance computing.

Interested researchers may not only submit a complete proposal, but are invited to submit a pre-proposal with their research idea. RIANA's scientific network will then provide personalised support, from proposal writing to data analysis, aimed at advancing both scientific research and industrial applications in nanoscience and nanotechnology.

Beyond standard user access to single facilities, RIANA offers a single-point access and a particularly strong user support by a network of junior scientists. The following Laserlab-Europe infrastructures offer access to laser related techniques: CALT, CELIA, CLF, CLL, CLPU, CLUR, CUSBO, FELIX, FERMI, HiLASE, INFLPR, LENS, LIDYL, LLC, LP3, MUT, and ULF-FORTH.

For more information and submission of a (pre-) proposal, please visit: *https://riana-project.eu*

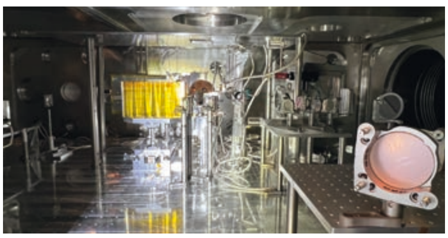
ELI ERIC advances joint user programme and progresses with strategic partnerships


ELI ERIC

The ELI user programme advanced with the conclusion of the 5th joint user call in October 2024. Since its launch in 2022, the user programme has received 478 experiment proposals involving 1400 unique users from institutes in 40 countries. Of the successful proposals over 140 experiments have been implemented so far. ELI maintains a biannual schedule for opening users calls with the 6th call scheduled for 25 March 2025. The annual ELI User Meeting is scheduled for 18-20 June 2025 in Szeged, Hungary.

Ongoing efforts at the ELI Facilities aim to enhance the technical performance parameters of experimental instruments, while commissioning, ramp up, and integrate further scientific equipment into the experimental offerings. Laser capabilities continue to improve with the set up of the HR Alignment laser and the installation of the SYLOS Alignment 2 system at ELI ALPS. At ELI Beamlines, the L3 HAPLS laser system was used in parallel operation which contributed to the successful commissioning of the Gammatron beamline, a multidisciplinary platform using hard X-ray radiation from a laser-plasma accelerator.

The ELI ERIC welcomed Bulgaria as a member and signed several MoUs with strategic partners, including a joint declaration of intent with Germany to boost collaboration in key areas such as medical sciences, laser-induced fusion, and ultrafast science. ELI ERIC is also preparing to introduce mission-based access to address high-impact scientific and technological challenges in the respective areas.


ELI ERIC

How to apply for access

Interested researchers are invited to contact the Laserlab-Europe website at www.laserlab-europe.eu/transnational-access, where they find relevant information about the participating facilities and local contact points as well as details about the submission procedure. Applicants are encouraged to contact any of the facilities directly to obtain additional information and assistance in preparing a proposal.

Proposal submission is done fully electronically, using the Laserlab-Europe Proposal Management System. Your proposal should contain a brief description of the scientific background and rationale of your project, of its objectives and of the added value of the expected results as well as the experimental set-up, methods and diagnostics that will be used.

Incoming proposals will be examined by the infrastructure you have indicated as host institution for technical feasibility and for formal compliance with the EU regulations, and then forwarded to the Access Selection Panel (ASP) of Laserlab-Europe. The ASP sends the proposal to external referees, who will judge the scientific content of the project and report their judgement to the ASP. The ASP will then take a final decision. In case the proposal is accepted, the host institution will instruct the applicant about further procedures.

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