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Lasers for Catalysis

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Laserlab Europe

Laserlab Forum

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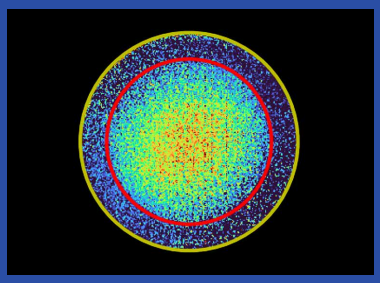
Lasers for Catalysis

Concept of pulsed photothermal catalysis on plasmonic nano-catalysts

Image adapted from Andrea Baldi and S. H. C. Askes, ACS Catalysis 13, 3419, 2023

In this Issue



Editorial

Sylvie Jacquemot

Catalysis lies at the heart of countless processes that support modern society, ranging from cleaner energy production and industrial chemistry to environmental remediation. In order to understand and improve these catalytic systems, scientists must navigate a complex landscape involving atomic-scale interactions, transient intermediates, and operating conditions ranging from ultrafast to industrially robust. In this context, lasers have become indispensable. This issue of Laserlab Forum highlights the growing role of laser-based technologies in catalysis research, showcasing recent advances from the Laserlab-Europe and Lasers4EU communities.

To support such increasingly multi-faceted research, Lasers4EU now offers a curiosity-driven multi-instrument access route. This scheme allows users to submit a single proposal and access as many complementary installations as needed – even over several years. And if you are looking for the right laboratory for your next project, the Lasers4EU Access Search Tool provides an easy way to identify suitable facilities. Learn more on page 12.

I wish you an inspiring reading and a Happy New Year!

Sylvie Jacquemot

News

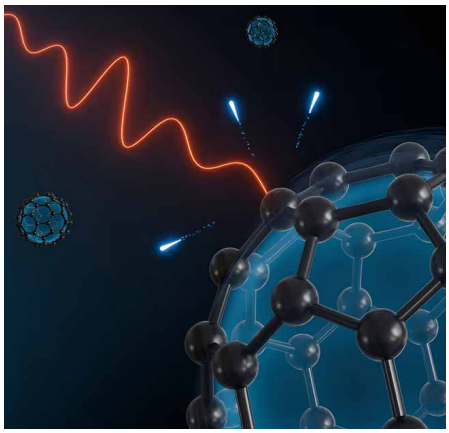
Sweden's most powerful laser delivers record-short light pulses

For the first time, researchers at Umeå University, Sweden, member of Laserlab Sweden and Laserlab-Europe, have demonstrated the full capabilities of their large-scale laser facility. In a study published in Nature Photonics, the team reports generating a combination of ultrashort laser pulses (FWHM pulse duration 4.3 fs, i.e., 1.6 optical cycles), extreme peak power (100 TW), and precisely controlled waveforms (RMS CEP stability of <300 mrad) that make it possible to explore the fastest processes in nature.

https://doi.org/10.1038/s41566-025-01720-2

Mattias Pettersson

Quantum correlation revealed by attosecond delay



RMT.Bergues

A team of researchers led by DESY and University of Hamburg in collaboration with Politecnico di Milano and Stanford used attosecond light pulses to study the ultrafast plasmonic dynamics in the fullerene C60, also known as the "buckyball". Using attosecond photoemission spectroscopy, the scientists precisely determined that it takes from 50 attoseconds to 300 attoseconds for the electron to escape the molecule during plasmonic excitation and that quantum electronic correlations play a major role in the collective dynamics. These insights offer a new understanding of light-matter interactions at extreme scales and imply potential advances in solar-energy harvesting, ultrasensitive sensors and photocatalysis by exploiting quantum effects in nanoplasmonics.

Laserlab Spain newly founded

The strategic network Laserlab Spain was founded in 2025 by the Spanish Ministry of Science, Innovation and Universities. It consists of 10 laser facilities* and 5 laser groups in Spain:

- CLPU*, Salamanca (coord. Giancarlo Gatti)
- ICFO*, Barcelona
- CLUR*, Universidad Complutense de Madrid
- Centro Láser UPM*, Universidad Politécnica de Madrid
- GS2M*, Universidad del País Vasco, Bilbao
- CEIT*, San Sebastián
- ALF*, Universidad de Salamanca
- STELA-L2A2*, Universidade de Santiago de Compostela
- GROC*, Universitat Jaume I, Castellón
- SCAI-MONL*, Universidad de Málaga
- LPG, Instituto de Óptica, CSIC, Madrid
- SIT, Universidad Carlos III, Madrid
- CAMPUS, Universidad Autónoma de Madrid
- DONLL, Universidad Politécnica de Catalunya
- GHPO, Universidad de Alicante

Laserlab Spain aims to establish a strategic link of the Spanish community with relevant European scientific infrastructures. CLPU, ICFO and CLUR provide the link between Laserlab Spain and Laserlab-Europe. The newly founded network will collaborate with the Specialised Group on Ultrafast Lasers (GELUR) of the Spanish Royal Society of Physics (RSEF) in the organisation of the international bi-annual meeting Ultrafast Science and Technology Spain (USTS).

About Laserlab-Europe and Lasers4EU

Laserlab-Europe AISBL brings together 48 leading laser research infrastructures across 22 European countries. It promotes the development and application of advanced lasers and laser-based technologies through coordinated networking and joint research.
Our key initiative, Lasers4EU, is your go-to resource for having access to a vast network of 29 cutting-edge laser research infrastructures across Europe. Whether you are a researcher seeking specialised facilities for your scientific projects or an industry professional aiming to leverage state-of-the-art laser technology, Lasers4EU offers a streamlined platform to connect you with facilities best suited to your needs. Beyond access, we provide comprehensive training opportunities, equipping users with the skills and knowledge required to fully utilise these world-class infrastructures.


ELI

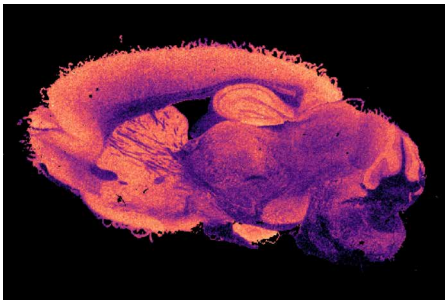
ELI's L4 ATON laser achieves 5 petawatt

The L4 ATON kilojoule laser at the Extreme Light Infrastructure (ELI) – Beamlines Facility achieved a peak power of 786 J energy compressed to 154 fs, corresponding to a peak power of 5.1 PW. The L4 ATON laser system was developed by a consortium of international partners made up of National Energetics (USA), EKSPLA (Lithuania) and ELI. L4 ATON combines optical parametric chirped pulse amplification (OPCPA) with a kilojoule-class, liquid-cooled glass amplifier, allowing operation at a repetition rate of one shot per minute, an order of magnitude higher than other lasers of comparable energy. With its stability and ability to repeat experiments at one-minute intervals, L4 ATON opens new possibilities for studies in laser-driven particle acceleration, extreme-state physics, and strong-field quantum electrodynamics (QED), as well as for further progress in laser-driven fusion research.

New technique combining imaging and spectroscopy for metabolic disease research using infrared free-electron laser

Researchers at HFML-FELIX have developed a new method to spatially detect and identify disease-related molecules directly in brain tissue using an infrared free-electron laser and mass spectrometry imaging. Traditionally, these experiments detect molecules by measuring their mass and charge and when coupled with imaging platforms can show where exactly these molecules are located in tissues. However, mass spectrometry alone cannot distinguish molecules that have the same mass but different (isomeric) structures – a critical limitation when trying to understand disease mechanisms and discover novel biomarkers. To overcome this, the team employed infrared ion spectroscopy using the powerful infrared free-electron laser at HFML-FELIX. With this technique, it is possible to excite ions trapped in the mass spectrometer to the point that they dissociate into fragments. By looking at which frequencies cause the molecule to fall apart, an infrared spectrum can be measured and the structure can subsequently be determined. This new approach promises novel diagnostic strategies, deeper insights into disease mechanisms and better evaluation of treatments.

https://doi.org/10.1021/acs.analchem.5c00948



+++ Three ERC Synergy Grants for projects involving Laserlab-Europe scientists +++

Fantastic news for the Laserlab-Europe community: Three projects involving researchers from within our network have been awarded prestigious ERC Synergy Grants. These grants have significantly fewer applications and approved projects than for other ERC calls, given the high requirements for interdisciplinarity, complementarity and demonstrating synergies between areas. The newly funded projects include researchers from our members DESY, CEA-LIDYL, CNR and POLIMI. More details will be featured in our next newsletter.

ERC Grants

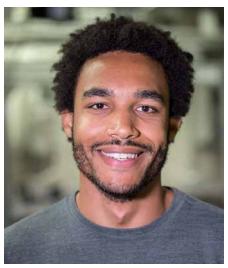
The European Research Council (ERC) promotes frontier research by awarding prestigious grants to outstanding researchers for projects of ground-breaking nature. Laserlab-Europe researchers have again been successful in the ERC's highly competitive selection process. Congratulations to the six scientists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

Rahul Trivedi (MPQ): Theory of noisy quantum simulation of many-body physics


Katharina Jarrah / MPQ

Rahul Trivedi, Research Group Leader with tenure in the theory division at the MPQ, has been awarded an ERC Starting Grant to develop new theoretical foundations for quantum simulation in the presence of noise. His project ToNQS aims to develop mathematical tools that can certify the reliability of analogue quantum simulators even under realistic, noisy conditions. Success would not only dispel long-standing doubts about such simulators, but also benefit fields such as condensed matter physics, quantum optics, high-energy physics, and complexity theory – long before fully fault tolerant quantum computers become a reality.

Vincent Wanie (DESY): Key exploration of intermolecular bonding in chiral recognition using advanced laser light beams


Maurizio Contran

With his ERC Starting Grant project KEBAB, DESY researcher Vincent Wanie and his team will develop a new experimental setup based on a special laser system in order to investigate how chiral molecules distinguish the chirality (handedness) of other molecules in order to form bonds with matching ones. This will be made possible by combining state-of-the-art ultrafast light sources with experimental methods that are particularly sensitive to the structure of molecules. The setup has a great importance as its functionality will provide critical information relevant to chemistry, pharmacy, and materials research.

Nicoletta Liguori (ICFO): Real-time nanoscale manipulation of structure and environment to understand light-harvesting regulation in photosynthesis


ICFO

In her ERC Starting Grant project MARIONETTE, ICFO researcher Nicoletta Liguori and her team will aim to understand how plants regulate light harvesting at the nanoscale, to perform photosynthesis safely under the sun, and protect themselves from photodamage by tuning the molecular environment and structure of single photosynthetic proteins. The team will implement and integrate novel spectroscopy methods and advanced molecular dynamics simulation approaches to change the proteins' structure and environment at a molecular scale, and follow in real time the effect of these changes to reconstruct how plants activate photoprotection.

Carmen Rubio-Verdú (ICFO): The holistic understanding of superconductivity in moiré quantum materials


Tomás Charles Carima

Also based at ICFO, Carmen Rubio-Verdú has received an ERC Starting Grant for her STMoiré project. She and her team will try to uncover the mechanisms behind the unusual behaviour of twisted 2D materials such as twisted bilayer graphene, which exhibit exotic properties like unconventional superconductivity. For this, they will use a complementary experimental approach, using scanning tunneling microscopy (STM) at extremely low temperatures, to study and understand the quantum phases of these materials at the atomic scale. Their ultimate goal is to discover, if possible, a new, never-before-seen form of superconductivity.

Laura Dreissen (LLAMS): Quantum-enhanced sensing with trapped ions for atomic parity violation (APV)


Sander Nieuwenhuys

Laura Dreissen from LaserLaB Amsterdam was awarded an ERC Starting Grant for her research on the weak interactions in atoms. Her project QuEST for APV focuses on detecting a very small effect in atoms that provides insight into one of the fundamental forces of nature – the weak interaction. This effect is related to a violation of parity, one of the fundamental symmetries in physics, which implies that the laws of nature behave slightly differently when viewed in a mirror. By precisely measuring this phenomenon, Dreissen and her colleagues aim to test the Standard Model of particle physics and potentially uncover evidence of new particles or forces, including "dark" particles that may be connected to dark matter.

Dierck Hillmann (LLAMS): Functional microscopy of individual neurons in the living human retina

Physicist Dierck Hillmann, also based at LaserLaB Amsterdam, has received an ERC Consolidator Grant for his project FunMicroRetina, which aims to enhance the resolution of retinal imaging. Conventional imaging uses light passing through the pupil, but this limits sharpness due to diffraction – similar to photographing through a keyhole. He and his team plan to use infrared light entering through other parts of the eye, like the white part (the sclera) or even the skull, to overcome this limitation and obtain much sharper images. With this, they might be able to better see individual cells in your eye and even visualise how they work.

Lasers for Catalysis

Catalysis is key to many things we rely on, from clean energy to industrial and environmental processes. To reveal how catalysts work and make them better, scientists must explore atomic-scale interactions and reactions that occur either extremely quickly or under demanding conditions. Lasers have become essential tools for meeting these challenges, providing the accuracy needed for this work. This issue of Laserlab Forum presents new advances from Laserlab-Europe and Lasers4EU.

Laser light reveals the secrets of catalysis (LLC, Sweden)

At Lund University, world-leading surface science at synchrotron facilities (MAX VI) can be combined with advanced laser (Lund Laser Center, LLC) and electron microscopy methods, to provide a more complete picture of how the gas-surface interaction drives a catalytic reaction.

For example, researchers have long been interested in how a reaction starts – a catalyst's "ignition" – and propagates across a catalytic surface. By using planar laser-induced fluorescence (PLIF), it is possible to image the product gas being formed just above the surface, in real-time. Combined with high-speed temperature measurement and reflectance microscopy (surface diagnostics are also needed simultaneously), it has been shown that ignition starts in the centre of the catalyst and spreads outwards like a wave in just a few milliseconds. The measurements revealed that this propagation is governed by the diffusion speed of gas molecules together with structural changes on the surface, not heat conduction in the material. It would have been impossible to gain this insight without the speed of the laser and its ability to probe the gas phase.

By directing light onto polycrystalline materials, which act as "libraries" of thousands of different crystal surfaces, optical reflectance microscopy can be used to study how

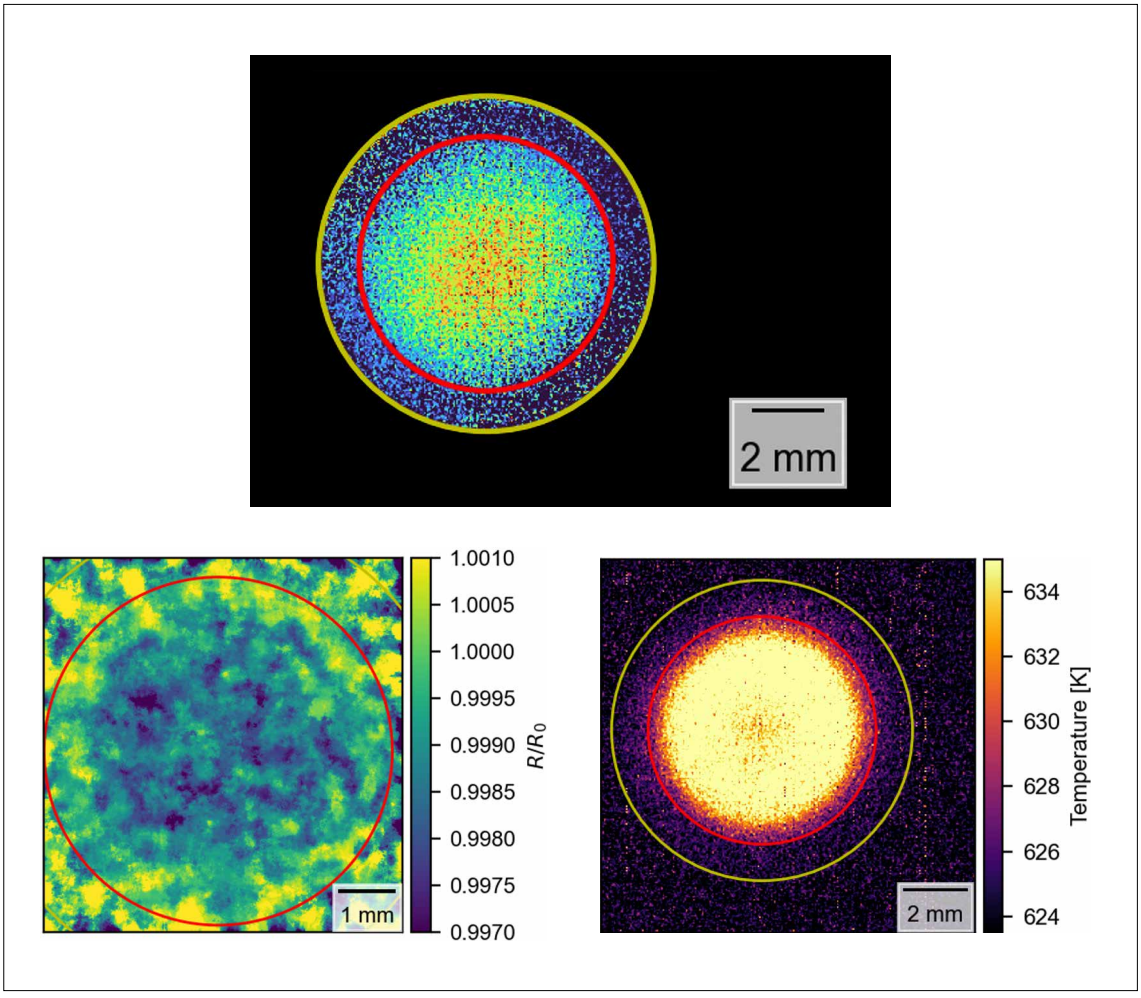


Image adapted from ACS Catal. 2022, 12, 11, 6589–6595

Images captured simultaneously with three different techniques: (above) PLIF image, showing the CO_2 concentration above the catalyst just before ignition; (bottom left) surface oxide on the sample obtained using optical reflectance; (bottom right) heat map of the sample

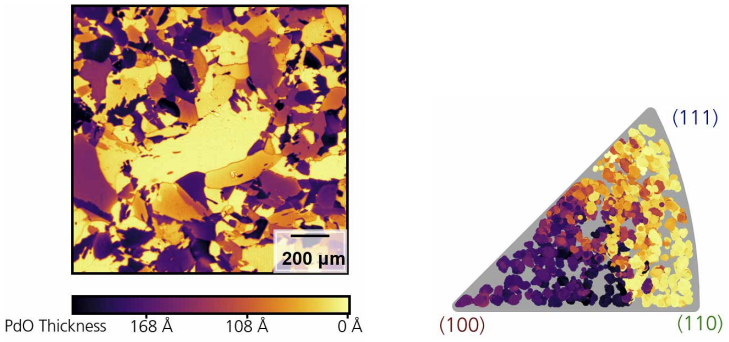


Image adapted from ACS Appl. Mater. Interfaces 2024, 16, 1, 444–453

Palladium oxide (PdO) thickness on a polycrystalline Pd sample, measured using optical reflectance; the triangle shows thickness as a function of surface structure

the reaction behaves on each unique surface simultaneously. When combined with laser techniques like PLIF, it is possible to get a more complete, multi-dimensional picture of the reaction, including the surface's atomic structure, macroscopic surface changes and the gas composition. These are examples of catalysis studies that have been funded by the Swedish Research Council and the Swedish Foundation for Strategic Research.

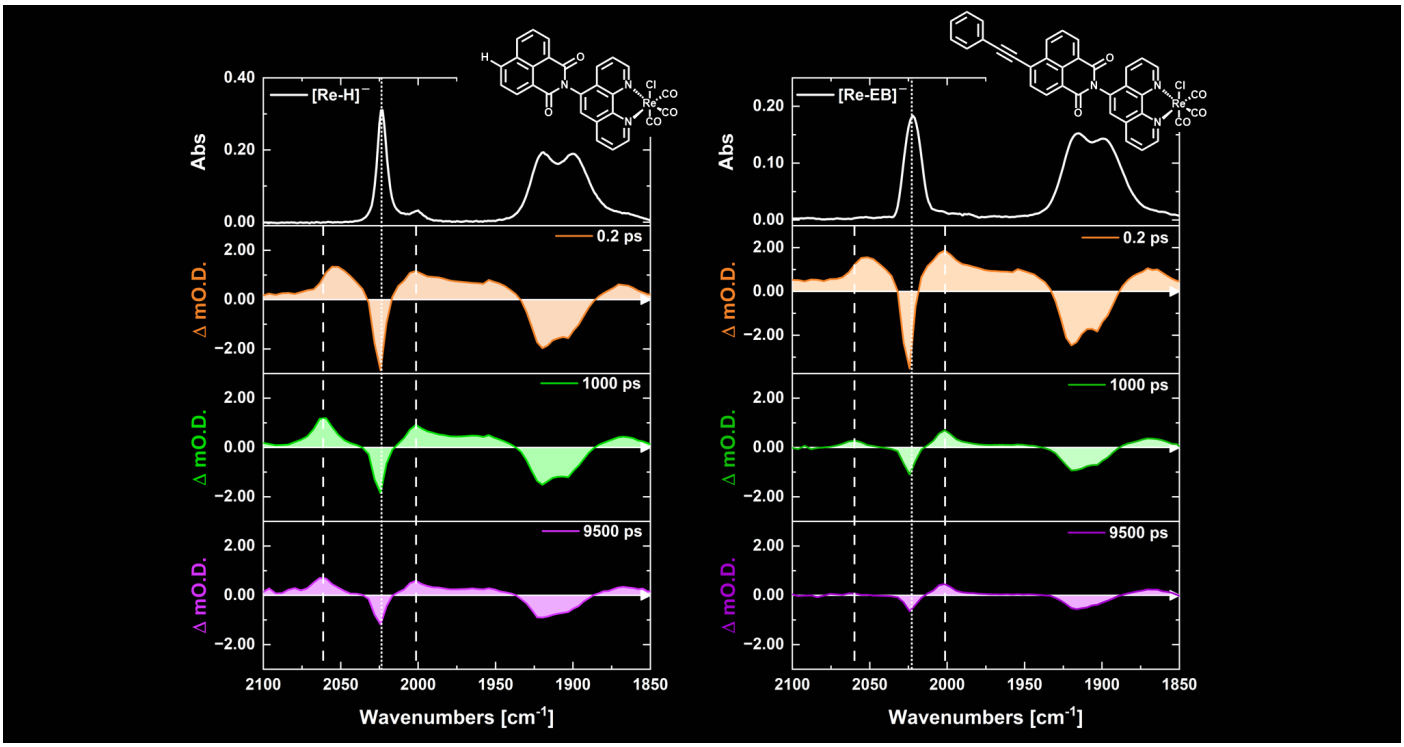
Applying these laser-based methods will not only provide fundamental understanding, but will also be crucial for designing the tailor-made, efficient catalysts of the future, needed to meet the demands of everything from cleaner energy to reduced emissions.

Johan Zetterberg (LLC)

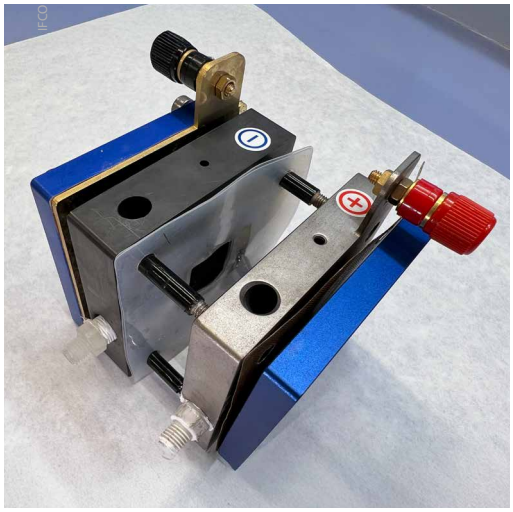
Photocatalytic CO_2 reduction probed by time-resolved infrared-spectro-electrochemistry for a mechanistic insight of the steps leading to the active catalyst (CLF, United Kingdom)

The photophysical properties of rhenium α-diimine complexes, widely known as CO_2-reducing photocatalysts, have been extensively studied using time-resolved techniques including time-resolved infrared (TRIR) spectroscopy.[1][2] Separately, electrochemical and in situ spectroelectrochemical (SEC) techniques have been employed to gain a better understanding of the catalytic cycle of rhenium complexes and their electrochemically reduced intermediates.[3][4] However, the photophysical properties of the reduced intermediates are often overlooked in photocatalysis, despite their presence under irradiation conditions. Here, the combination of TRIR and SEC techniques (TRIR-SEC) provides a new approach in identifying how intermediates in the photocatalytic cycle behave under incident light and in turn, further understanding of the pathway leading to the active catalyst.

TRIR-SEC spectra at 0.2, 1000, and 9500 ps following 420 nm excitation and the FTIR spectrum in a 10-1 M TBAPF6 DCM solution of the $[Re\text{-}R]^-$ species [manuscript in progress]



Mary Pryce



PEM water electrolyzer employed in the study

Researchers at Dublin City University, the University of Reading and the University of Chemistry and Technology Prague have carried out TRIR-SEC experiments at the Central Laser Facility (CLF, part of UKRI Science and Technology Facilities Council). Two rhenium-naphthalimide complexes [Re-R] were prepared for the experiments and studied as intramolecular photocatalysts. Upon excitation of the singly reduced species $[Re\text{-}R]^{-}$, localised on the naphthalimide (NI) moiety, two excited states were populated (see figure). A metal-to-ligand charge transfer (MLCT) like excited state with transient bands shifted to higher frequencies, and an intraligand charge-transfer (ILCT) like excited state with transient n(CO) bands shifted to lower frequencies similar to $[Re\text{-}R]^{2-}$; in both intermediates electron density redistributes onto the acceptor phenanthroline (phen) moiety. For the electrochemically doubly reduced species $[Re\text{-}R]^{2-}$, located on both the NI and phen moieties, photoexcitation results in the reorganisation of the spin density within the NI-phen triplet-biradical, more towards phen as indicated by increased Re→CO π-back-bonding. This process may trigger Re-Cl cleavage when Re(II) in MLCT-photoexcited $[Re\text{-}R]^{-}$ is reduced photochemically by triethylamine (TEA).

This study provides a compelling demonstration that combining ultrafast time-resolved spectroscopy with electrochemistry can offer a powerful tool for identifying the photophysical processes, and reactive charge-transfer excited states, involved in catalytic cycles. Such studies may lead to the development of novel photocatalytic materials with improved designs, which consider the excited state properties of any intermediate species formed during photocatalysis.

Sayantan Bhattacharya, Partha Malakar, Greg Greetham (CLF)
Jack Biddulph, Mary T. Pryce (Dublin City University)
František Hartl (University of Reading)
Martin Pižl (University of Reading, University of Chemistry and Technology Prague)

[1] A. Vlček, in A.J. Lees (eds), Photophysics of Organometallics, ed., Springer Berlin Heidelberg, Berlin, Heidelberg, vol. 29, 115–158, 2009
[2] J.E. Yarnell *et al.,* Inorg. Chem. 50, 7820–7830, 2011
[3] C.W. Machan *et al.,* Organometallics 33, 4550–4559, 2014
[4] F.J.R. Cerpentier *et al.,* Front Chem. 9, 795877, 2021

New catalyst unveils the hidden power of water for green hydrogen generation (ICFO, Spain)

Water electrolysis offers a path to generate green hydrogen that can be powered by renewables and clean electricity. To date, water electrolysis implemented via proton exchange membrane (PEM) has required catalysts based on scarce, rare elements, such as platinum and iridium. This is particularly challenging in the case of anode catalysts, which have to operate in highly corrosive acidic environments – only iridium oxides have shown stable operation in the required industrial conditions.

In the search for possible solutions, a team led by ICFO researchers has recently reported a new catalyst design in *Science*.[1] This design offers a potential alternative to the use of scarce materials for sustained water electrolysis in industrially-relevant conditions.

To obtain the novel catalyst, the team harnessed previously unexplored properties of water. Taking cobalt-tungsten oxide (CoWO4) in a crystal structure – which is very abundant and cheap – as a starting material, they designed a delamination process using basic water solutions whereby tungsten oxides (WO42-) would be removed from the lattice. This action left 'holes' in the lattice, which were spontaneously filled with water (H2O) and hydroxyl (OH-) groups. It was discovered that this exchange shielded the sample, making the cobalt ion dissolution thermodynamically unfavourable, thereby effectively holding the catalyst components together and protecting them from degradation in acidic conditions.

From left to right: F. Pelayo García de Arquer, Marinos Dimitropoulos, Lu Xia, Aparna M. Das, Viktoria Golovanova, Anku Guha and Ranit Ram

The delaminated catalyst was then assembled into a PEM reactor, and the initial performance was truly remarkable, achieving high activity and durability. The stability time (over 600 hours) represents a big step towards making catalysts for water electrolysis that are not dependent on iridium or similar rare elements. The team now aims to scale the technique up to industry levels of production.

F. Pelayo García de Arquer, Marinos Dimitropoulos, Lu Xia, Aparna M. Das, Viktoria Golovanova, Anku Guha and Ranit Ram (ICFO)

[1] R. Ram *et al.*, Science 384, 1373-1380, 2024

Dynamic catalysis: a new playground for laser science (LaserLaB Amsterdam, The Netherlands)

Catalysis lies at the heart of most chemical processes in industry and daily life. Traditionally, catalysts operate at steady-state conditions: a fixed temperature and pressure, where the activity and selectivity are dictated by fundamental thermodynamic limits. While this approach has enabled over a century of chemical innovation, it leaves little room to tune both reaction rate and product selectivity independently, and limits opportunities to innovate towards a more sustainable industry.

Dynamic catalysis is emerging as a way to break this steady-state paradigm. Instead of treating catalysts as static surfaces, they can be deliberately perturbed on the timescale of the catalytic cycle. By oscillating the catalyst's electronic state, structural configuration, or temperature at (ultra)fast timescales (picoseconds to milliseconds), it is possible to alternate between different rate-limiting regimes, and dynamically control the amount of surface species, intermediates, and their ratios. This concept introduces the possibility of "programmable chemistry," where the external stimuli directly dictate the outcome of the reaction.

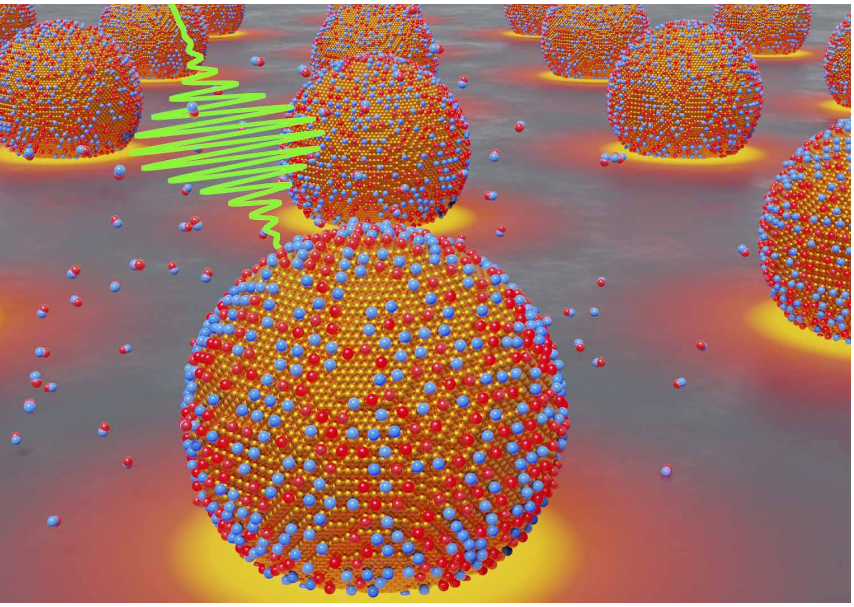


Image adapted from Andrea Baldi and S. H. C. Askes, ACS Catalysis, 13, 3419, 2023

Concept of pulsed photothermal catalysis on plasmonic nano-catalysts. Short bursts of thermal energy can lead to higher conversion and "exotic" surface coverages.

Lasers and light-sensitive catalysts are uniquely suited to this challenge. Pulsed lasers offer exceptional control over how quickly, how much, and how often the catalyst is stimulated. At femtosecond to microsecond scales, pulsed light can selectively generate excited states, drive localised photothermal heating, launch intense strain waves through the material's lattice, or even completely restructure catalytic surfaces. Excitingly, such transient effects can directly influence the height of reaction barriers, determine which reactants and intermediates are bound to the catalyst, and induce reaction kinetics in ways inaccessible to steady-state operation.

At the LaserLab Amsterdam (LLAMS at Vrije Universiteit Amsterdam), research is underway to explore this concept. Through theory and modelling, the research group has explored how pulsed light and nanoscale thermal gradients can modulate catalytic reaction pathways and enhance selectivity. To translate these ideas into practice, two advanced photo-reactors have recently been constructed that allow precise control of pulse energy, duration, and repetition rate, while reaction products are probed with mass spectrometry and gas chromatography. These setups open the door to testing dynamic operation across a vast range of reactions and conditions, with the aim of pushing this technology closer to industrial relevance.

For the laser community, this represents an exciting frontier. So far, lasers have been used extensively to probe catalysts and chemical conversion, for example with time-resolved spectroscopy. Now, there is an opportunity to use lasers to actively program catalysis and control chemistry. The Laserlab-Europe community can play a central role in shaping this new era of dynamic and sustainable chemical manufacturing.

Andrea Baldi and Sven Askes
(LaserLaB Amsterdam, The Netherlands)

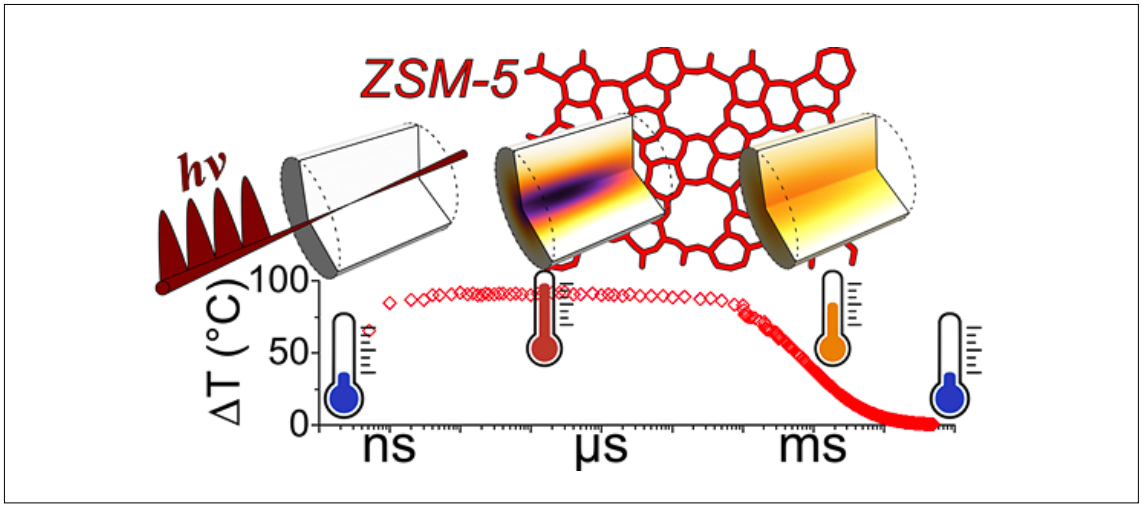
[1] Andrea Baldi and S. H. C. Askes, ACS Catalysis 13, 3419, 2023
[2] M. Monai *et al.* ChemRxiv, 2025

The development of advanced IR techniques for catalysis studies at the CLF (CLF, United Kingdom)

Many areas of the chemical industry, renewable energy processes, and emissions control rely on high surface area solid catalysts to make a desired chemical process accessible, selective, and efficient. In developing these "heterogeneous" catalysts, molecule-scale characterisation of the catalyst and observation of the chemical processes catalysed is key. Infrared (IR) spectroscopy is important for gaining such molecular bond level information.

Since the advent of pulsed IR laser techniques, how to make use of the extra dynamical and spectral information of ultrafast IR spectroscopy in heterogeneous catalysis applications has been an important, open question. The UK's Central Laser Facility (CLF) have developed two unique ultrafast IR spectroscopy applications to heterogeneous catalysis: temperature (T)-jump spectroscopy and two dimensional (2D)-IR spectroscopy. For the T-jump technique, the CLF demonstrated laser heating of solid catalysts by up to 150°C in nanoseconds in combination with transient-IR spectral probing from nanoseconds to seconds. Combining this with laser synchronised sample motion results in a new instrument with great potential for studying irreversible thermally-activated chemical reactions.[1] The CLF team have been applying the technique to explore the chemistry of organic molecules in zeolite catalysts, with the aim of uncovering the chemical processes that occur too quickly to observe by normal IR spectroscopy.

2D-IR spectroscopy is important for heterogeneous catalysts because it can help in deciphering their often complicated and congested IR spectra. 2D-IR accesses molecular structure and dynamical information unobtainable from ordinary IR techniques and enables quantitative analysis.[2] To obtain 2D-IR spectra of solid catalysts, the is-



IR laser based Temperature jump (above) and 2D-IR spectroscopy techniques applied to heterogeneous catalysts such as ZSM-5 have been developed at the CLF

sue of extreme optical scattering first has to be addressed. Here, the CLF have developed approaches enabling 2D-IR spectra of solid pellets to be observed, [3] allowing 2D-IR to be used to decipher the IR spectra of defects in zeolite catalysts, distinguishing them from water and revealing their unusual dynamical structures.[4]

Paul Donaldson (CLF)

[1] A.P. Hawkins *et al.*, Chem. Sci. 15, 3453-3465, 2024
[2] P. Donaldson, Anal. Chem. 94, 17988-17999, 2022
[3] P. Donaldson *et al.*, J. Chem. Phys. 158, 114201, 2023
[4] P. Donaldson *et al.*, Chem. Sci. 16, 6688-6704, 2025

PLANKT-ON: Advancing artificial photosynthesis for net-zero energy conversion (POLIMI, Italy)

Funded by the EU through the Horizon Europe programme, PLANKT-ON (*Plankton-like Protocells for Artificial Photosynthesis targeting Carbon Neutral Energy Vectors*) is now into its third year of research, consolidating earlier achievements and entering a phase of technological integration and validation. The project's vision is ambitious: to develop a disruptive, net-zero-emissions solar technology that simultaneously meets global energy needs and contributes to the reoxygenation of our planet.

Inspired by natural plankton, PLANKT-ON is assembling the first synthetic plankton-like protocells capable of autonomously using light, water, and CO_2 to generate oxygen and formate, a green hydrogen vector. These biohybrid microcompartments are designed as containers of two synergic subdomains that mimic the plastids and CO_2-enzyme organelles of photosynthetic microorganisms. The artificial plastid oxidises water to oxygen and reduces a methyl viologen cofactor, which then drives the CO_2-rich organelle to selectively produce formate through a cascade enzymatic process.

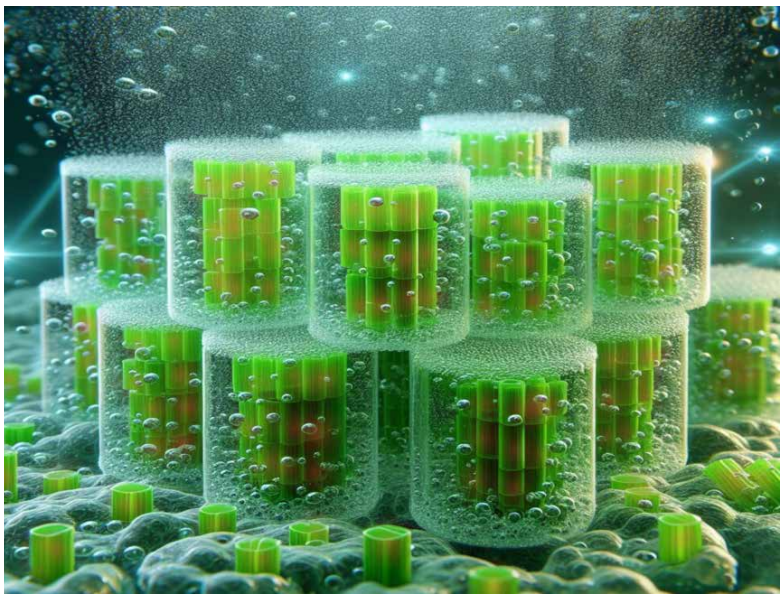
The project has already achieved several major milestones. Protocells with controlled structural organisation have been assembled and functionalised with validated photo-organelles, supported by optimised photoactive building blocks based on chromophores enhanced for cross-linking and broadband light harvesting. Transient absorption mapping has revealed charge-separation and hole-transfer timescales relevant to water oxidation, and measurable light-driven activity towards oxygen and formic acid targets has been successfully demonstrated.

These advances mark a crucial step towards demonstrating a wireless, self-sustaining artificial photosynthetic system, capable of storing solar energy in chemical form without a traditional electrochemical infrastructure.

The PLANKT-ON consortium unites six partners across four European countries – INSTM (coordinator Professor Marcella Bonchio), the Politecnico di Milano (POLIMI) and a commercial organisation Enphos (Italy), CEA (France), CIC biomaGUNE (Spain), and the University of Bristol (UK) – who bring expertise in diverse areas, from structural biology and nanotechnology to ultrafast spectroscopy and catalysis.

Margherita Maiuri (POLIMI)

Illustration of an artificial photosynthetic system on a photoanode that mimics the structure and function of Photosystem II (PSII) in chloroplasts



Tailoring optical anisotropy of materials through femtosecond laser excitation

Gallium sulphide (GaS) is a monochalcogenide material that has attracted particular attention in optical technology development, due to the ability to tune its bandgap for UV-light detection applications. *In situ, in operando* X-ray diffraction analysis has been used to investigate local atomic changes induced in GaS by femtosecond laser pulses, and evidence elongation of the unit cell along its *c*-axis. *Ab initio* calculations have been used to support the findings. The light-induced structural changes are expected to enhance the anisotropy of GaS's physical properties and deliver optical properties of interest for reconfigurable photonics applications.

Femtosecond laser sources are highly versatile and agile tools for customising materials, able to provide them with new optical functions or tailor their intrinsic properties in a controlled engineering manner by localised machining. With the advancements in such laser-based technology, it is possible to apply them to modify the permittivity of a wide variety of materials, with applications in many fields, ranging from photonics and medicine to biology and the micro-electronics industry. [1]

With support of the Laserlab-Europe and Lasers4EU access programmes, a research consortium has been established, bringing together experts in materials science (ELI Beamlines, Czech Republic; ICMATE-CNR, Italy; University of Santander, Spain), laser processing (LP3, France), advanced calculations (CNEA-CONICET, Argentina), and X-ray material diagnostics (ELI-Beamlines, LP3). The consortium aimed to obtain detailed understanding of the structural and electronic transformation of solid materials when exposed to pulsed laser excitation, and to derive a dedicated laser processing strategy to facilitate the controlled modification of their optical properties.

Gallium sulphide (GaS) was the first material selected for investigation. This emerging monochalcogenide material is of strong interest in the fields of photonics and optoelectronics owing to its remarkable characteristics, which offer bandgap tunability from the visible to the near-UV, along with remarkable air stability. [2] Because of these appealing properties, GaS has already been integrated into various optoelectronic applications, including novel UV photodetectors with fast response times. [3] It has also been proposed as a wide bandgap phase-change material (PCM) for reconfigurable on-chip photonic components, [4] but greater understanding of how light modifies GaS at the atomic level is needed to realise this potential.

Thin crystalline GaS films around 500 nm thick were grown by chemical vapour deposition, with rhombohedral

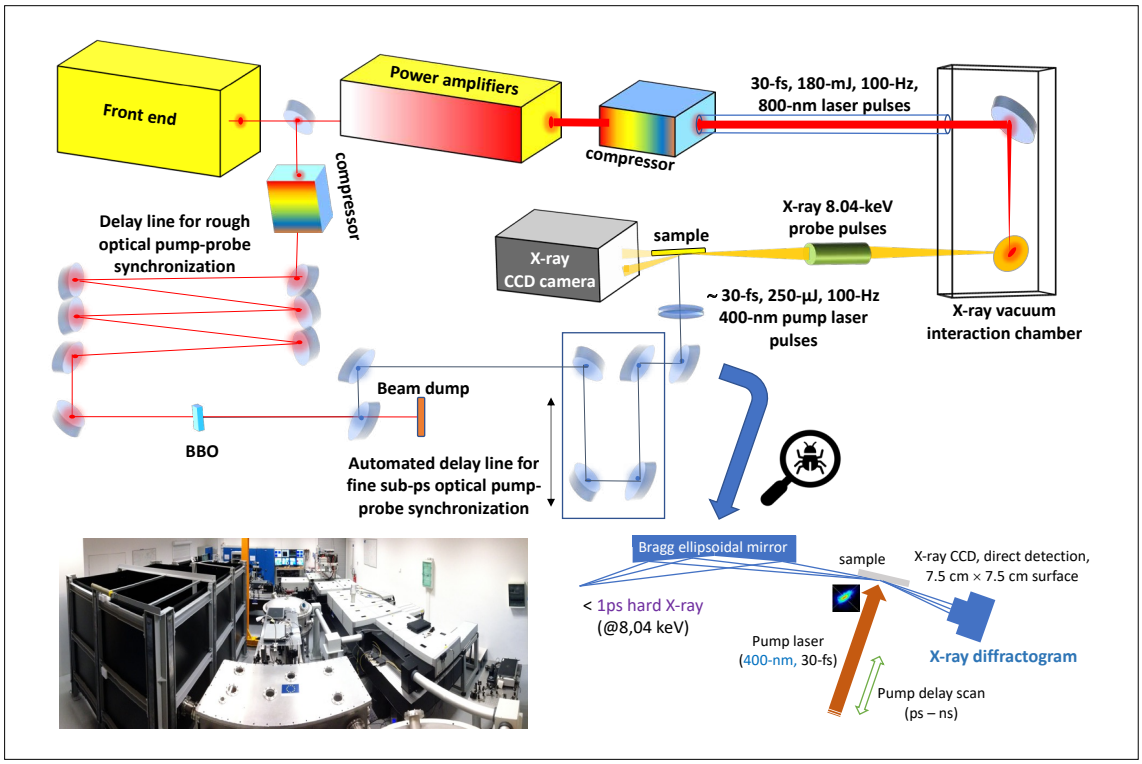


Figure 1: Schematic of the experimental setup (top), with (bottom-left) a general photograph of the ASUR-LP3 installation and (bottom-right) a detailed view of the (time-resolved) X-ray diffraction experiment

symmetry (space group $R\bar{3}m$) and preferred *c*-axis orientation on a (100) Si substrate. [5] X-ray diffraction analysis was then used to determine how, and for which excitation fluence, GaS films were irreversibly transformed following laser irradiation.

Experiments were performed at the ASUR platform in the LP3 laboratory (see Figure 1). A 100 Hz, 30 fs, 180 mJ Ti:sapphire laser system, shot on a copper disk, generated Cu-Kα radiation at 1.54 Å wavelength (8.04 keV). A second 30 fs 1 mJ laser beam was used to provide the pump beam: this was propagated through a 200 µm thick BBO crystal to generate 400 nm femtosecond illumination for the experiments, selected to target above bandgap excitation of GaS. [5] A CCD X-ray detector, equipped with a 90 cm^2 chip, enabled the X-ray diffraction pattern from the sample to be measured *in situ* and *in operando* over an adjustable angular region. Moreover, the set-up allowed a rocking curve of any peak of the diffracting (rotating) sample to be captured within a reasonable exposure time (100 seconds).

Pulses from the pump laser illuminated the sample surface in a repetitive irradiation regime (≈ 1000 shots in 10 seconds) at fluences < 19 mJ/cm^2, and at normal incidence. By the studying of the (003) peak, the laser fluence needed to permanently change the local structural order of the material was determined to be $F_{th} \cong 10$ mJ/cm^2 (see Figure 2, left).

An X-ray diffraction Θ-scan rocking curve was captured around the same (003) peak (see Figure 2, right), chosen as an indicator of the lattice distortion of the material's unit cell along the *c*-axis (001). Upon laser pumping, there was a shift to smaller Θ-angle, indicating an increase in the interplanar distance d_{hkl}. Using Bragg's law, $n\lambda = 2d_{hkl}\sin\theta$ at the given angle, d_{003} can be calculated at ≅ 8.46 Å in the pumped region ($\Delta\Theta \cong 0.5°$), which corresponds to an increase of around 10% of the initial distance between two consecutive (003) planes ($c \cong 25.38$ Å). Such an increase is inconsistent with the formation of the energetically-close GaS hexagonal phase for which the diffraction pattern also has peaks at the same Θ angular region (002 peak). For transformation towards the hexagonal phase, the peak would be expected to shift to a higher Θ angle, corresponding to smaller interplanar distance.

These results and observations suggest that repeated illumination by a 400 nm femtosecond laser induces an atomic rearrangement in GaS, in which the initial $R\bar{3}m$ structure remains unchanged but is stretched along the *c*-axis, most likely due to thermomechanical stress generated by the laser pulses. Density functional theory (DFT) first principles calculations were used to determine the impact that this stretching would have on its electronic and optical properties. As shown in Figure 3, the structural change induces an in-plane refractive index contrast (Δn) of ≈ 0.1, which is almost constant over a large spectral region (~0.5 – 4 eV) with negligible losses (Δk = 0). This change in optical properties was accompanied by an increase in the bandgap of ~0.45 eV compared to the pristine structure. [6]

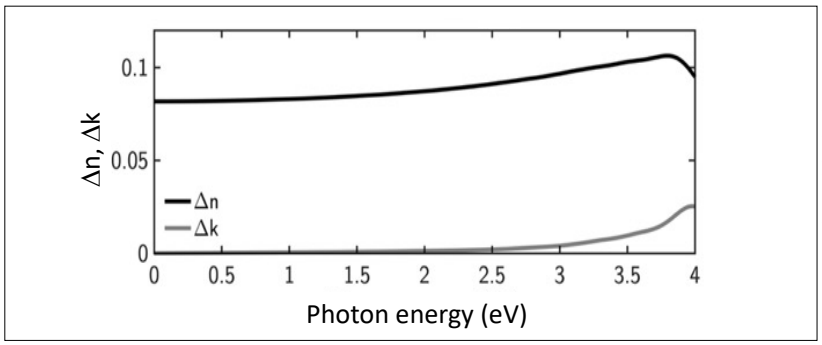


Figure 3: GaS refractive index contrast (Δn, Δk) between with and without UV laser illumination in the low-loss spectral region

Interestingly, this is the first time that laser-assisted transformation has been observed for GaS and paves the way for future investigations into light-induced structural dynamics in the material at the atomic level. The higher degree of *c*-axis orientation that can be engineered by 400 nm femtosecond laser pulses is expected to enhance the anisotropy of the material's physical properties, which could be of interest for reconfigurable photonics applications.

Details of this transnational access project have recently been published in *Optical Materials Express*. [6]

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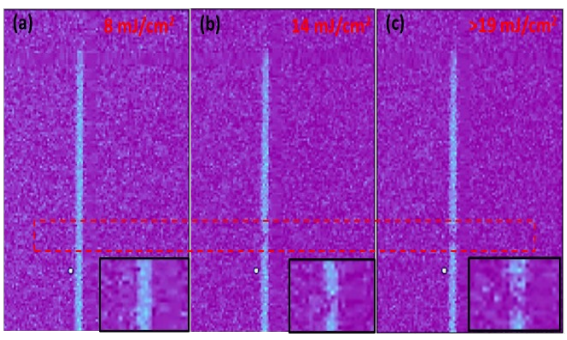
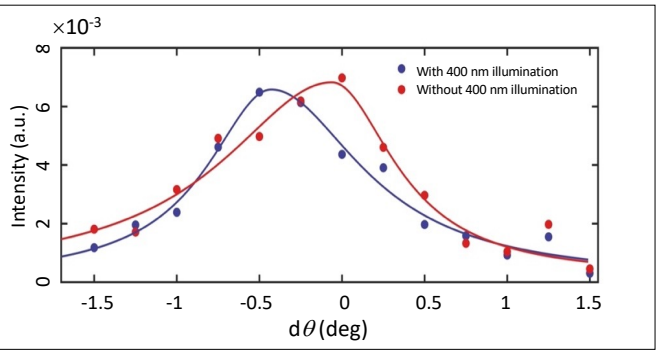
[2] Y. Gutiérrez *et al.,* Opt. Express 30, 27609-27622, 2022
[3] S. Yang *et al.,* Nanoscale 6, 2582-2587, 2014
[4] Y. Gutiérrez *et al.,* Adv. Optical Mater. 12, 2301564, 2024
[5] Y. Gutiérrez *et al.,* Adv. Optical Mater. 12, 2303002, 2024
[6] K. Khakurel *et al.,* Opt. Mat. Express 15, 2534-2544, 2025

Figure 2: (Left) Recorded (003) peak of GaS with different pump fluences (a) 8 mJ/cm^2, (b) 14 mJ/cm^2 and (c) > 19 mJ/cm^2. The red dotted rectangle encloses the pumped region and the insets show the zoomed-in pumped regions, demonstrating 'post-mortem' changes in the (003) diffraction peak of the sample. (Right): A permanent shift in the rocking curve of (003) peak induced by the multipulse pump with fluence slightly higher than F_{th}.





Lasers4EU launches multi-instrument access route

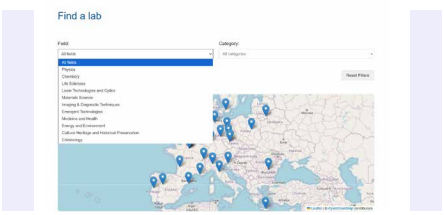
Lasers4EU provides access to state-of-the-art laser technologies and services from primary and secondary laser sources to a wide range of laser-based instruments and techniques at 29 leading laser research institutions across Europe.

Alongside the existing curiosity-driven single-instrument access route, Lasers4EU has now introduced a curiosity-driven multi-instrument access route. Users who require access to multiple installations in different facilities, even over several years, are now only required to submit a single proposal for the entire duration.

This allows users to make the most of the techniques and instruments offered by the Lasers4EU consortium to boost their research while minimising administrative effort. Users benefit from free transnational access (including travel and accommodation) to these laser research laboratories.

Lasers4EU Access Search Tool:
Explore access opportunities across our facilities

To help you identify the facility that best suits your research needs, Lasers4EU offers an Access Search Tool. Here, you can simply select your scientific field and area of interest, and the tool will guide you to detailed profiles of facilities aligning with your research goals.
lasers4.eu/find-a-lab



Laserlab-Europe and Lasers4EU Annual Meeting

From 26–29 May 2026, a joint annual meeting of the Laserlab-Europe AISBL and Lasers4EU will take place at HiLASE Centre and ELI Beamlines in Dolní Břežany, Czechia. Aside from the General Assembly meetings, the agenda will also incude sessions on AI for photonics, standardized performance assessment, data science and AI for spectroscopy and imaging technologies, cultural heritage and will feature a poster and exhibition area as well as lab tours.
laserlab-europe.eu/event/annual-meeting-2026/

Successful RIANA Laserlab-Europe & RADIATE users' meeting

The RIANA Laserlab-Europe & RADIATE users' meeting in nanoscience was a great success, bringing together more than 65 researchers from different European institutions in Seville, Spain.

During the conference from 19-21 October 2025, the latest results obtained by users of both networks were presented, future lines of cooperation were discussed, and new applications of accelerator- and laser-based techniques in the field of nanoscience were explored. A space was also dedicated to the presentation of the RIANA project, a European project in which more than fifty major European infrastructures collaborate with users in the field of nanoscience and nanotechnology.

The meeting consolidated the close collaboration between the European infrastructures and reinforced the shared commitment to promoting scientific excellence and innovation in the field of advanced research using ion and photon beams.

How to apply for access

Interested researchers are invited to contact the Lasers4EU website at lasers4.eu/become-a-user/how-to-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 Lasers4EU 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 Lasers4EU. 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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