FELs OF EUROPE NEWS 2|25

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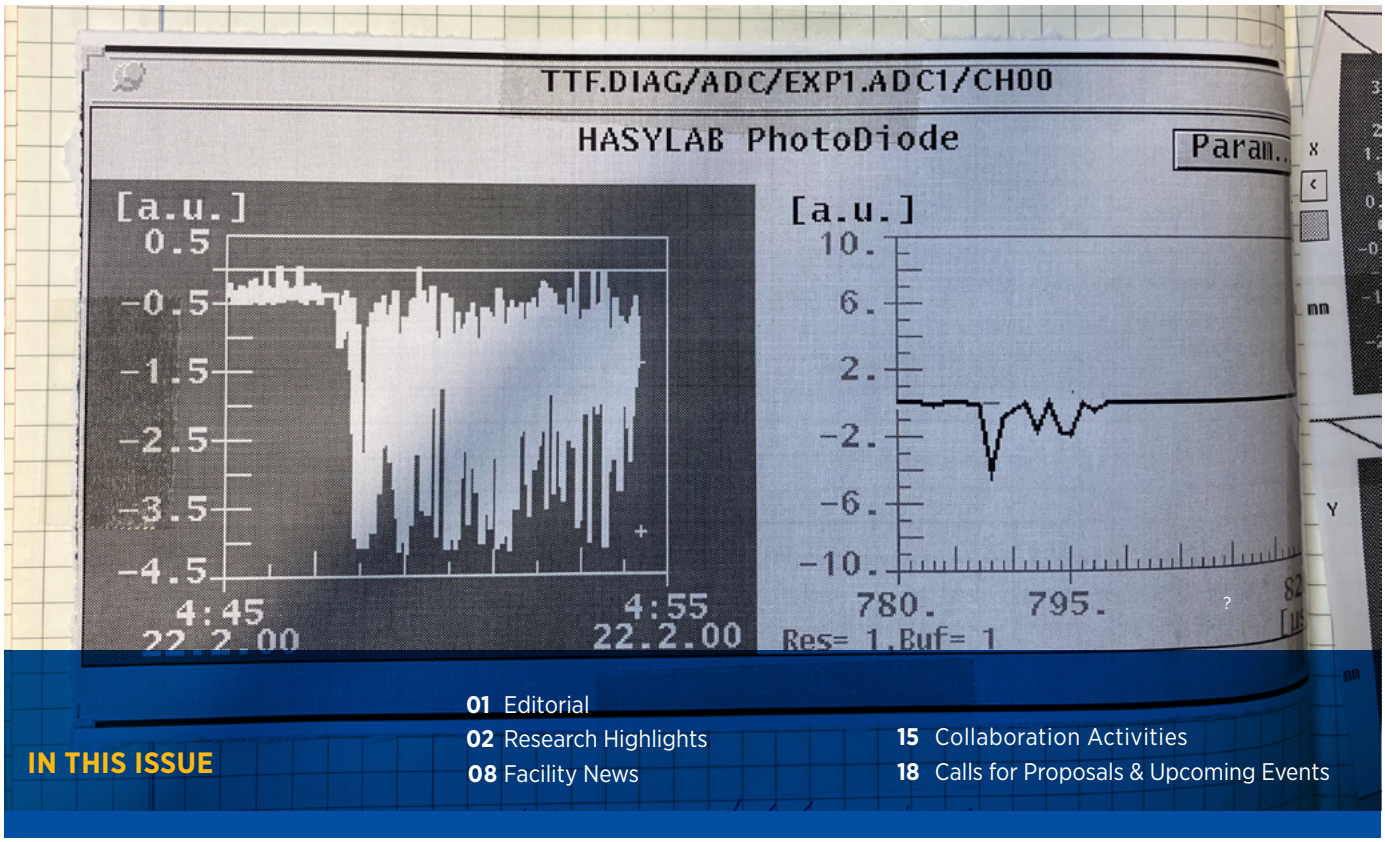

IN THIS ISSUE

EDITORIAL

25 years ago, at the Tesla Test Facility (TTF1) at DESY, research with FELs entered into a new era with first lasing at short wavelengths in the "Self-Amplified Spontaneous Emission" (SASE) mode. Only 5 years later – and then renamed into FLASH – the expanded facility started regular operation for users from all over the world. In the past 20 years, a number of facilities have opened their doors in Europe and worldwide and numerous new scientific ideas, applications and technologies have grown from the first unpretentious intensity signal on a photodiode, shown above, to a strong and vibrant community. For well over a decade now, FELs of Europe still actively works on bringing our FEL community in Europe together on a regular basis. A Memorandum of Understanding between the involved European facilities, signed originally in 2012, forms the basis for our work and was extended for the 2nd time until 2030. The by now traditional PhotonDiag workshop took place in Liverpool in early September to discuss new ideas in the field. Just a few weeks later in late September, the more recently established "FELs of Europe Topical Workshop on Selected Problems in FEL Physics: from soft X-rays to THz" took place in a rainy Mediterranean at Grado. Again, also this third edition was held as a very open discussion meeting. It is planned to continue both event series in 2027 with the locations to be determined soon.

As an outlook into 2026, the next "Science @FELs" conference will take place at PSI, 21-25 September 2026, immediately followed by the "Forum on Advanced FEL Techniques". In between these large events, the FELs of Europe online tutorial series offers new input from all across the field a few times a year. In 2025, the FELs of Europe management has rotated again after a two-year period. The chair's baton was handed from Manfred Helm, FELBE to Elke Plönjes, FLASH at the steering committee meeting held at the CLIO infrared free electron laser in Orsay in July 2025. At the same time, Marie-Emmanuelle Couprie, SOLEIL has left the management board and will be superseded by Gregor Knopp, SwissFEL. Thus, the management board now comprises Manfred, Elke and Gregor. We would like to sincerely thank Manfred for his efficient lead over the past two years as chair and Marie-Emmanuelle for her collaborative work in the management board. Our very long-term member Britta Redlich, FELIX has left the steering committee altogether to become new Photon Science director at DESY. We would like to thank Britta for her many guiding contributions over the past decade. Sandra Brünken and Jos Oomens follow in her footsteps to represent FELIX. We hope that you will enjoy the newsletter – as usual coming together thanks to the FELIX team as well as all contributors – and wish you a happy holiday season and a successful year 2026!

Elke Plönjes
Chair FELs OF EUROPE

A new spectroscopy for ultrafast molecular dynamics: time-resolved shake-down XPS

In ultrafast molecular dynamics, electronic and structural reorganization are coupled on a femtosecond timescale. Linear molecules have served as simple benchmarks in pump–probe spectroscopy, yet key questions remain regarding their dynamics immediately preceding dissociation. Carbon disulfide (CS_2) is a paradigmatic example: although its primary sub-picosecond photo-dissociation pathway into a sulfur atom (singlet and triplet) and a correlated CS fragment is well established, the detailed sequence of events leading to bond rupture remains elusive. This complexity arises from the interplay of coupled stretching and bending motions, along with competing electronic processes such as internal conversion (IC) and intersystem crossing (ISC).

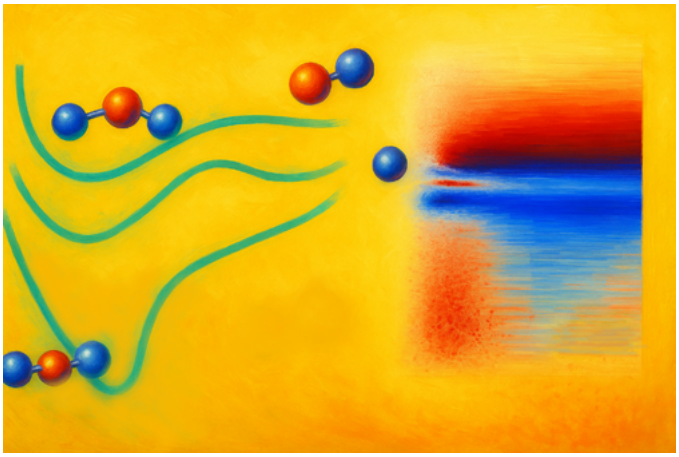

Fig. 1: Artist's rendition of the spectroscopic characterization of CS^2 photo-dissociation.

Probing these dynamics requires techniques that are sensitive to both electronic and nuclear motion. Valence photoelectron spectroscopy provides a broad view of the molecular bonding structure, while core-level photoelectron spectroscopy inspects the local chemical environment. Traditionally, these aspects have been addressed separately. In this experiment, we combined them within a single experimental campaign, allowing for a comprehensive view of the excited-state dynamics in CS_2. The experiment was conducted at the Low Density Matter beamline of the FERMI free-electron laser in Trieste. Excitation was achieved using a 200 nm pump-pulse. The FEL probe-pulse was generated by the FEL-2 machine: its first stage produced the 12th harmonic of a 248 nm seed (20.66 nm), and in the second stage the 6th harmonic of this latter pulse was generated (6.89 nm). For valence photoelectron spectra, only the first stage was employed, with the second stage switched off; both stages were used for core-level measurements.

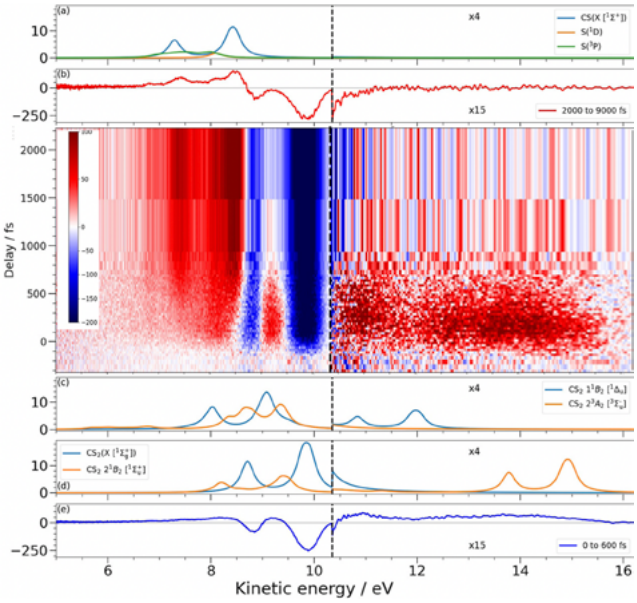

Fig. 2: Experimental time-resolved differential X-ray photoelectron spectrum of CS_2 obtained upon scanning the time delay between the 200 nm pump and 179.9 eV probe, and comparison of the experimental XPS spectra at early and late delays with the theoretically calculated ones. *Picture adapted from J. Am. Chem. Soc. 147, 36, 32851–32860 (2025).*

The combination of high-quality data and advanced theoretical modeling (Fig.2) enabled us to isolate the contributions of the valence-excited singlet states from the triplets in the pre-dissociation photodynamics. In particular, we tracked, via satellites states, the evolution of singlet states in the early stages preceding dissociation. Core-level spectroscopy proved uniquely powerful in this context: by deriving and exploiting propensity rules for the weak shake-down satellite processes, immune to spectral congestion, we identified signatures of both bright and dark singlet states and followed the redistribution of their populations through internal conversion. These results show that time resolved shake-down spectroscopy is a powerful and general tool that has great potential as a next-generation probe of photo-induced molecular dynamics.

Michele Di Fraia

Original publication:
H. J. Thompson, M. Bonanomi, J. Pedersen, O. Plekan, N. Pal, C. Grazioli, K. C. Prince, B. N. C. Tenorio, M. Devetta, D. Faccialà, C. Vozzi, P. Piseri, M. B. Danailov, A. Demidovich, A. D. Brynes, A. Simoncig, M. Zangrando, M. Coreno, R. Feifel, R. J. Squibb, D. M. P. Holland, F. Allum, D. Rolles, P. Decleva, M. S. Schuurman, R. Forbes, S. Coriani, C. Callegari, R. S. Minns, M. Di Fraia, Shake-down spectroscopy as state- and site-specific probe of ultrafast chemical dynamics, J. Am. Chem. Soc., 147, 36, 32851–32860 (2025).
DOI: 10.1021/jacs.5c09162

European XFEL reveals quantum fluctuations in complex molecules

Due to the Heisenberg uncertainty principle of quantum physics, atoms and molecules never come completely to rest, even in their lowest energy state. Researchers at European XFEL in Schenefeld near Hamburg have now been able to directly measure this quantum motion in a complex molecule for the first time. For this, however, they had to make the molecule explode in the process. Absolute standstill only exists in classical physics. In the quantum world, even the ground state with the lowest energy is characterised by persistent fluctuations. This is due to a quantum-mechanical principle discovered by Werner Heisenberg a hundred years ago during the development of quantum mechanics. The so-called zero-point fluctuations are a quantum effect that prevents atoms from remaining precisely at a fixed position, even at temperatures near absolute zero. At European XFEL, researchers have made the previously invisible directly observable – and the quantum world a bit more tangible.

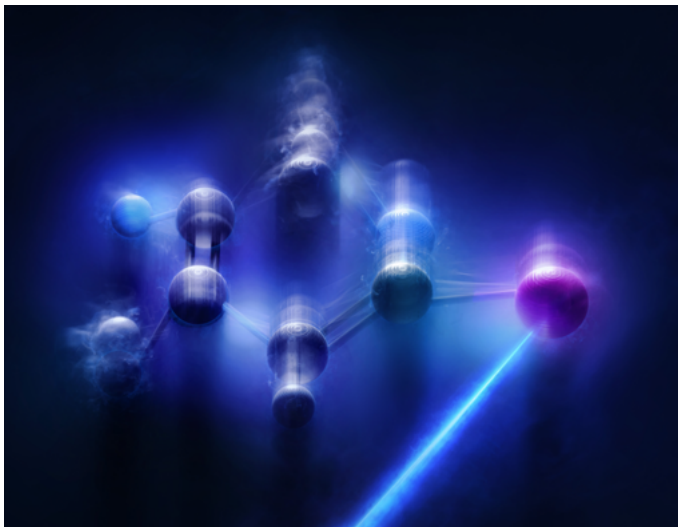

Fig. 1: Visualisation of collective quantum fluctuations of the structure of a complex 2-iodopyridine molecule.

An international team led by Rebecca Boll from the SQS (Small Quantum Systems) instrument at European XFEL, Ludger Inhester from the DESY research centre, and Till Jahnke from the Max Planck Institute for Nuclear Physics in Heidelberg, succeeded in visualising the collective trembling of an entire molecule. Using a sophisticated experiment and refined data analysis, they were able to measure the quantum fluctuations of the 2-iodopyridine molecule (C_5H_4IN), which consists of eleven atoms – a milestone in molecular imaging.

The researchers employed a method as spectacular as its name: Coulomb Explosion Imaging. The ultrashort, extremely intense X-ray laser pulses of European XFEL strip numerous electrons from the atoms of individual 2-iodopyridine molecules very rapidly. The remaining atomic cores become positively charged, repelling each other. The result resembles a microscopic big bang: the atomic cores fly apart in an explosion.

Nonetheless, from the measured flight directions and velocities of the fragments, the researchers can reconstruct the original arrangement of the atoms – and more than that: for the very first time, they were able to visualise the tiny quantum mechanical fluctuations. The 2-iodopyridine molecule is a so-called pyridine ring. It consists of a carbon ring incorporating a nitrogen atom. An iodine atom is attached to this pyridine ring. From a classical perspective, the entire molecule is perfectly planar – meaning that all its atoms lie exactly within one plane. If the molecule would be a classical object all atoms and fragments would fly off exactly within the molecular plane after a Coulomb explosion. As the researchers studied the molecule in its ground state, they could exclude deviations due to possible molecular vibrations. Nevertheless, the team detected charged atoms outside the classically expected molecular plane. Their measurements matched detailed simulation calculations that also included machine learning methods. In these calculations, they explicitly had to include the quantum fluctuations in order to reproduce the data. Furthermore, they could see the collective nature of the quantum fluctuations in the measurement data: That is, the atoms in the molecule did not tremble independently of each other, but moved in coordinated patterns. The measurement data were recorded with a detector called a COLTRIMS (REMI) reaction microscope – one of the devices available to users at the SQS instrument. With this, many of the fragments can be recognised and spatially assigned at the same time. One challenge was that not all fragments of the molecule can be detected in every X-ray pulse. The researchers overcame this obstacle by using a new statistical analysis method developed by Benoît Richard from DESY and the University of Hamburg. They were able to reconstruct the complete momentum distribution of the molecule even from fragmentary datasets.

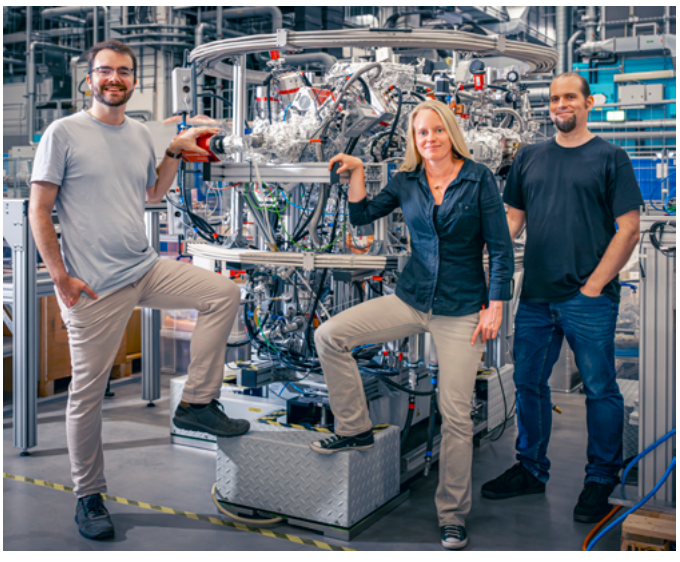

Fig. 2: Three researchers at the COLTRIMS Reaction Microscope (REMI). From left to right: Benoît Richard (CFEL DESY/CUI), Rebecca Boll (European XFEL), and Till Jahnke (Max Planck Institute for Nuclear Physics / Goethe University Frankfurt/Main).

EuXFEL

The very intense X-ray flashes from European XFEL make each molecule explode very efficiently and in a very similar way. They were able to decipher the structure of the entire molecule. The new method opens entirely new avenues for exploring complex quantum mechanical systems. Coulomb Explosion Imaging does not just provide averaged values, such as X-ray crystallography for example, but allows to investigate individual molecules. In the future, this technique could be used to study even larger molecules, the researchers are convinced. And time-resolved movies of internal motions of the molecules are possible with a time resolution of less than one femtosecond.

Fig. 3: Rebecca Boll at the COLTRIMS (REMI) reaction microscope of SQS instrument of European XFEL, where the experiment was carried out.

A follow-up project will be funded next year within the Excellence Strategy of the German federal and state governments as part of the recently extended Excellence Cluster “CUI: Advanced Imaging of Matter”. This cluster at the University of Hamburg is a cooperation with DESY, the Max Planck Institute for the Structure and Dynamics of Matter (MPSD), and European XFEL. The work impressively demonstrates what is possible when cutting-edge laser technology, quantum mechanics, and sophisticated data analysis come together.

Gerhard Samulat,
Rebecca Boll,
Ludger Inhester,
Till Jahnke

Original paper:
B. Richard et al., Imaging collective quantum fluctuations of the structure of a complex molecule, Science, 389, 650-654 (2025).
DOI: 10.1126/science.adu2637

Visual media and explaining video:
https://media.xfel.eu/XFELmediabank/catalog/Presse_XFEL_2023/c/15255

HFML-FELIX

Uncovering the catalytic activity of organocatalysts via infrared spectroscopy using the laser light from FELIX

Catalysts shape our everyday life, with applications in food production, pharmaceutical synthesis and green energy production, among others. Most currently used catalysts are metal-based, making them expensive, environmentally unfriendly, and often toxic. Inspired by the functionality of enzymes, however, so-called organocatalysts have gained a great deal of attention, given their potential to be cheap, stable, less harmful, and environmentally friendly. In a reaction mediated by an organocatalyst, such as the Michael addition of malonates to nitroolefins illustrated in Fig. 1, both reactants are believed to be simultaneously activated by forming multiple hydrogen bonds. This offers multiple coordination sites and degrees of activation, making organocatalyst highly versatile. At such, the structure of the catalyst and the relevant inter- and intra-molecular interactions play a crucial role in the catalytic activity, an information that is notoriously difficult to obtain at an atomic level. Such knowledge is however crucial for the rational design of new and more efficient organocatalysts. Researchers at HFML-FELIX and Radboud University and the Van ’t Hoff Institute for Molecular Sciences (University of Amsterdam) have now developed a new methodology to investigate the reactive complexes of an organocatalyst, accessing its conformation and the subtle chemical interactions at play. As a prototypical reaction, the Takemoto organocatalyst interacting with 1-(2-nitroethyl)naphthalene was

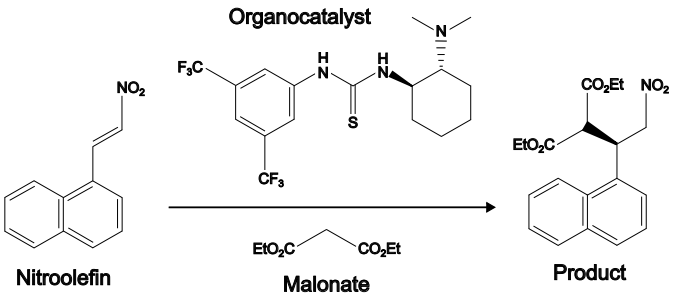

Fig. 1: Scheme of the Michael addition of malonates and nitroolefins mediated by the Takemoto organocatalyst.

investigated. Using the technique of laser desorption, molecular beams of neutral species were generated and crossed by the infrared laser light of FELIX, which allowed for recording infrared spectra of the bare catalyst as well as of the catalyst–nitroolefin complex. Crucially, the recorded mass-selected infrared spectra carry direct information about both geometry and chemical bonding, the two ingredients determining catalytic activity. In the first stage, experiments were performed on the bare catalyst, as depicted in Fig. 2. The wide tunability and high laser power of FELIX allowed recording infrared spectra of high quality over the broad range from 650 to 3500 cm^{-1}. This is crucial, since key fingerprint

vibrational features of the catalyst are found in this range, as well as vibrational modes that are sensitive to the subtle interactions with the nitroolefin. Very important was the recent upgrade of the FEL-2 undulator at HFML-FELIX, which allows reaching the range from 5 to 2.7 µm (2000 – 3700 cm^{-1}) with high power. A comparison with vibrational spectra computed with density functional theory (DFT) let to the solution of a long-standing problem concerning the preferred conformation of the bare catalyst, which purely computational studies so far had not been able to determine unambiguously. Next, the more challenging experiment involving the catalyst–nitroolefin complex was conducted, requiring a careful tunning of experimental conditions during laser desorption to form the hydrogen-bonded complex. Although the intensities in mass spectra were lower than for the bare species, an infrared spectrum with high signal-to-noise ratio could be recorded (see Fig. 3). Importantly, the spectrum was measured simultaneously with the spectra of the bare species, thus allowing for a direct comparison of the three under the same experimental conditions, and thereby providing sensitivity to subtle changes in the infrared spectrum induced by complexation.

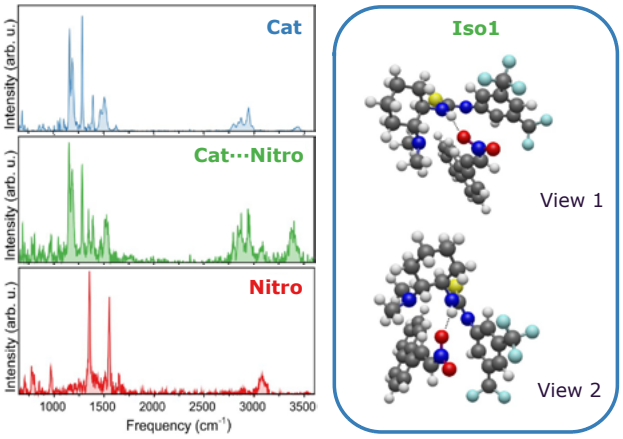

Fig. 3: Comparison of the IR spectra measured for the bare catalyst (blue), bare nitroolefin (red), and catalyst-nitroolefin complex (green). Complementary DFT calculations allow an identification of the conformation of the complex depicted in the right panel.

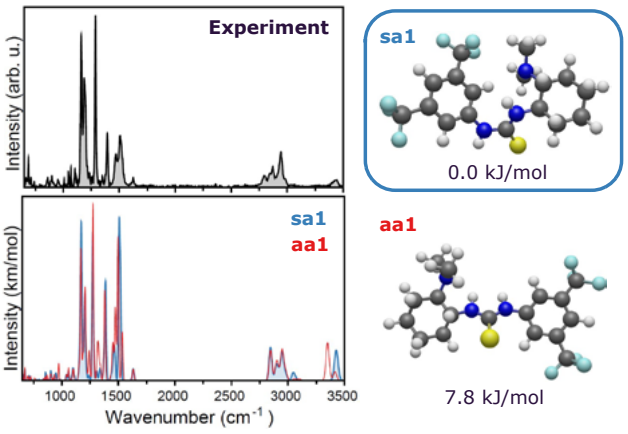

Fig. 2: IR spectrum of the bare catalyst (top), compared with the vibrational spectra computed for two conformations (bottom). The geometries of both conformers are shown at the right side of the figure, highlighting the assigned conformer.

With the help of extensive DFT calculations, the binding site adopted by the nitroolefin on the catalyst was identified, revealing a conformation stabilized by the formation of a single hydrogen bond, as depicted in Fig. 3. Significantly, the observed shifts in the vibrational spectrum of the complex can be traced back to the formation of this hydrogen bond and its interaction strength. Moreover, the analysis showed a change induced in the conformation of the catalyst upon complexation, suggesting that the specific conditions of the molecular beam allow freezing intermediate states along the reaction pathways of the system. Further experiments will be conducted for the catalyst interacting with the malonate as well as with both reactants simultaneously, thus providing a complete picture of the complicated organocatalytic activity. The general applicability of this approach holds great promise for extending it also to other relevant complex catalytic reactions.

Piero Ferrari
Wybren Jan Buma
Alexander K. Lemmens

Original Publication:
P. Ferrari, A. K. Lemmens, W. J. Buma, Light on catalytic reaction mechanisms: uncovering the conformation of thiourea-based organocatalysts and their interaction with nitroolefins using far-infrared spectroscopy, J. Phys. Chem. Lett. 16, 24, 6178–6184 (2025).
DOI: 10.1021/acs.jpclett.5c01093

Stabilising fleeting quantum states with light

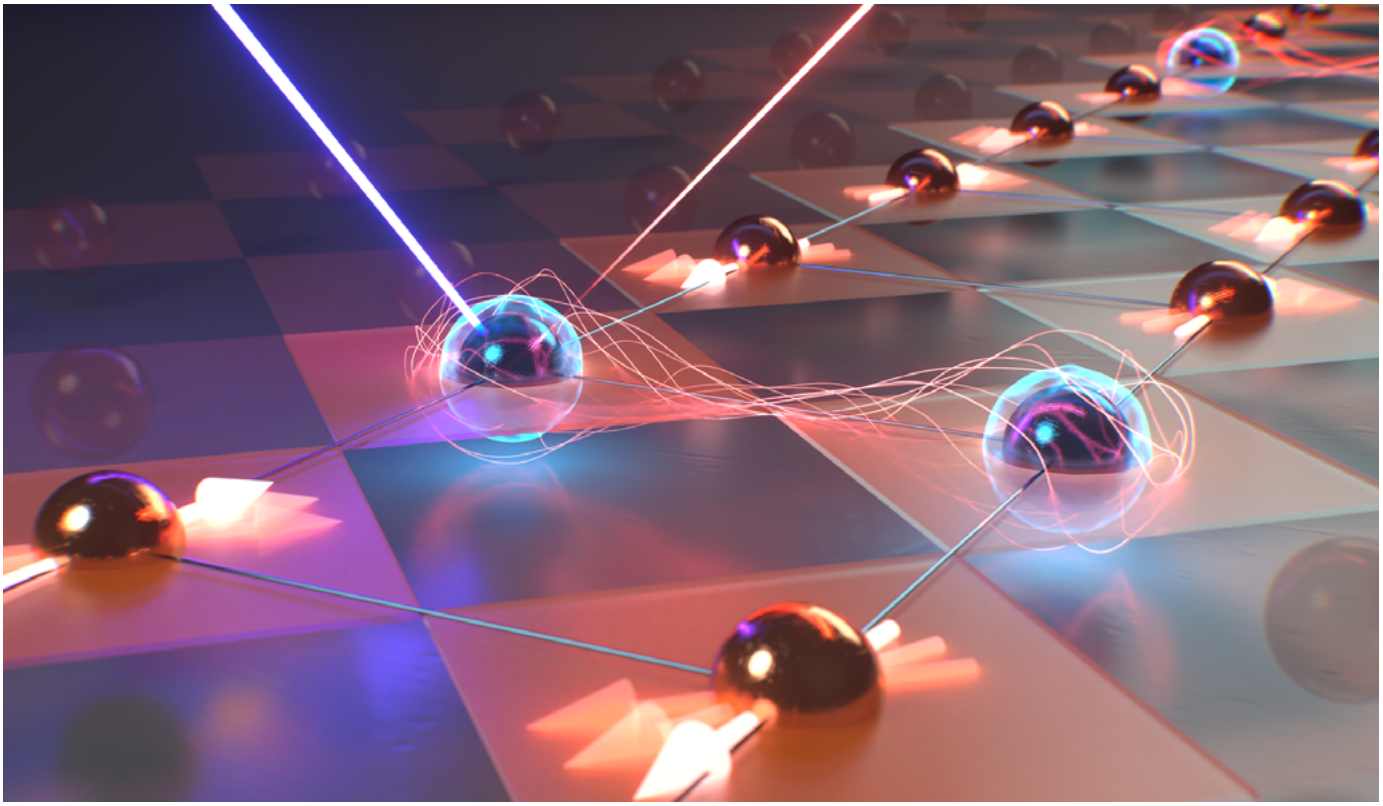

Fig. 1: Laser pulses trigger electronic changes in a cuprate ladder, creating long-lived quantum states that persist for about a thousand times longer than usual. (Brad Baxley/Part to Whole).

Quantum materials exhibit remarkable emergent properties when they are excited by external sources. However, these excited states decay rapidly once the excitation is removed, limiting their practical applications. A team of researchers from Harvard University and the Paul Scherrer Institute PSI have now demonstrated an approach to stabilise these fleeting states and probe their quantum behaviour using bright X-ray flashes from the X-ray free electron laser SwissFEL at PSI.

Some materials exhibit fascinating quantum properties that can lead to transformative technologies, from lossless electronics to high-capacity batteries. However, when these materials are in their natural state, these properties remain hidden, and scientists need to gently ask for them to pop up. One way they can do this is by using ultrashort pulses of light to alter the microscopic structure and electronic interactions in these materials so that these functional properties emerge. But good things do not last forever – these light-induced states are transient, typically persisting only a few picoseconds, making them difficult to harness in practical applications. In rare cases, light-induced states become long-lived. Yet our understanding of these phenomena remains limited, and no general framework exists for designing excited states that last. A team of scientists from Harvard University together with PSI colleagues overcame this challenge by manipulating the symmetry of electronic states in a copper oxide compound. Using the X-ray free electron laser SwissFEL at PSI, they demonstrated that tailored optical excitation can induce a 'metastable' non-equilibrium electronic state persisting for several nanoseconds – about a thousand times longer than they usually last for.

Steering electrons with light

The compound under study, $Sr_{14}Cu_{24}O_{41}$ – a so-called cuprate ladder – is nearly one-dimensional. It is composed of two distinct structural units, the ladders and chains, representing the shape in which copper and oxygen atoms organise. This one-dimensional structure offers a simplified platform to understand complex physical phenomena that also show up in higher-dimensional systems. "This material is like our fruit fly. It is the idealised platform that we can use to study general quantum phenomena," comments experimental condensed matter physicist Matteo Mitrano from Harvard University, who lead the study. One way to achieve a long-lived ('metastable') non-equilibrium state is to trap it in an energy well from which it does not have enough energy to escape. However, this technique risks inducing structural phase transitions that change the material's molecular arrangement, and that is something Mitrano and his team wanted to avoid. "We wanted to figure out whether there was another way to lock the material in a non-equilibrium state through purely electronic methods," explains Mitrano. For that reason, an alternative approach was proposed.In this compound, the chain units hold a high density

of electronic charge, while the ladders are relatively empty. At equilibrium, the symmetry of the electronic states prevents any movement of charges between the two units. A precisely engineered laser pulse breaks this symmetry, allowing charges to quantum tunnel from the chains to the ladders. “It's like switching on and off a valve,” explains Mitrano. Once the laser excitation is turned off, the tunnel connecting ladders and chains shuts down, cutting off the communication between these two units and trapping the system in a new long-lived state for some time that allows scientists to measure its properties. This work represents a major step forward in controlling quantum materials far from equilibrium, with broad implications for future technologies. By stabilising light-induced non-equilibrium states, the study opens new possibilities for designing materials with tuneable functionalities. This could enable ultrafast optoelectronic devices, including transducers that convert electrical signals to light and vice versa—key components for quantum communication and photonic computing. It also offers a pathway toward non-volatile information storage, where data is encoded in quantum states created and controlled by light.

www.psi.ch/en/news/science-features/stabilising-fleeting-quantum-states-with-light

Elia Razzoli
Matteo Mitrano

Original publication:
H. Padma et al., Symmetry-protected electronic metastability in an optically driven cuprate ladder, Nature Materials (2025).
DOI: 10.1038/s41563-025-02254-2

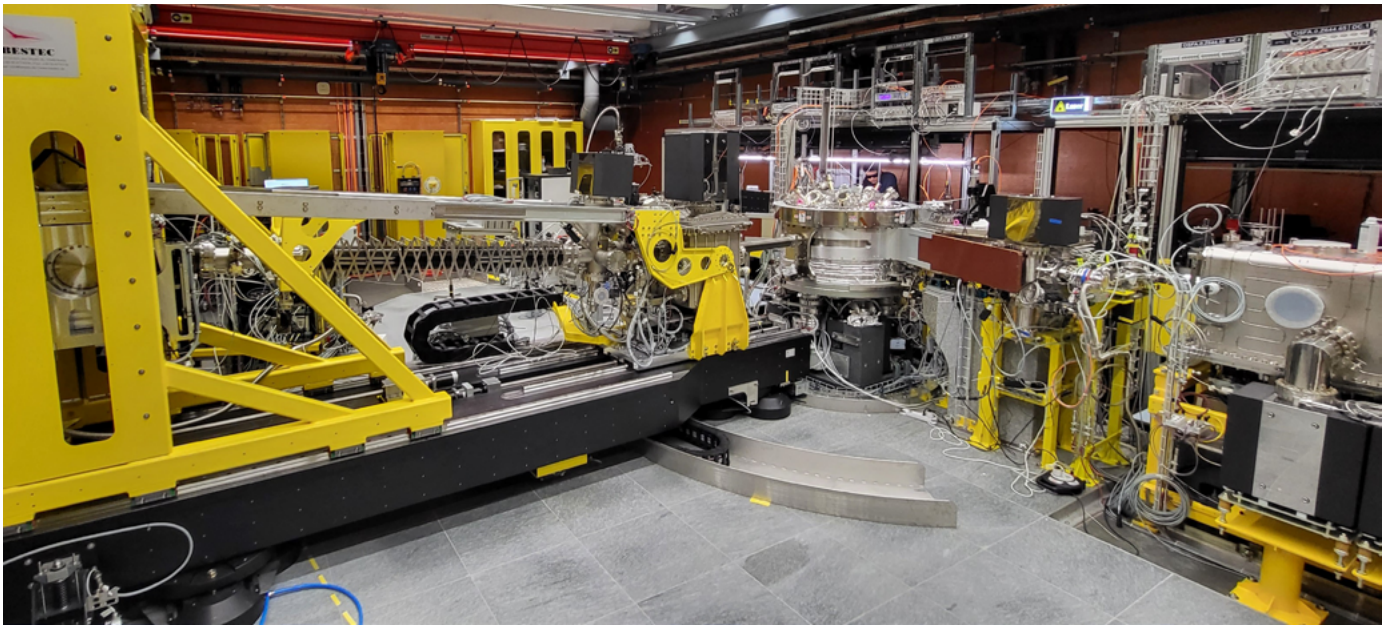

Fig. 2: An X-ray flash illuminates a molecule. (Image: University of Uppsala / Raphael Jay).

FLASH turned 25 – and has just been upgraded to a unique high-repetition rate seeded FEL

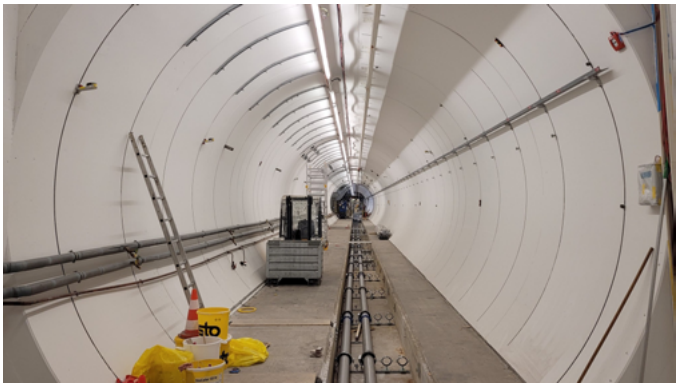

Fig. 1: View into the emptied FLASH1 tunnel in autumn 2024, providing about 120 m of space for a new electron beamline, undulators, laser and photon beamlines and all the related infrastructure around.

25 years ago, on February 22nd, 2000, FLASH made history as the world's first short wavelength free-electron laser yielding SASE pulses around 100 nm [1]. This marked the beginning of a new era in ultrafast X-ray science and paved the way for worldwide investments in FEL facilities, transforming the fields of ultrafast and X-ray science. Several hallmark experiments have been performed at FLASH that demonstrated the unique capabilities of short wavelength FELs. These include the first single-shot coherent diffractive imaging experiment, the first XUV multi-photon photoionization at ultra-high intensities (up to 1016 W/cm^2), the first femtosecond time-resolved magnetic scattering experiment, and the first studies of XUV-FEL driven ultrafast chemical reactions [2]. Key developments in photon diagnostics and beamline instrumentation have been made at FLASH and are now used at many FEL facilities around the world [2]. FLASH continues to push the boundaries of FEL science by sustained machine and instrumentation upgrades. Since 2016 FLASH is providing users with pulses from a second FEL line FLASH2, operated in parallel to FLASH1. The FLASH2020+ long-term upgrade program [3], aiming to keep FLASH at the forefront of FEL science, is in full swing now. A first larger upgrade shutdown in 2021/22 has mainly been devoted to boost the accelerator to 1.35 GeV, yielding shorter wavelengths down to 3.2 nm (~390 eV) at FLASH2 with some headroom to reach even shorter wavelengths in the future. Furthermore, a new 'laser heater', which is an essential ingredient for optimizing the new seeded FLASH1, has been installed. In the last user campaign, the laser heater could already be used to optimize the third harmonic afterburner, which has been installed at FLASH2, with respect to its polarization contrast. The FLASH1 branch was transformed into a fully external seeded machine in a second large upgrade shutdown, from June 2024 to August this year. The FLASH1 branch is now equipped with APPLE III-type undulators with variable gap and full polarization control. The seeding will be operating at the FLASH-typical MHz repetition rate in the bunch train scheme, providing unique opportunities worldwide for FEL-based science. Seeding is powered by an inhouse-developed optical laser system. A new photon transport beamline with pulse-resolved photon diagnostics tailored to seeded FEL pulses was installed to optimally utilize the high-repetition rate seeded pulses. About 120 m of the FLASH1 tunnel had to be completely cleared (Fig. 1) to make space for new state-of-the-art equipment (Fig. 2) which is presently being commissioned.

All these upgrades are taking FLASH1 to the 'next level' in the FEL parameter range. The seeded FLASH1 will yield more stable pulses with respect to SASE FELs, with strongly reduced spectral and temporal jitter and much narrower spectral bandwidth. The FLASH users will benefit from this high spectral resolution and stability as well as the high longitudinal coherence.

Fig. 2: View into the filled FLASH1 tunnel close to the shutdown end (photo: K. Honkavaara, taken on July 31, 2025). In the background one sees some of the yellow frames of the new Apple III undulators and at the top right the new air-conditioning.

The well-established photoemission community will use the spectral and temporal characteristics for faster and more systematic experiments. Nonlinear experiments will benefit from the close to Fourier-transform limited pulses. The stable pulses will allow higher fidelity measurements with methods that require averaging over several pulses – as in the case of ion traps. Being complementary to the either particularly short (few fs) or more intense (up to mJ) SASE pulses at FLASH2, these new FEL properties at FLASH1 will have a broad impact on the methods and science cases of many of our user communities and are expected to expand the FLASH science fields. Early November we will begin with user operation at the FLASH2 branch. At the end of 2024, we issued a call for proposals related to the corresponding FLASH2 beamtimes in late 2025 and the first half of 2026. The new FLASH1 FEL branch, equipped with external seeding, first needs to be thoroughly commissioned until presumably early 2026. First experiments with the seeded FLASH1 will then be community-driven proposals, and all users are invited to join the process. After these user community experiments, we will continue with proposals running through the regular project review panel (PRP) process for FLASH1 as well. We expect to publish a call for FLASH1 proposals towards the beginning of 2026. This FLASH1 call will then be related to beamtimes from late 2026 on. At that point,

FLASH

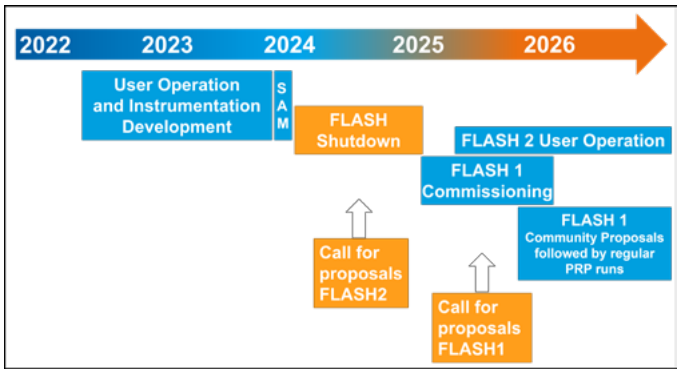

Fig. 3: Sketch of the FLASH timeline until end of 2026.

FLASH will again be in regular user operation at both ends, with many new features as demanded by our user community. The overall timeline until end of 2026 is sketched in Fig.3.

Rolf Treusch

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STRF UKRI

UK XFEL project approaches major milestone

The UK XFEL project is approaching a major milestone, with its Conceptual Design and Options Analysis (CDOA) report set to inform the UK's direction for the future of X-ray science. This milestone is the culmination of three years of technical studies, community consultation, and strategic planning to develop routes to the 'next generation' of XFEL capabilities. Led by the Science and Technology Facilities Council, the project developed a Science Case (2020), which demonstrated the mission need for UK access to new XFEL capabilities. The present phase (supported by the UK Research and Innovation Infrastructure Fund) has strengthened connections with established XFEL users and new research communities. Since 2023, the UK XFEL team has hosted a series of Town Hall meetings around the UK (see Issue 14) and other events to define the requirements for a future machine. The project's science team, led by Professor Jon Marangos (Imperial College London) is now capturing the community's priorities in a refreshed and expanded Science and Technology Case, to be published alongside the CDOA. This will describe frontier science across a wide range of fields, as well as the technologies anticipated to benefit from the research. The project aims to secure UK access to the next generation of frontier large-scale XFEL facilities, which could potentially be realised by developing a new facility in the UK or investing at existing XFELs. Towards this goal, the team have developed a conceptual design based on very high repetition rate (100 kHz – 1 MHz) operation: coupling various accelerator, laser, and end station technologies with the emergence of AI, to translate unprecedented data throughput to future discoveries across a host of disciplines. It includes advanced FEL techniques to generate extreme X-ray pulse qualities, including 'laser-like' temporal coherence, widely separated two-colour pulses and extremes of photon energy and pulse energy. The x-rays will combine with a comprehensive suite of lasers and other sources to trigger and probe a multitude of effects. Crucially, the design sets out how to realise a step-change increase in efficiency and capacity, to reduce the wait between related experiments, and bring down their cost. This is targeted through a robust and highly modular design, coupled to transformative impacts of AI, digital twinning, and robotics. The aim of realising the next generation of XFELs is a truly international endeavour, with strong collaborative ties. The Options Analysis aspect of the project has assessed various routes for UK involvement in terms of strategic, socioeconomic, and environmental sustainability factors. As the UK XFEL project approaches this milestone, the team invites researchers, industry partners, and policymakers to engage with the reports and help shape the next era of science enabled by ultrafast X-rays. Sign up to our mailing list here xfel.ac.uk to be alerted of the publication of the UK XFEL CDOA.

David Dunning,
Paul Aden

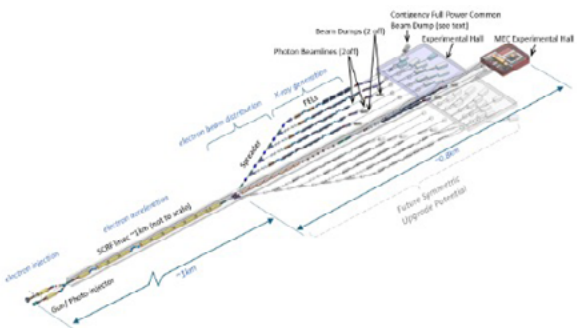

Fig. 1: An outline of the conceptual design for a next generation XFEL providing a unique combination of capabilities to meet the needs of the UK XFEL Science and Technology Case.

EuXFEL

European XFEL warmed up for the first time

Fig. 1: For the first time since its start eight years ago, the European XFEL, with its superconducting cavities, has now been warmed up to room temperature for mandatory maintenance and extensive conversion work. It will be available for experiments again in spring 2026. (photo: European XFEL / Heiner Müller-Elsner).

For more than eight years, the temperature inside the European XFEL electron accelerator was minus 271 degrees Celsius – colder than in space. Now, for the first time, the accelerator has been warmed up to room temperature for mandatory maintenance and extensive conversion work. The accelerator was built by DESY in collaboration with international partners. The fact that everything went smoothly is testament to the extreme care with which the facility was installed ten years ago. Warming up to room temperature must be done carefully in order to prevent possible damage.

The immediate reason for the operational break is a mandatory inspection of helium valves, which was not possible when the system was cold. In addition to this, a large number of new installations are planned, which the teams at European XFEL and DESY have been preparing for years. The work is an important step towards implementing the future strategy of European XFEL. Key milestones include installing a completely newly developed electron source at the beginning of the accelerator, the construction of a new instrument in the experiment hall in Schenefeld and preparatory steps for the installation of new superconducting undulators for increased light intensity and shorter wavelengths. The implementation of all these innovations required precise planning and tireless effort. Once the current work has been completed, the facility will be cooled down again to minus 271 degrees Celsius before it is available for experiments again in spring 2026. Since 2017 more than 11,000 visits – including multiple stays – researchers have conducted about 500 experiments at the world's largest X-ray laser and published their results in prestigious journals.

Gerhard Samulat,
Frederico Alves Lima

HZDR

DALI

The Dresden Advanced Light Infrastructure (DALI), the THz source planned at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) as a successor to ELBE, has achieved a significant milestone. The Federal Ministry for Research, Technology, and Space (BMFTR) has included the project on its shortlist of priority research infrastructures in Germany (as one out of nine projects). This announcement was made by Federal Research Minister Dorothee Bär at a press conference in Berlin on Tuesday, July 8, 2025. With this recognition, DALI is now among a select group of major scientific initiatives considered especially worthy of support due to their potential to secure and enhance Germany's long-term innovation capabilities.

Manfred Helm

HFML-FELIX transforms into national research institute and welcomes new director

Signing of the collaboration agreement in December 2024. Photo credits: HFML-FELIX.

As of 1 January 2025, HFML-FELIX has officially become part of the Foundation for Dutch Scientific Research Institutes (NWO-I), joining nine other national research institutes. This milestone secures structural funding for the next ten years and strengthens the role of HFML-FELIX in the Dutch and international research landscape. As the tenth national research institute, HFML-FELIX will continue its work within a broad national partnership consisting of Radboud University, NWO, and six other universities: Delft University of Technology, Maastricht University, University of Twente, University of Amsterdam, Leiden University, and University of Groningen as well as the Radboud University Medical Center. In addition, Utrecht University has recently signed the collaboration agreement to also join as strategic partner.

Together, this consortium will develop a coordinated national research programme, enabling the lab to make lasting contributions to scientific progress and to tackling societal challenges.

In close collaboration with the new partners, five topic lines were drafted that will shape its future activities:

- Mapping and manipulating quantum phases of matter
- Molecular structure identification and reactivity in infrared
- Dynamic self-organisation in soft molecular matter
- Non-equilibrium phases of matter
- Innovative instruments for advanced spectroscopy

In September 2025, Prof. Dr. Marc Baldus took over as director of HFML-FELIX, succeeding interim director Prof. Dr. Frank Linde. Linde served in this role from January 2025, following the departure of Prof. Dr. Britta Redlich, who became director of the Photon Science Division at the Helmholtz Center DESY. Prof. Dr. Baldus, a professor of NMR spectroscopy at Utrecht University and former scientific director of the Bijvoet Center for Biomolecular Research, is internationally recognised for pioneering work on molecular systems. He describes his motivation for taking on the new challenge at HFML-FELIX: ‘As a physicist and spectroscopist, I always considered the idea to combine high-field magnet technology and free-electron lasers to explore the properties and structure of materials as realized at HFML-FELIX highly innovative. In fact, such a strategy strongly aligns with my own research mission to combine technological and conceptual advances in fundamental science with broad impact ranging from science to society. I find the recent development of HFML-FELIX to become a national research institute in partnership with seven Dutch universities an exciting opportunity to shape the future of this internationally renowned research institute.’

Karlijn Meinders,
Meike Arnold

Prof. Dr. Marc Baldus, Director of HFML-FELIX

CLARA reaches 250 MeV milestone

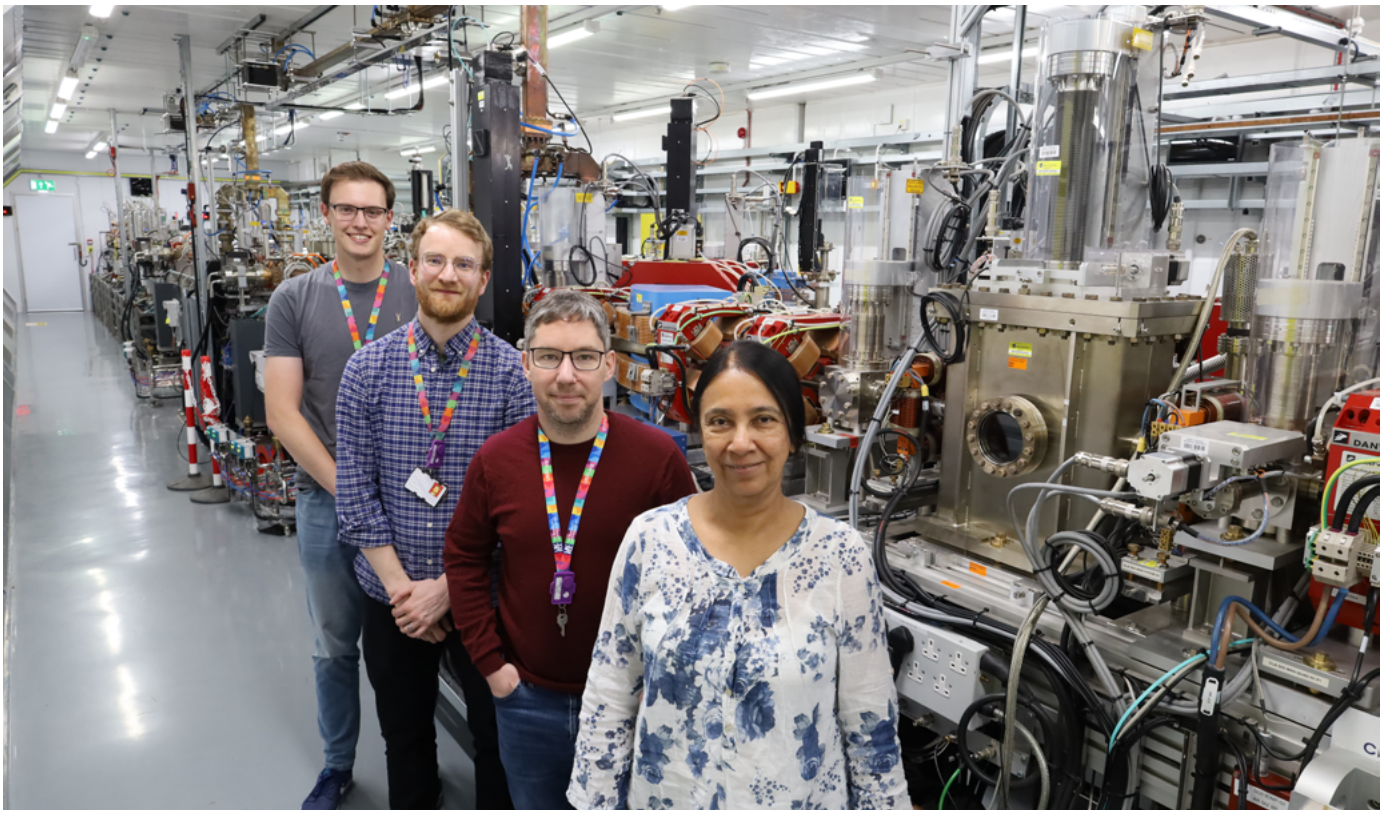

Fig. 1: Part of the CLARA team pictured inside the facility: (from R to L) Deepa Angal-Kalinin, James Jones, Thomas Pacey and Lukas McCormack. Credit STFC.

The Compact Linear Accelerator for Research and Applications (CLARA) based at Science and Technology Facilities Council's Daresbury Laboratory in the United Kingdom has successfully accelerated electrons to an energy of 250 million electron volts (MeV). This breakthrough marks a significant moment in the development of one of the world's brightest medium-energy electron beams, opening the door to a new generation of experiments previously unattainable in the UK. CLARA has been designed to develop and test next-generation accelerator technologies and is due to welcome its first users in 2026. This new UK accelerator capability will allow researchers to use 250 MeV high brightness electron bunches at 100 Hz repetition rate to explore innovations that will shape the future of medicine, high energy physics, material science and beyond. Having reached the 250 MeV milestone, CLARA can now support more ambitious research programmes and prototype technologies that were previously out of reach in the UK. A key part of this is the commissioning of FEBE (Full Energy Beam Exploitation), a shielded experimental area that allows researchers to conduct experiments without interrupting accelerator operations. This ensures faster setup times, stable beam delivery and greater flexibility for complex research. CLARA will also feature a new 120 terawatt ultra-short-pulse laser, enabling unique experiments that combine high-powered lasers with bright electron beams.

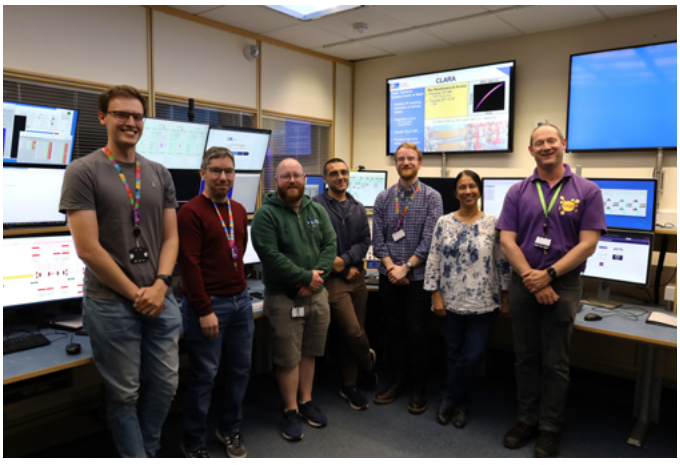

Fig. 2: Part of the CLARA team pictured in CLARA control room: (from R to L) Ryan Cash, Deepa Angal-Kalinin, Thomas Pacey, Alex Brynes, Aaron Farricker, James Jones, and Lukas McCormack. Credit STFC.

Deepa Angal Kalinin

TARLA

Progress at TARLA: From First Electron Acceleration to Upcoming 40 MeV Milestone

TARLA achieved its first electron acceleration to 18.5 MeV in April 2024. Following this milestone, efforts have focused on stabilizing the helium plant and enhancing the injector beamline to improve reliability. In parallel, the design of the compressor beamline connecting both cryomodules has been completed, with manufacturing to commence in the coming months. The first acceleration to 40 MeV is targeted by the end of 2026. While the compressor beamline progresses, the first commissioned cryomodule will support a focused nuclear physics program. Activation experiments based on photonuclear reactions with Bremsstrahlung photons will be conducted to study nuclei with very short half-lives. For rapid post-irradiation analysis, a rabbit system was installed to transfer samples from the irradiation point to the counting setup within seconds. Necessary shielding, interlocks, and operational procedures have been established, and the experimental campaign is planned to begin at the end of 2025 following scheduled helium plant maintenance. In 2023, the Turkish Energy, Nuclear and Mineral Research Agency (TENMAK) assigned TARLA to design, manufacture, and deliver the Turkish Soft X-ray Photoelectron Spectroscopy (TXPES) beamline at SESAME. As Branch B of the Helmholtz-SESAME Soft X-ray Beamline (HESEB), TXPES is the first beamline designed and installed by a SESAME member state. It provides tunable photon energies from 90 eV to 1800 eV for electronic structure and chemical bonding studies. The end station, equipped with a PHOIBOS 150 CMOS analyzer supplied by SPECS GmbH, supports X-ray and ultraviolet photoelectron spectroscopy as well as low-energy ion scattering. Initial beam tests have been successfully completed in July 2025, and the beamline is undergoing final alignment (Fig. 1). Beam time is shared equally between researchers from Türkiye and the international user community.

Baris Yildirimdemir and Ozlem Karsli

Fig. 1: TARLA and SESAME staff after successful installation of the TXPES Beamline (June 2025).

EuXFEL

A pioneering spectrometer for hard X-rays

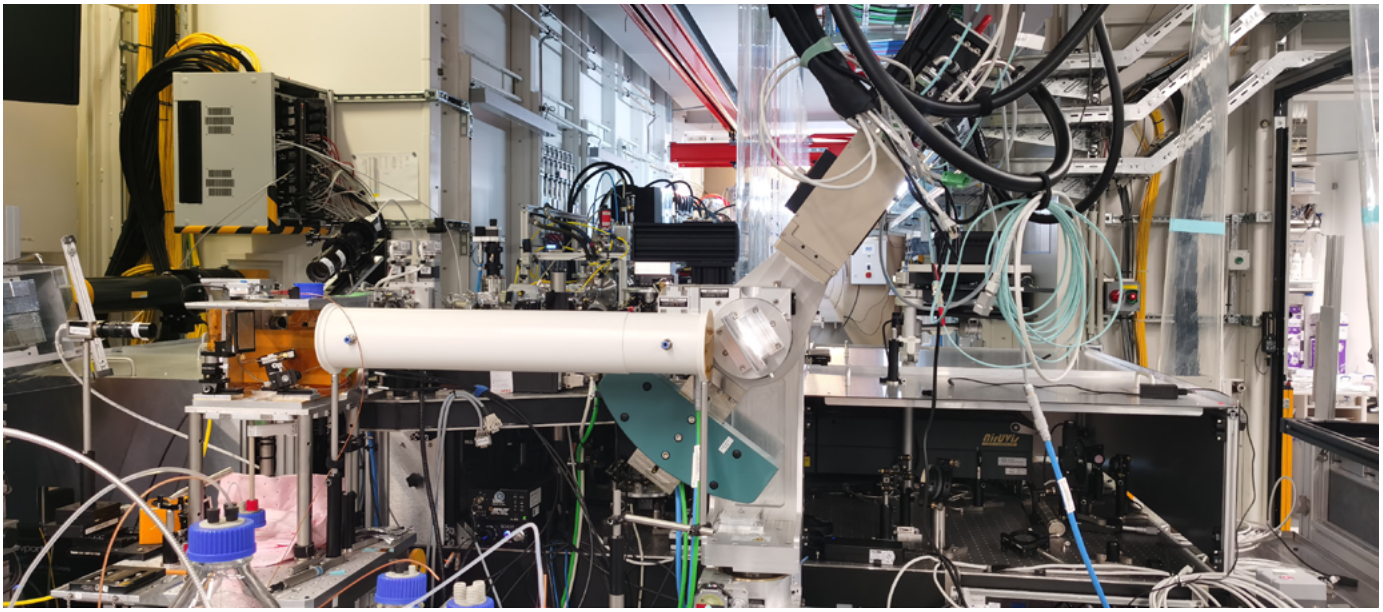

Fig. 1: The new Laue spectrometer in position at the FXE instrument of European XFEL. The crystal analyser in the centre of the image is clearly visible.

Researchers at the European XFEL have developed a new device for X-ray measurements at high photon energies – a so-called Laue spectrometer. It enables X-ray light with photon energies of over 15 kiloelectronvolts to be detected with improved efficiency and highest precision. Traditionally, X-ray spectrometers work in what is known as Bragg geometry: The X-ray light hits the crystal and is then diffracted by the atomic planes parallel to the surface, similarly as mirrors reflect visible light. A unique characteristic of European XFEL is the ability to provide X-ray light with very high energy. In this high photon energy regime, a large proportion of the X-ray light simply passes through the crystal unused, which is why the performance of X-ray spectrometers using analysers, known as Johann or Von Hamos spectrometers, decreases rapidly with increasing X-ray energy. Researchers at the FXE instrument at European XFEL have now developed a new spectrometer to obtain meaningful results even at energies well above 15 keV. It works in the so-called Laue geometry. This means that the X-rays pass through the crystal and are diffracted by atomic layers perpendicular to the surface. The higher the X-ray energy, the more efficiently the Laue analyser works. The optimised design with a fixed curvature and a short bending radius results in analysers without noticeable surface distortions, which considerably simplifies the setup and measurement with the Laue spectrometer. The performance of this spectrometer greatly surpasses previous designs with dynamically curved Laue analysers. The newly developed device called High Energy Laue X-ray Emission Spectrometer (HELIOS) is now installed and available to all users at European XFEL. It provides an extremely high precision of about 1.2 x 10^{-4} at a photon energy of around 18.6 keV. Compared to conventional spectrometers, it achieves a signal strength that is 4 to 22 times higher. This makes it possible to detect particularly interesting electronic transitions in so-called 4d transition metals, which are otherwise very difficult to measure. The 4d transition metals include technically important elements such as niobium, molybdenum, ruthenium, palladium and silver. The new spectrometer opens up completely new spectroscopic possibilities at high X-ray energies. Examples include the measurement of photocatalytic properties of nanoparticles containing 4d metals, research into dye sensitisation for solar cell applications, and the investigation of strongly correlated materials that could be used as superconductors or as battery cathodes or anodes for efficient energy storage.

Gerhard Samulat

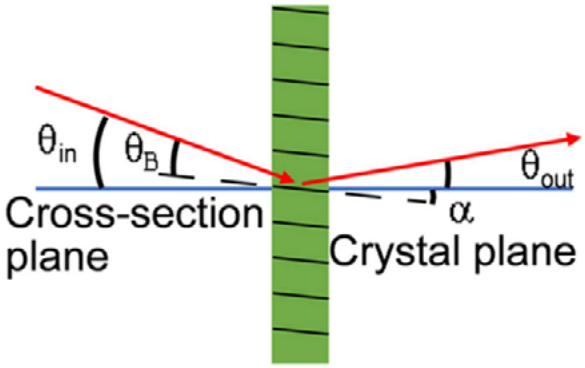

Fig. 2: Contrary to regular spectrometer the new Laue spectrometer is diffracting the X-ray beams (red arrows) by atomic layers almost perpendicular to the surface.

Original publication:
F. A. Lima et al., A high-energy Laue X-ray emission spectrometer at the FXE instrument at the European XFEL,
Journal of Synchrotron Radiation, 32, 506-523 (2025).
DOI: doi.org/10.1107/S1600577525001389

EuXFEL

European XFEL and CNRS deepen collaboration

European XFEL and its shareholder, the French National Centre for Scientific Research (CNRS), will further deepen their collaboration with the foundation of a new CNRS International Research Laboratory (IRL) at European XFEL. The aim is to further promote the use of X-ray free electron lasers in France for a wide range of fields, from condensed matter physics, structural biology and photochemistry to geosciences and astrophysics.

In its first year, the new collaboration will host 5 senior scientists from CNRS or other French institutions at European XFEL. They will work together with European XFEL staff on research and development projects. The IRL will help French scientists to build up a network of experts and specialists in different disciplines, who will be able to assist other French researchers in writing proposals to obtain beamtime as well as in setting up and running experiments, and in processing the data generated. The IRL will be funded for an initial period of 5 years.

The new collaboration will further strengthen the already very active and successful French user community at European XFEL. It will help to develop innovative technologies and address global challenges for the benefit of society, and could also serve as model for future collaborations with other partner countries.

The National Centre for Scientific Research (CNRS) is a major player in basic research on the global stage. In its unique position as a specialist in multiple fields it brings together different scientific disciplines to shed light on and gain insight into current global challenges, in partnership with public sector, social and economic stakeholders. With an annual budget of €4 billion, the CNRS employs 33 000 people, including 28 000 scientists, in 1100 research laboratories in France and abroad.

Gerhard Samulat

Fig. 1: The European XFEL Management Board with a CNRS delegation. (photo: European XFEL).

STRF UKRI

PhotonDiag 2025 Conference

The 7th FELs of Europe PhotonDiag conference took place in Liverpool, UK from 2nd to 4th September 2025. PhotonDiag is the première conference focused on the technical aspects of photon delivery to science experiments on advanced, accelerator-based photon sources and free-electron laser (FEL) sources in particular. It covers the thematic areas of photon diagnostics, photon beamlines

and optics, photon detectors and computational techniques associated with these areas. The conference was organised by the Accelerator Science and Technology Centre (ASTeC) of STFC Daresbury Laboratory in conjunction with Diamond Light Source. It was hosted by Liverpool University in the excellent facilities of the Guild of Students. The attractive location is at the heart of Liverpool and opposite the landmark of Liverpool Metropolitan Cathedral. The event was sponsored by Axilon AG, Strumenti Scientifici Cinel S.r.l, JJ X-ray, Omniscan Ltd and XDS Oxford Ltd. Over the three days of the conference, the 68 delegates enjoyed a wide-ranging set of talks and posters. In total, there were 13 invited talks, 24 contributed talks and 20 posters. An important part of the conference is the opportunity for experts to interact with each other, exchanging ideas and fostering collaborative solutions to the complex challenges presented by todays and tomorrows advanced photon sources. Despite the busy talk schedule, there was plenty of time to talk over refreshment breaks whilst enjoying the excellent catering provided by the University. The conference dinner took place in the historic setting of the Victoria Gallery and Museum on the evening of the 3rd, a venue that garnered much appreciation.

Mark Roper

ELETTRA

Topical Workshop on Selected Problems in FEL Physics: from Soft X-rays to THz

The 3rd edition of the international FELs of Europe event, "Topical Workshop on Selected Problems in FEL Physics: from Soft X-rays to THz", has just concluded in Grado, on the northern Adriatic Sea coast. It followed the first workshop in Dresden (2022) and the second in Hamburg (2023).

The workshop has established itself as a leading forum for the European community—while remaining open to non-European partners and competitors—covering Free-Electron Lasers (FELs) ranging from IR/THz to soft X-ray photon energies. This year's edition was organized by Elettra Sincrotrone Trieste, with Manfred Helm (HZDR), Primož Rebernik Ribič, and Simone Di Mitri (Elettra) serving as conference chairs.

The event brought together 50 experts (14 women) from 10 countries and 21 research institutions, universities, and laboratories. The program featured 23 plenary talks and 8 round tables, providing a broad and up-to-date overview of cutting-edge research in the field, as well as stimulating and constructive discussions on the present and future challenges of coherent light sources. Conference sessions covered a wide range of topics, including:

- infrared and THz coherent sources (special operation modes, pump-probe, high field, superradiance);
- attosecond pulses in SASE FELs;
- advancements in externally seeded FELs;
- structured light in THz and VUV seeded FELs;
- electron beam and FEL pulse diagnostics, including integration with machine learning algorithms;
- microbunching instability in accelerators;
- undulator design and operational aspects of short-wavelength FELs.

Preparations are already underway for the next edition, which is expected to be hosted by one of the FELs of Europe partners in about two years.

Simone Di Mitri

(photo: Elettra Trieste).

European XFEL Young Scientist Award for Patrick Heighway

Patrick Heighway deserves the prestigious prize for his pivotal role in measuring X-ray diffraction at extreme pressures and temperatures at the HED-HiBEF Instrument of European XFEL. His work combines experimental data with molecular dynamics simulations to provide critical insight into the nature of release pathways of shock compressed materials, kinematics of plasticity, and the fundamental interaction of grains in compressed polycrystalline materials. This work is important for many different fields, including geophysics, fundamental material science, shock and plasma physics, the search for novel materials, and understanding pathways to fusion energy.

The European XFEL Young Scientist Award recognises young researchers who are at the beginning of their career but are already making outstanding contributions to research at the European XFEL.The prize money amounts to 2,000 Euro and the winner was invited to give a talk as part of the plenary session of the European XFEL User Meeting on 21 January 2025 in Hamburg.

For the first time, the board of the European XFEL User Organisation also awarded prizes for posters presented at this year's European XFEL Users' Meeting. Poster prizes were awarded to Daniele Rocchetti (CFEL, Hamburg), Calum Prestwood and Carolina Camarda (both European XFEL). Their topics were "Elastic scattering enhancement via transient resonances" (Rocchetti), "Tracking atomic populations and transitions in x-ray heated mid-Z transition metals" (Prestwood), and "Electronic properties of Ferropericlase (Mg,Fe)O obtained from dynamic compression experiments using DiPOLE100-X at European XFEL" (Camarda).

Patrick Heighway from Oxford University–winner of the European XFEL Young Scientist Award 2025 (photo: European XFEL / Axel Heimken).

SEASON'S GREETINGS FROM FELs OF EUROPE

Wishes you a Happy New Year!

About FELs of Europe

FELs OF EUROPE is an initiative of the ESFRI projects EuroFEL and European XFEL. It is a collaboration of all free electron laser (FEL) facilities in Europe, with the goal to meet technological and scientific challenges of these novel and rapidly developing technologies, and to provide a worldwide unique, pan-European research infrastructure that enables exploiting the full scientific potential of these unique accelerator based short-pulse light sources. The collaboration includes 14 facilities in 10 countries.

All members are either operating or developing free electron laser (FEL) facilities and/or advanced short-pulse light sources (SPS), based on accelerator technologies. Due to their unique properties, these light sources provide a step change in the ability to address research needs across the disciplines of physics, chemistry, materials, and life sciences. FELs will improve our understanding of processes on a molecular level, leading to development of new materials and methods for tomorrow's technological advancement, clean environment, sustainable energy, and health care.

FELs OF EUROPE will facilitate the enhancement and exploitation of the full scientific potential of FELs in an efficient way by promoting joint technical development and collaborating closely with users and related communities. It will promote efficient open access to the research infrastructure and optimal conditions for users.

More info at: www.fels-of-europe.eu

CURRENT AND UPCOMING CALLS FOR PROPOSALS

www.fels-of-europe.eu/user_area/call_for_proposals

UPCOMING EVENTS

The next Science@FELs conference will take place 21-25 September 2026 at Paul Scherrer Institute, Switzerland.

Registration will open April 2026.

Users' Meeting at DESY and European XFEL. 26.01.2026 to 30.01.2026
photon-science.desy.de/users_area/users'_meeting/index_eng.html

www.xfel.eu/users/user_events/users__meetings/2026_users__meeting/index_eng.html

The next PhotonDiag Workshop and Topical Workshop on Selected Problems in FEL Physics are scheduled for 2027. Place and further details will be published in due time.

Further information on Fels of Europe events can be found at www.fels-of-europe.eu

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www.fels-of-europe.eu/e212752/e214606/e216453/

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