FELs OF EUROPE NEWS 2|21

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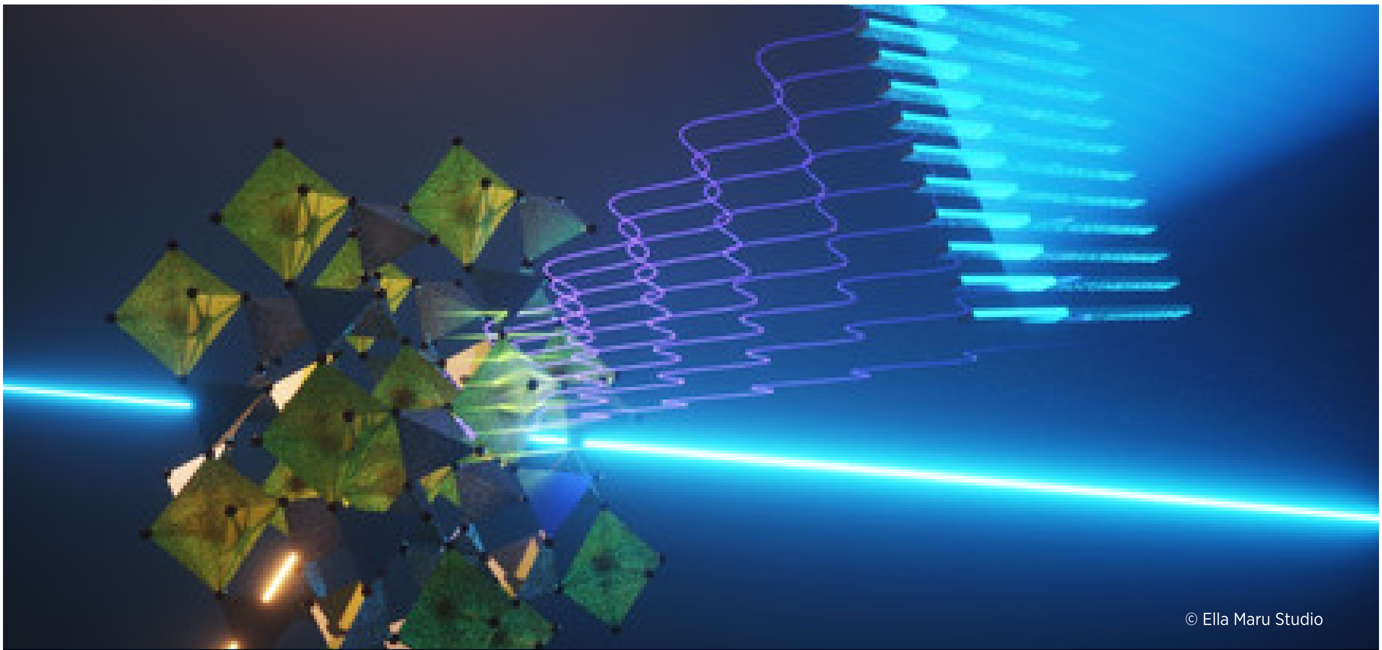

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IN THIS ISSUE

EDITORIAL

It is a great pleasure to present the July 2021 issue of the FELs OF EUROPE Newsletter! This issue is published while Europe is in a crucial moment in the fight against the COVID-19 pandemic, the vaccination campaign is progressing fairly well and we all hope for a healthier future. The different FEL facilities in Europe have contributed to scientific developments in the fight with several experiments successfully performed; this result was possible thanks to the effort in developing, in some cases, tools for remote operation, and facilitating remote access to the users, extending sample mail-in to various classes of experiments and giving priority access to SARS-CoV-2 research. In other words, our community increased its resilience in exceptional and troubled times, and an outcome of that is also the DIGITAL LEAPS initiative, to which FELs OF EUROPE has given a significant contribution.

Our collaboration even strengthened the cooperation over the last months. FELs OF EUROPE invited the Budker Institute of Nuclear Physics (BINP) in Novosibirsk to join the collaboration with its NovoFEL infrared and THz user facility and they gladfully accepted to become full member of FELs OF EUROPE. Nikolay Vinokurov is representing BINP in the Steering Committee and we are happy to host in this issue a contribution describing the activities at NovoFEL.

In our last newsletter we announced the start of a series of FELs OF EUROPE webinars dedicated to tutorials on science performed at FELs and other short-pulse facilities; the first seminar was actually held on March 1st, 2021 by Giorgio Margaritondo. It was a big success and so other two tutorials followed and there is a rich and interesting program also for the second semester of 2021; you will find more detailed information in this issue.

It is also time to prepare the FELs OF EUROPE events in 2022, which we all hope that will be back to in person meetings. We invite you to save the dates for the SCIENCE@FELs conference, which will be held from 20 to 23 September, 2022, in Hamburg, organized jointly by DESY and European XFEL, and for the PhotonDiag 2022 workshop, to be held from 4 to 7 October, 2022, in Berlin, organized by the Helmholtz Zentrum Berlin. In both cases satellite meetings will possibly be organized on the last day.

Finally, Michele Svandrlik's term as chair of the FELs OF EUROPE Steering Committee ended on June 30, 2021, after serving in this role for four years.It is our pleasure to announce that, in its meeting on June 23, the Steering Committee unanimously appointed Serguei Molodtsov as the new chair of the collaboration for the next two years. The Management Board will be completed by Manfred Helm and Marie-Emmanuelle Couprie; in the next months a smooth handover will be guaranteed.

We wish to thank Michele for his four years of chairmanship and to express our best wishes to Serguei, Manfred and Marie-Emmanuelle for a successful contribution in further developing the activities and initiatives of FELs OF EUROPE!

We hope you will enjoy the newsletter and wish you all a relaxing and healthy summer break!

Michele Svandrlik and Serguei Molodtsov

Snapshot of the hand-over toast at the end of the management board meeting on June 30th to thank Michele for his great leadership and to welcome Serguei as new chair.

FERMI

Demonstration of Plasmonic-mediated Charge Transfer in Hybrid Semiconductor-Plasmonic Photocatalyst

In the past decade, the growing attention to the ecological issue and the energy shortage together with the rising price of the rare-earth elements have brought photocatalysis into the spotlight as the green response to classic thermal catalysis. The potential applications range from green energy production e.g. solar-to-fuel conversion (water splitting, reduction of CO_2 or hydrogen production) and environmental remediation to healthcare treatments, such as photodynamic therapy. In conventional catalysis, metals like platinum, gold or silver are common materials employed as catalysts. Conversely, in photocatalysis, the photoactivated catalysts are mainly based on semiconductors. Photocatalysts based on narrow band-gap semiconductors efficiently absorb visible light, but the consequent electronic excitation promotes not only the desirable photochemical reaction, but also parasitic photodegradation processes, which compromise the chemical stability of the material. Photocatalysts based on wide-gap semiconductors do not possess a large absorption cross-section in the visible range. Furthermore, they show poor charge separation, high charge-recombination rates caused by surface defects and they are prone to the formation of photoinduced small polarons, which inhibit the carriers mobility in the material. The aforementioned intrinsic properties strongly affect the efficiency of bulk semiconductors as catalysts activated by direct exposition to sunlight. To overcome such limitations, the strategies that have been explored involve structural and chemical engineering in order to tune the properties of semiconductor materials in a controlled fashion (visible light sensitization, chemical stability, carriers mobility). In the last decade, it was explored an alternative solution: integrating the semiconductor with metallic nanostructures to form hybrid semiconductor-plasmonic heterojunctions [1]. In this way, it is possible to enhance the activity of the semiconductor using the strong interaction of light with metallic nanostructures. This effect, called localized surface plasmon resonance (LSPR), is caused by the coherent and collective excitation of surface electrons of the nanostructures which oscillate with a resonant frequency that closely depends on the size, geometry, dielectric environment and distance of the nanostructures. Thus, the coupling of plasmonic nanostructures with catalyst are particularly promising to extend the light absorption range of semiconductors because metal nanostructures act as tunable light antennas across the full solar radiation spectrum. This field, called plasmonic photocatalysis, was triggered for the first time in the mid-2000s [2] and it has been receiving increasing attention during the last decade thanks to the increasing ability in the designing of nanostructures and to the development of time-resolved spectroscopies. Time-resolved characterization of this heterojunction excitation is fundamental to understand the plasmonic enhancement processes. The mechanisms involved in the conversion steps are diverse and still largely unexplored on the experimental side, due to the challenges posed by the investigation of interfacial effects occurring on a wide range of time scales. Theoretical descriptions typically identify three main groups of mechanisms for LSPR energy/charge transfer: electron transfer processes, dominating below 100 fs, photo-thermal conversion, which occurs on the ps time scale, and electric field enhancement which prevails for NPs with diameters above a few tens of nm.

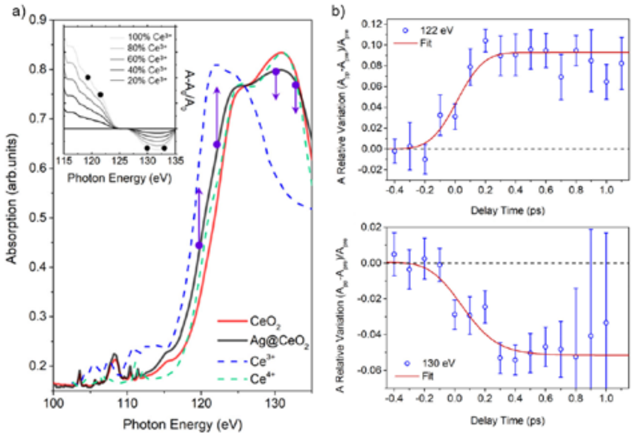

Fig 1 a.) Ce $N_{4,5}$ XAS absorption spectra measured in transmission mode for CeO_2 (solid red line) and Ag@CeO2 (solid black line) samples. The reference spectra of Ce^{4+} (dashed green line) and Ce^{3+} (dashed blue line) samples are also reported. The inset reports the relative variation of the absorption during Ce reduction ($Ce^{4+} \rightarrow Ce^{3+}$). Purple points, and the black points in the inset, indicate the selected FEL energies used to probe the variations of absorption. b. Relative variation of absorption at 122 eV (top) and 130 eV (bottom) as a function of pump-probe delay time and corresponding fit (red curve).

Recently we investigate a model system of silver nanoparticles embedded in a thin film of CeO_2 using pump-probe x-ray absorption spectroscopy at the EIS-TIMEX endstation selecting probe energies across the Ce N4,5-edge. X-ray absorption spectroscopy (XAS) represents a valuable tool to obtain element-specific information with very high sensitivity to the electronic structure of the individual elements present in the system [3]. This peculiarity of XAS provides a fundamental piece of information that is not accessible via ultrafast spectroscopies in the ultraviolet, visible and infrared range, which are sensitive to probe delocalized valence and conduction bands. The unique performance of FERMI FEL combining the possibility of using ultrashort light pulses with fine-tuneable photon energy within 20-300 eV and remarkable spectral stability and purity has allowed us to investigate the response of hybrid semiconductor-plasmonic photocatalyst. In our work, published in the ACS journal Nano Letters, we have demonstrated the capability of FELs to explore dynamic processes in functional materials. We observed how silver nanoparticles embedded in the CeO_2 catalyst transfer electrons to the oxide through an ultrafast (less than 200 fs) and highly efficient mechanism. The observed charge transfer is associated with the ultrafast changes (< 200 fs) of the Ce $N_{4,5}$ absorption edge (Figure 1a and b), compatible with the cerium oxidation state variation, $Ce^{4+} \rightarrow Ce^{3+}$, as represented in Figure 1a) triggered by the selective excitation of the silver nanoparticles with a visible pump (430 nm or 2.9 eV).

Stefano Pelli Cresi

Original publication:
Pelli Cresi, J. S. Principi, E.; Spurio, E. Catone, D. O'Keeffe, P.Turchini, S.Benedetti, S. Vikatakavi, A. D'Addato, S. Mincigrucci, R. Foglia, L. Kurdi, G. Nikolov, I. P. De Ninno, G. Masciovecchio, C. Nannarone, S. Kopula Kesavan, J. Boscherini, F. Luches, P. Ultrafast Dynamics of Plasmon-Mediated Charge Transfer in Ag@CeO2 Studied by Free Electron Laser Time-Resolved X-Ray Absorption Spectroscopy. Nano Lett. 2021, 21 (4), 1729–1734. https://doi.org/10.1021/acs.nanolett.0c04547.

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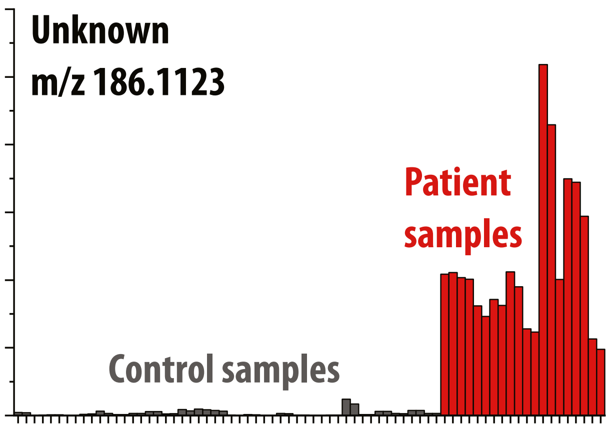
[1] Atwater, H. A.; Polman, A. Plasmonics for Improved Photovoltaic Devices. Nat. Mater. 2010, 9 (3), 205–213. https://doi.org/10.1038/nmat2629
[2] Furube, A.; Du, L.; Hara, K.; Katoh, R.; Tachiya, M. Ultrafast Plasmon-Induced Electron Transfer from Gold Nanodots into TiO2 Nanoparticles. J. Am. Chem. Soc. 2007, 129 (48), 14852–14853. https://doi.org/10.1021/ja076134v.
[2] Cresi, J. S. P.; Spadaro, M. C.; D'Addato, S.; Valeri, S.; Benedetti, S.; Bona, A. D.; Catone, D.; Mario, L. D.; O'Keeffe, P.; Paladini, A.; Bertoni, G.; Luches, P. Highly Efficient Plasmon-Mediated Electron Injection into Cerium Oxide from Embedded Silver Nanoparticles. Nanoscale 2019, 11 (21), 10282–10291. https://doi.org/10.1039/C9NR01390C

FELIX Laboratory

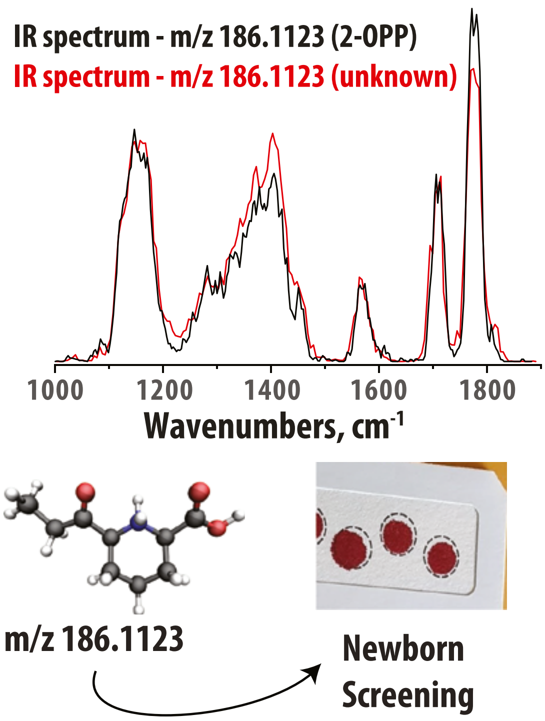
New biomarkers for pyridoxine-dependent epilepsy identified using the FELIX lasers

Researchers at the Translational Metabolic Laboratory (Radboudumc) and at HFML-FELIX laboratory (Radboud University) have discovered novel biomarkers for pyridoxine-dependent epilepsy (PDE-ALDH7A1) using their unique combination of untargeted metabolomics and infrared ion spectroscopy - these results have recently been published in the Journal of Clinical Investigation[1].

Pyridoxine-dependent epilepsy is an inborn error of metabolism that results in severe epilepsy in newborns. The biochemical basis of this condition is a secondary inactivation of vitamin B6 which functions as an important cofactor for many enzymatic processes in the body. While vitamin B6 supplementation mostly resolves epilepsy in patients and lysine reduced diet therapy improves developmental outcomes, these treatments must be started in the first days of life to be effective. Ideally, early diagnosis in newborn screening would allow for the earliest possible detection in patients and the initiation of personalized treatment therapy. In this direction, the research began by searching for molecular biomarkers that would be suitable for this purpose. Using state-of-the-art



An unknown molecular feature (m/z 186.1123) was identified as elevated in the body fluids of PDE patients while absent in the body fluids of controls. The molecular structure of m/z 186.1123, however, could not be elucidated and was of unknown biochemical relevance.



The molecular structure of m/z 186.1123 was determined comparing IR spectra measured by IRIS using FELIX to quantum-chemically calculated IR spectra of candidate molecular structures and finally confirmed using an in-house synthesised reference compound. This directly enabled the development of a newborn screening protocol for PDE based on these novel metabolites.

liquid chromatography/mass spectrometry-based metabolomics techniques, a new molecular feature of mass-to-charge ratio (m/z) 186.1123 was first detected in PDE patient body fluids that was not found in control samples. However, the molecular structure of this detected compound was not possible to identify using even these advanced analytical techniques.

Thus, to identify this new molecular feature, the research team turned to infrared ion spectroscopy (IRIS) using FELIX and determined it to be 2-oxopropylpiperidine-2-carboxylic acid (2-OPP) – a previously unknown human metabolite. Interestingly, 2-OPP was found to be a highly diagnostic biomarker for PDE and was also shown to be suitable for inclusion in common newborn screening protocols.

Several biochemical and pathophysiological implications were also discovered around 2-OPP; it was discovered that 2-OPP accumulates in the brain tissues of patients and ALDH7A1 knock-out mice, and that it causes epilepsy-like behavior in a zebrafish model system. Together, these findings point to 2-OPP itself being a possible contributor to the incompletely understood aspects of neurotoxicity in PDE ALDH7A1. Furthermore, 2-OPP levels appears to increase upon ketosis which translates directly into clinical practice by emphasizing the importance of avoiding catabolism in PDE patients.

Jonathan Martens and Karlien Coene

Original Publication:
Engelke U, et al. Untargeted metabolomics and infrared ion spectroscopy identify biomarkers for pyridoxine-dependent epilepsy. Journal of Clinical Investigation, Accepted Manuscript, 2021, https://doi.org/10.1172/JCI148272.

PSI

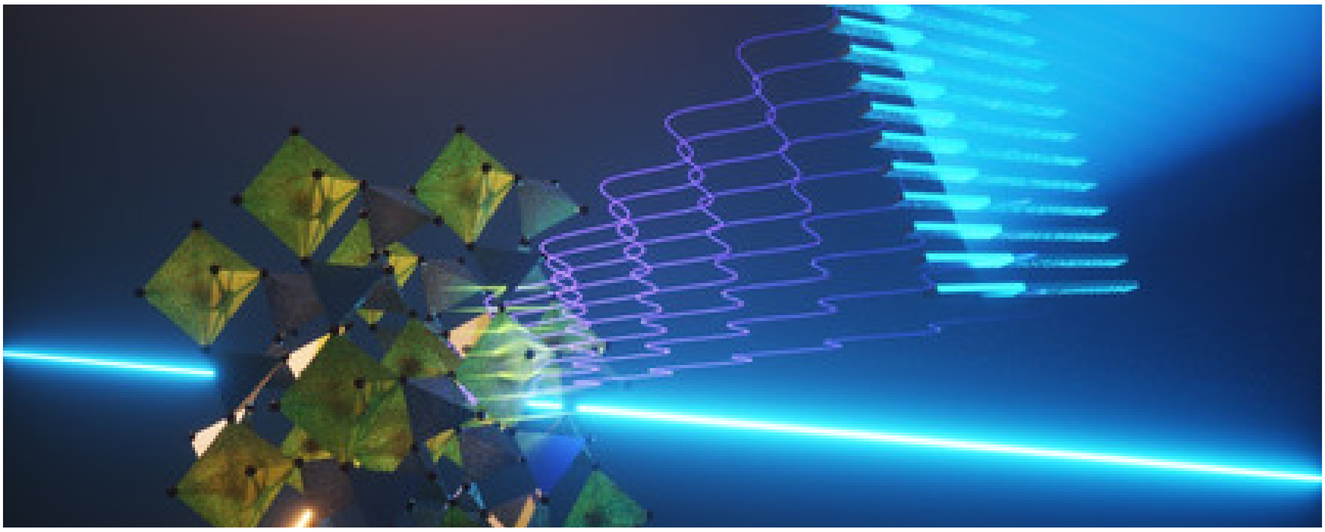
A uniquely sharp X-ray view

Researchers at the Paul Scherrer Institute PSI have succeeded for the first time in looking inside materials using the method of transient grating spectroscopy with ultrafast X-rays at SwissFEL. The experiment at PSI is a milestone in observing processes in the world of atoms.

The structures on microchips are becoming ever tinier; hard disks write entire encyclopedias on magnetic disks the size of a fingernail. Many technologies are currently breaking through the boundaries of classical physics. But in the nanoworld, other laws apply – those of quantum physics. And there are still many unanswered questions: How does heat actually travel through a semiconductor material at the nanoscale? What exactly happens when individual bits are magnetised in a computer hard disk, and how fast can we write? There are still no answers to these and many more questions mainly because current experimental techniques cannot look deeply and precisely enough into the materials and because some processes take place far too quickly for conventional experimental methods. But if we want to push ahead with technical miniaturisation, we need to understand such phenomena at the atomic level.

At its core, this is a method called transient grating spectroscopy. Spectroscopy is a proven set of methods used by physicists to obtain information about a material, such as the chemical elements and compounds it consists of, its magnetic properties, and how atoms move within it. In the particular variant called transient grating spectroscopy, the sample is bombarded with two laser beams that create an interference pattern. A third laser beam is diffracted at this pattern, creating a fourth beam that contains the information about the sample's properties.
Lasers can look inside a sample only with resolution limited to hundreds of nanometres. To go beyond this, X-rays are needed. PSI researcher Cristian Svetina, together with Jeremy Rouxel and Majed Chergui at EPFL in Lausanne, Keith Nelson at MIT in the USA, Claudio Masciovecchio at Fermi FEL in Italy, and other international partners have now succeeded for the first time in making transient grating spectroscopy accessible to an X-ray laser, using very hard X-rays with an energy of 7.1 kiloelectronvolts, which corresponds to a wavelength of 0.17 nanometres, or about the diameter of medium-sized atoms. The advantage: For the first time, it is possible to look inside materials with a resolution down to individual atoms as well as with ultrashort exposure times of fractions of femtoseconds (one millionth of a billionth of a second), which even allows videos of atomic processes to be recorded. In addition, the method is element-selective, meaning that one can selectively measure specific chemical elements in a mixture of substances. The method complements well established techniques such as inelastic neutron and X-ray scattering, adding better resolution in terms of both time and energy.

In practice, the experimental setup looks like this: SwissFEL sends a beam with a diameter of 0.2 millimetres, consisting of ultrashort X-ray pulses, onto a transmission phase grating made of diamond, which looks like a fine comb under the microscope. Diamond is used because it is not destroyed even by high-energy X-rays. It was made especially for this experiment by Christian David of the Laboratory for Micro and Nanotechnology at PSI. The spacing between the teeth of the comb is two micrometres, but this can go down to nanometres if needed. They break the X-ray beam into fine partial beams that overlap behind the grating, thus creating the transient grating diffraction pattern. Behind the grating, one-to-one images of the grating can be observed, repeated at regular intervals – so-called Talbot planes. If you place a sample in one of these planes, some atoms within it become excited, just as if it was sitting at the location of the grating. Only the atoms that "see" the X-rays in this periodic modulation are excited, while the neighbours that don't experience the irradiation remain in the ground state. This is the chief attraction of the method, since it enables researchers to selectively excite characteristic domains of interest.



Grafic: Ella Maru Studio

Excitation of the atoms alone, however, does not provide any information. For this, a kind of camera with a flash is needed to briefly expose the sample. In transient grating spectroscopy, this is done by a laser that targets the sample at an angle and shoots images with a minimal time delay to the X-ray beam from SwissFEL at the experimental station Bernina. The information comes out of the back of the sample and hits a detector that records the image. Initial experiments have shown one advantage of the method: It does not produce any unwanted background signal. "If the atoms are excited, you see a signal; if they are not excited, you see nothing," Svetina explains. This is extremely valuable when measuring samples that emit only weak signals and that cannot be seen with other techniques where a background obscures the signal.

However, the researchers have not yet taken the final step. So far, only the beam that excites the sample is an X-ray beam. The flash of the camera still comes from a laser, so it is visible light. The pinnacle would be reached if that too were an X-ray beam. Svetina: "We want to take this final step in the course of the year." And they have additional support: SLAC's LCLS and the PULSE Institute, both at Stanford in California, the RIKEN SPring-8 centre in Japan, and DESY's FLASH in Germany have joined the collaboration team.

Bernd Müller

Original publication:
Hard X-ray Transient Grating Spectroscopy on Bismuth Germanate
Jeremy R. Rouxel, Danny Fainozzi, Roman Mankowsky, Benedikt Rosner, Gediminas Seniutinas, Riccardo Mincigrucci, Sara Catalini, Laura Foglia, Riccardo Cucini, Florian Doring, Adam Kubec, Frieder Koch, Filippo Bencivenga, Andre Al Haddad, Alessandro Gessini, Alexei A. Maznev, Claudio Cirelli, Simon Gerber, Bill Pedrini, Giulia F. Mancini, Elia Razzoli, Max Burian, Hiroki Ueda, Georgios Pamfilidis,Eugenio Ferrari, Yunpei Deng, Aldo Mozzanica, Philip Johnson, Dmitry Ozerov, Maria Grazia Izzo,Cettina Bottari, Christopher Arrell, Edwin James Divall, Serhane Zerdane, Mathias Sander, Gregor Knopp,Paul Beaud, Henrik Till Lemke, Chris J. Milne, Christian David, Renato Torre, Majed Chergui, Keith A.Nelson, Claudio Masciovecchio, Urs Staub, Luc Patthey and Cristian Svetina

Nature Photonics, 22.04.2021
DOI: 10.1038/s41566-021-00797-9

Proposal for DALI - Dresden Advanced Light Infrastructure

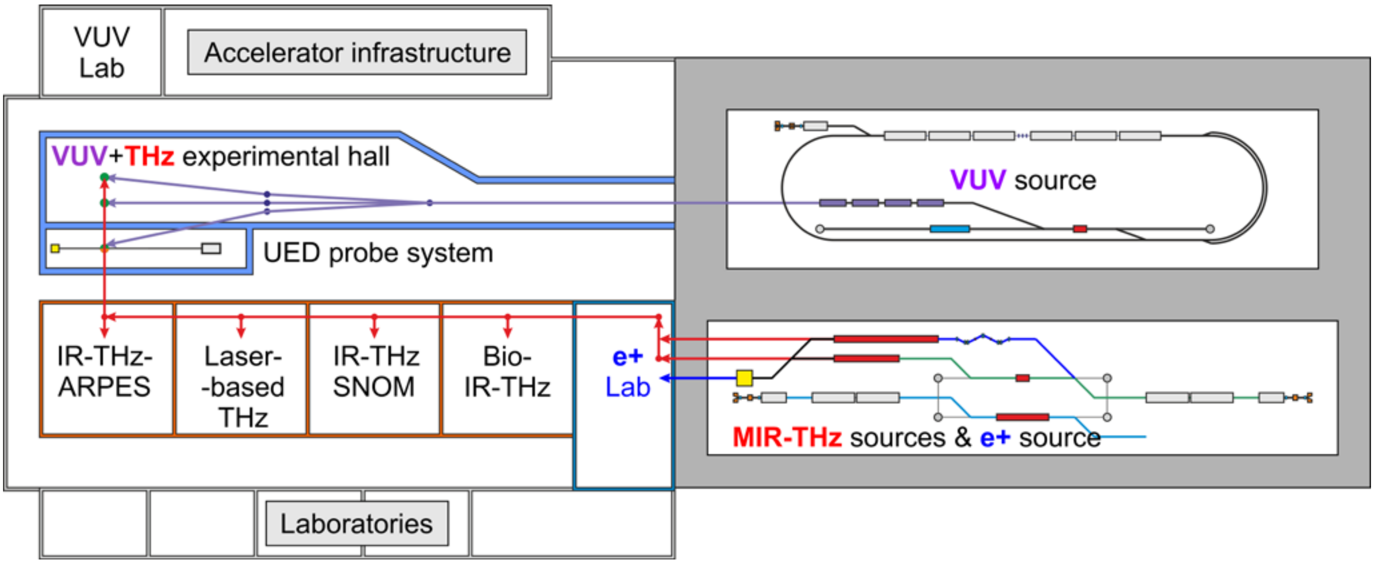


Fig. 1: Envisioned layout of DALI (conception and drawing: Pavel Evtushenko). The labels for the user labs are only examples.

The Dresden Advanced Light Infrastructure (DALI) is being designed as a successor to the ELBE facility, which has been operated since 2004. DALI will be the ultimate THz source, spanning the entire range from 0.1 to 30 THz (wavelength 3 mm to 10 µm) with extremely intense and flexible – with regard to repetition rate, bandwidth, polarization, pulse form, and pulse delays – radiation pulses. This will be complemented by a coherent VUV source between 5 and 25 eV photon energy (wavelength 250 – 50 nm), therefore enabling new research directions beyond condensed matter physics. These include, e.g., discovering mechanisms and exploring the dynamics of chemical reactions, which in turn would open the possibility of controlling chemical reaction pathways, in gas phase, in solution or at surfaces, or resolving complex dynamics of biomolecular processes initiated by strong-field pulses. Strong-field phenomena in condensed matter will of course remain an important research area, e.g. for coherently controlling collective phenomena and new quantum phases.

A preliminary conceptual design report (preCDR) has been completed in 2020 with input from many potential user groups. Presently HZDR staff is working on the full CDR, which will be followed by a detailed technical design report. Subsequent inclusion in the German National Roadmap for Research Infrastructures would then guarantee the funding for this 200 M€ investment.
The basic layout of the new DALI facility is shown in Figure 1. Two superconducting CW RF accelerators generate electron beams of 300 MeV and 50 MeV, respectively. VUV and THz radiation is generated in appropriate undulators and guided into the user laboratories. The radiation will be available to users in individual experimental stations. In addition to the photon sources, a high-intensity positron source for materials research and an ultrafast electron diffraction (UED) facility are also envisioned.

DALI – short characteristics
The Dresden Advanced Light Infrastructure (DALI) is designed as an integrated, accelerator-based THz and VUV source that covers the frequency range from 0.1 THz to 30 THz with coherent, semi-narrowband (≈10% spectral bandwidth) few-cycle radiation pulses and the VUV spectral range from 50 nm to 250 nm with intense, quasi-transform-limited sub-picosecond pulses. Driven by a superconducting 50 MeV electron linear accelerator (LINAC), the THz source will provide radiation with high pulse energy (100 µJ – 1 mJ) and high repetition rate (100 kHz up to 1 MHz), an unprecedented combination of both parameters being a factor of at least 100 larger compared to what is available to date. The VUV FEL source will be based on a 300 MeV superconducting accelerator, implemented as a 150 MeV recirculation LINAC, and provide up to 30 µJ pulse energy at 0.1 – 5 MHz repetition rate. With a sub-100 fs synchronization, this combined, worldwide unique THz/VUV facility will open a wealth of new avenues for investigations of nonlinear and high-field-driven phenomena.

Manfred Helm

MAX IV

Design of a FEL for MAX IV

A conceptual design of a soft X-ray FEL (the SXL) has been completed for the MAX IV Laboratory. The SXL project was initiated by the Swedish user community with a request for enhanced capabilities at MAX IV to deliver coherent ultrashort pulses in the soft X-ray range. The frame was set for the 1-5 nm wavelength range and to make use of the already operating 3 GeV linear accelerator at the facility.

A Conceptual Design Study was initiated with funds from the Knut and Alice Wallenberg Foundation and supported by the MAX IV Laboratory, Uppsala University, Stockholm University, The Royal Institute of Technology (KTH), Lund University and the Lund Laser Centre (LLC). The final report was ready in March 2021 and is available to download from https://www.maxiv.lu.se/soft-x-ray-laser/ .

The SXL is envisaged as an extension to the current MAX IV buildings (see fig 1) and is planned such that a future expansion also into a hard X-ray FEL, driven by an extended linac at higher electron energies, can be fitted.

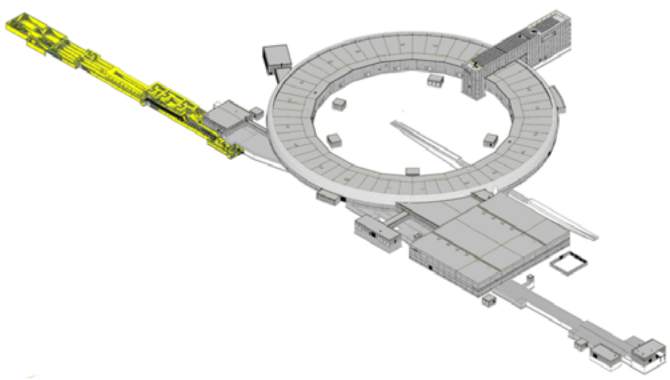


Fig 1. The SXL extension, in yellow, housing the undulators and beamlines.

The science

The SXL with a target in the soft X-ray wavelength range 1-5 nm, specialized in producing very short pulses, housing ample pump-probe capabilities, 2 pulse-2 colour FEL pulses with full polarization control, will open up new fields of research in ultrafast science. The Science case was elaborated by more than 100 Swedish prospective users in connection to a workshop in Stockholm (see more at https://indico.maxiv.lu.se/event/141/ from where the original Science case can also be downloaded).

Four scientific areas have been put in focus:

- atomic, molecular and optical physics (AMO)
- chemistry
- condensed matter
- life science

In the field of AMO, the fundamentals of ultrafast charge dynamics will be possible to study in atoms and molecules, crucial for several chemical, biological and physical processes in larger molecular systems such as photosynthesis and charge transfer through DNA.

In chemistry, the SXL will enable to probe how molecules evolve on timescales of electronic and nuclear motion. Specific research fields include heterogeneous catalysis and photovoltaics, both of crucial relevance to attaining an energy sustainable society.

For condensed matter, a number of fields will take advantage of the SXL, including the study of ultrafast magnetism with the understanding of fundamental processes such as ultrafast demagnetization. In this context, the full polarization control allowed by the SXL will be a key feature.

Nanoscale imaging techniques in life sciences, with imaging of large heterogeneous objects such as living cells and X-ray scattering in protein solutions, is another field that will make advances through the use of the SXL.

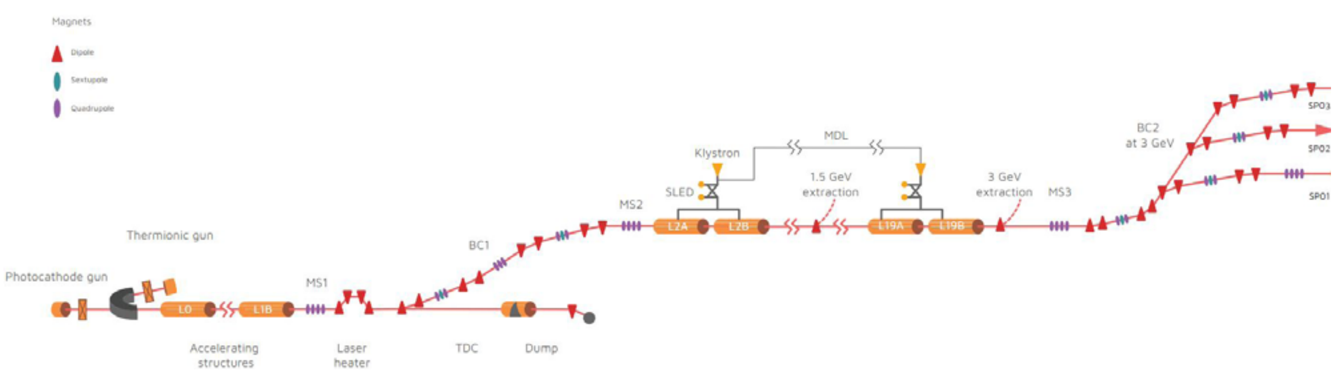


Fig 2. The MAX IV linac for the SXL project. Electron guns, linac and bunch compressors are already in operation (not to scale).

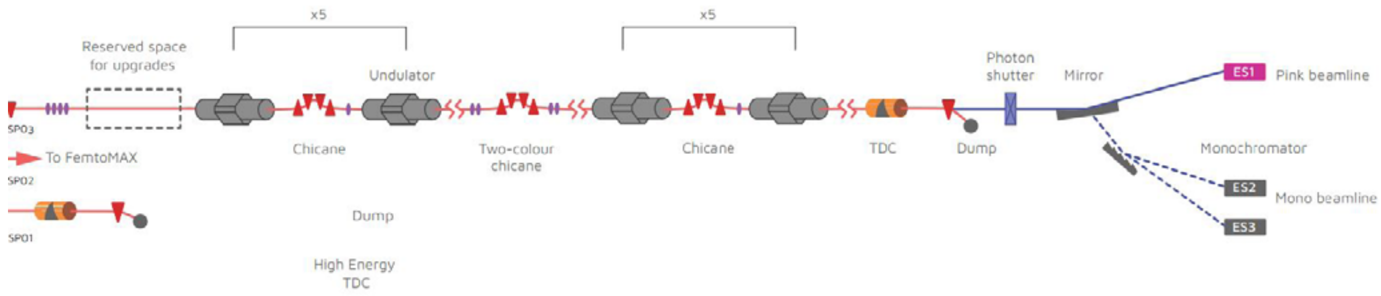


Fig 3. The undulator chain, photon beam transport and beamlines (not to scale)

Overall layout

The MAX IV linac is today used as injector for the 3 GeV storage ring and drives the Short Pulse Facility and will continue to do so. Routine operation of low emittance pulses with pulse lengths compressed below 100 fs is already established (see figure 2). To the linac a new building housing twenty helical undulators, two beamlines (pink and mono) and their experimental stations is added (see figure 3).

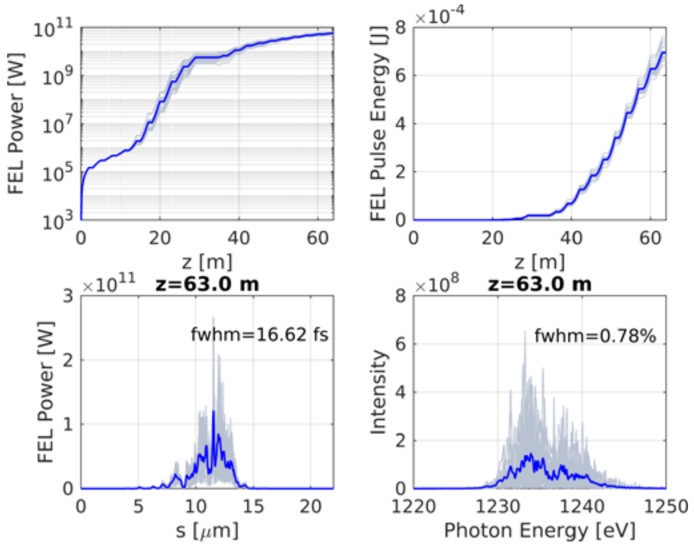


Fig 4. SXL performance in standard SASE operation mode at 1 nm (1250 eV).

The FEL

The FEL is designed to be flexible for future upgrades, while fulfilling the demands put forward in the science case for the SXL. The linac system can provide very short electron pulses (down towards 1 fs), however a standard SASE mode is assumed to be the main focus initially (see fig 4). The layout consists of twenty 2 m long APPLE-X type undulators. The optics is a FODO lattice which also includes chicanes for phase shifting and medium delay options between every undulator. These chicanes will give the possibility

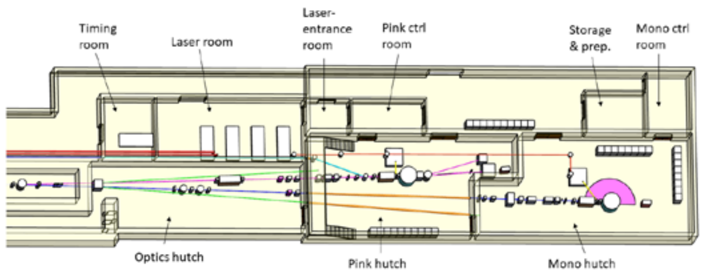


Fig 5. Layout of the beamline and experimental area.

to implement seeding by HBSASE and develop schemes for sub fs pulses. After ten modules a stronger chicane is introduced to serve both for 2 pulse production and preparing for seeding using self-seeding with a monochromator system. The system is also prepared to house seeding through Echo Enabled Harmonic Generation (EEHG).

Beamlines

The SXL design has grown out from a science case taking advantage of the installations already in operation at MAX IV. With the design study the SXL has been put on the MAX IV strategic agenda and work is now continuing into technical studies and preparations for funding of the build-up of the complete SXL. In the continued work an updated science case is a key element in the process forward.

Conclusion

The SXL design has grown out from a science case taking advantage of the installations already in operation at MAX IV. With the design study the SXL has been put on the MAX IV strategic agenda and work is now continuing into technical studies and preparations for funding of the build-up of the complete SXL. In the continued work an updated science case is a key element in the process forward.

Sverker Werin

NovoFEL joins FELs of Europe: The Novosibirsk free electron laser facility

The Novosibirsk FEL facility [1] includes three FELs [2] operating in the terahertz, far-, and mid- infrared spectral ranges, as it is shown in Fig. 1.

It has rather long history, but its potential has not been fully revealed so far. The first FEL of this facility has been operating for users of terahertz radiation since 2004. It remains the world's most powerful sources of coherent narrow-band radiation in its wavelength range (90 – 340 μm). The second FEL was commissioned in 2009. Now it operates in the range of 35 – 80 μm, but we plan to replace its undulator soon with a variable-period one [3], shown in Fig. 2, and its short wavelength boundary will be shifted down to 15μm.
The average radiation power of the first and second FELs is up to 0.5 kW and the peak power is about 1MW. The third FEL was commissioned in 2015 to cover the wavelength range of 5 – 20μm. Its undulator comprises three separate sections. Such lattice is suited very well to demonstrate the new off-mirror way of radiation outcoupling in an FEL oscillator (so called electron outcoupling [4]), which we also plan for near future. We also intend to improve the accelerator injection system. As a result, the average electron beam current and consequently the radiation power of all the three FELs will increase.

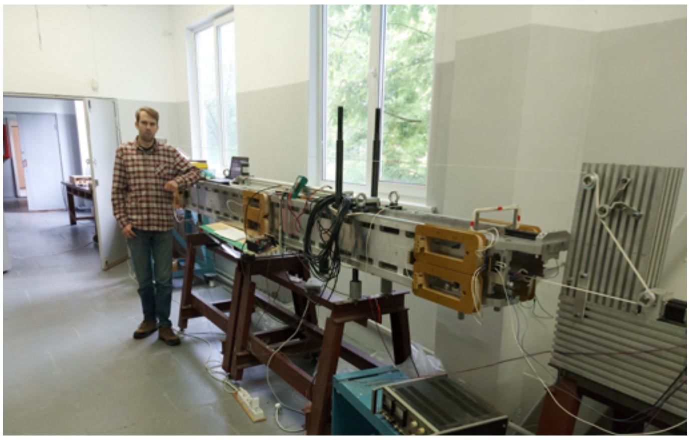


Fig 2. Engineer Yaroslav Gorbachev making final tests of the variable-period undulator.

Undulators of the FELs are installed on the first, second, and fourths orbits of the multi-turn energy recovery linac (ERL). The scheme of the Novosibirsk ERL with three FELs is shown in Fig. 1. The Novosibirsk ERL is the first multi-turn ERL in the world. Its peculiar features include the normal-conductive 180 MHz accelerating system, the DC electron gun with the grid thermionic cathode, three operation modes of the magnetic system, and rather compact (6×40 m2) design.

The NovoFEL accelerator has a rather complex design. One can treat it as three different ERLs that use the same injector and the same linac. Starting from low-energy injector, electrons pass several times through accelerating radio frequency (RF) structure (main linac). After that, they lose part of their energy in FEL undulator. The used electron beam is decelerated in the same RF structure, and the low-energy electrons are absorbed in beam dump.

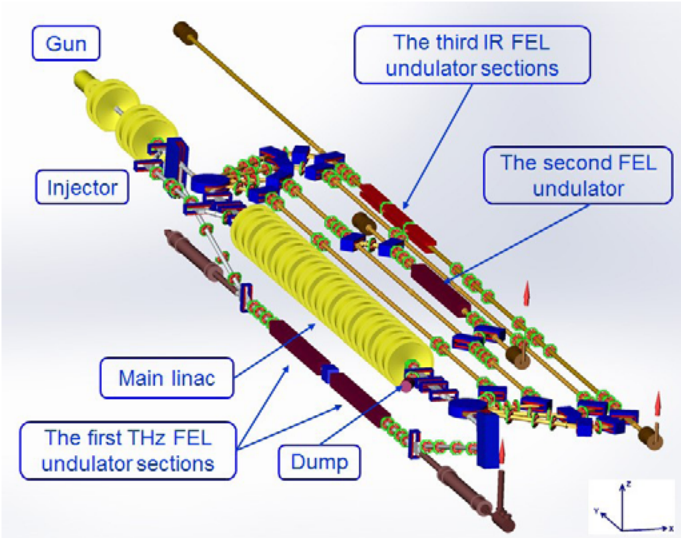


Fig 1. The Novosibirsk ERL with three FELs (top view).

The first ERL of the facility has only one orbit. It is placed vertically (see Fig. 1). The second and the third ERLs are two and four-turn ERLs, respectively. Their beamlines are placed horizontally. The injector is common for all the ERLs. It includes an electrostatic gun and one bunching and two accelerating cavities. The gun voltage is 300 kV, which is applied to the grid-controlled thermionic cathode. The gun provides 1-ns bunches with a charge of up to 1.5 nC, a normalized emittance of about 20 μm, and a repetition rate of zero to 22.5 MHz. After the 180.4-MHz bunching cavity, the bunches are compressed in the drift space (about 3 m long), accelerated up to 2 MeV (total energy) in the two 180.4-MHz accelerating cavities, and injected by the injection beamline and the chicane into the main accelerating structure of the ERL (see Fig. 1). The accelerating structure consists of 16 normal-conducting RF cavities, connected to two waveguides. The operation frequency is 180.4 MHz. Such a low frequency allows operation with long bunches and high currents.

TABLE 1. Basic accelerator and FEL parameters

	1st FEL	2nd FEL	3rd FEL
Electron energy , MeV	8.5 – 13.4	21 -22.8	39 - 42
Peak current, A	10	30	50
Average current, mA	20	10	4
Wavelength, μm	90 - 340	37 - 80	8 - 11
Average radiation power, kW	0.5	0.5	0.1

Table 1. Basic accelerator and FEL parameters

The choice of the working ERL and corresponding FEL is determined by commutation of bending magnets. The first FEL is installed under the accelerating RF structure. Therefore, after the first passage through the RF structure, the electron beam with an energy of 11 MeV is turned by 180 degrees in the vertical plane. After being used in the FEL, the beam returns to the RF structure in the decelerating phase. In this mode, the ERL operates as a single-orbit machine.

For operation with the second and third FELs, two round magnets (a spreader and a recombiner) are switched on. They bend the beam in the horizontal plane, as shown in Fig. 1. After four passes through the RF accelerating structure, the electron beam gets in the undulator of the third FEL. The energy of electrons in the third FEL is about 42 MeV. The used beam is decelerated four times and goes to the beam dump.

If the four magnets on the second track (see Fig. 1) are switched on, the beam with an energy of 20 MeV passes through the second FEL. After that, it enters the accelerating structure in the decelerating phase due to the choice of the length of the path through the second FEL. Therefore, after two decelerations the used beam is absorbed in the beam dump.

It is worth noting that all the 180-degree bends are achromatic (even second-order achromatic on the first and second horizontal tracks), but non-isochronous. That enables beam longitudinal "gymnastics" to increase the peak current in the FELs and to optimize deceleration of the used beam.
The basic accelerator and FEL parameters for all FELs are listed in Table 1.

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http://accelconf.web.cern.ch/f07/PAPERS/TUAAU02.PDF
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[6] V. N. Volkov et al., Phys. Procedia, 84, 86 (2016). https://doi.org/10.1016/j.phpro.2016.11.015.

The possibilities for users to conduct their experiments have been significantly expanded recently by implementation of the new operation mode [5]. In this mode, single or periodic radiation macropulses of duration of down to 10 μs can be obtained. The radiation power modulation is done electronically by controlling the FEL lasing, and it can be triggered by an external signal. The current of the Novosibirsk ERL is now limited by the electron gun. A new RF gun was built and tested recently. It operates at a frequency of 90 MHz. An average beam current of more than 100 mA was achieved [6]. We plan to install this gun in the injector, the existing electrostatic gun kept there. The RF gun beamline has already been manufactured and assembled on the test setup. The beam parameters were measured after the first bending magnet and at the beamline exit.

Nikolay Vinokurov

COLLABORATION ACTIVITIES

Save the date Science@FELs 2022 and PhotonDiag 2022

The International Science@FELs Conference will take place from 20-23 September, 2022 organised by DESY and the European XFEL. Following the first ever fully online Science@FELs 2020 also organized by DESY and European XFEL, we hope to be able to finally see you again in person in Hamburg.

Science@FELs is organised as a regular biannual activity of FELs OF EUROPE in collaboration also with LaserLab Europe. It focusses on scientific highlights achieved during the last years at FELs and laser facilities world-wide. The meeting will bring together scientists from all areas active in research with FELs, featuring invited and contributed talks, poster sessions, tours of the European XFEL and FLASH and tutorials for PhD students and young postdocs.

The 6th FELs OF EUROPE workshop on FEL Photon Diagnostics, Instrumentation and Beamline Design, PhotonDiag 2022, will take place at the Helmholtz-Zentrum Berlin from 4-7 October 2022, following a virtual format in 2020 organized by the Paul Scherrer Institute. The PhotonDiag workshop – hopefully in person as well - concentrates on new developments and advances in the field of photon diagnostics and FEL beamlines design, X-Ray-Optics, ranging from new devices for online measurements, to data processing and machine learning, new experimental challenges and future developments for next generation X-ray light sources.

Elke Ploenjes-Palm, Serguei Molodtsov,
Frank Siewert, Jens Viefhaus

FELs of Europe Tutorials

FELs of Europe, together with the LEAPS Strategy Group SG2 on FELs, has started a regular online tutorial series for young scientists in the field of science with FELs inviting distinguished scholars in the field. Starting in the second half of 2021, Laserlab Europe will join in and suggest speakers from their network on a regular basis. The tutorials, which are organized by DESY and European XFEL, take place on the first Monday of the month at 17:00 (CET).

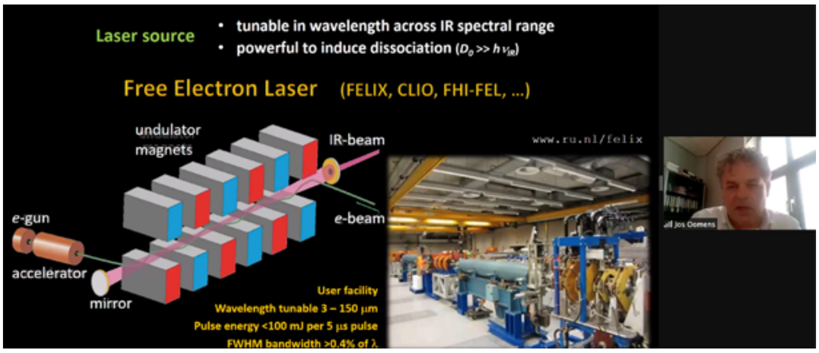
At the Science@FELs 2020 conference, the first online Science@FELs organized by DESY and European XFEL, a small number of focus tutorials led by eminent FEL scientists and specifically addressing younger members of the FEL community were well received in the community. The tutorials introduce hot topics in the field of FEL science with larger depth than usually possible in conference talks. Based on the very positive reception of these tutorials, Fels of Europe has started the online tutorial series for scientists from all over the world on March 1, 2021.

List of speakers for 2021:

- 1 March 2021 - Giorgio Margaritondo (EPFL): "FEL basics, generation and applications"
- 3 May 2021 - Jon Marangos (Blackett Laboratory Extreme Light Consortium, Imperial College London): "X-rays for Few to Sub-Femtosecond Measurements"
- 5 July 2021 - Jos Oomens (Radboud University, FELIX Laboratory): "FEL based infrared ion spectroscopy: new opportunities in physical and analytical chemistry"
- 6 September 2021 - Nina Rohringer (DESY): tba
- 4 October 2021 - Anders Nilsson (Stockholm University): tba
- 8 November 2021 - Francesca Calegari (DESY): tba
- 6 December 2021 – speaker from Laserlab Europe

Please register for the events at: www.desy.de/foetutorials

Elke Ploenjes-Palm

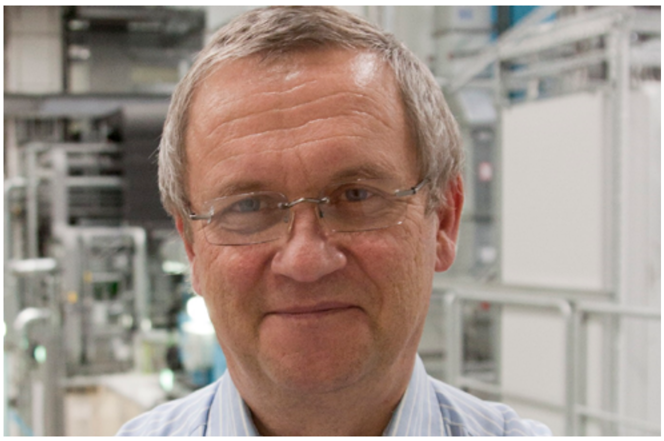


Snapshot during the FELs of Europe Tutorial on July 5th.

Serguei Molodtsov takes over as FoE chairman

European XFEL scientific director Serguei Molodtsov has been appointed chairman of the FELs OF EUROPE (FoE). A pan-European body, FoE is a collaboration of all free electron laser (FEL) and short-pulse facilities in Europe. Setting up this collaboration was an initiative led by the ESFRI projects (EuroFEL) and European XFEL, and the collaboration currently lists 14 facilities in 10 countries as partners. "FELs or free electron lasers are rapidly evolving, novel technologies and the aim of the FoE collaboration is to provide a pan-European platform for the research community to fully exploit the scientific potential of these unique accelerator based light sources," says Molodtsov.

Molodtsov's chairmanship is slated for a 2-year term. "I want to focus on coordination of networking activities of the FoE members both within the collaboration and with other large-scale facilities," he says. "It is also very important to develop a common approach when it comes to interacting with user communities and the European synchrotron and FEL user organization (ESUO)," he adds.



Serguei Molodtsov has been appointed chairman of the FELs OF EUROPE (FoE)

ESUO – update on activities and developments

The European Synchrotron and FEL User Organisation (ESUO) is very pleased to report on its news and activities related to the synchrotron and FEL user community. ESUO would like to warmly thank FELs of Europe for giving this opportunity.

ESUO represents about 25 000 users of the LEAPS facilities and its vision is to support a thriving (European) synchrotron and FEL user community, working towards equal opportunities for access and participation for all scientists based solely on the scientific merit of their ideas1.

On July 2nd, 2021, the 15th ESUO General Assembly meeting took place as an online event. ESUO delegates from 25 ESUO member countries, together with participants from the CALIPSOplus project and LEAPS (partially) took part in the ESUO webinar. During the meeting, ESUO presented proposed ESUO medium-term activities as part of the H2020 European CALIPSOplus[2] project and LEAPS[3], as elaborated by the ESUO executive committee during the preceding weeks (http://www.esuo.eu/wp-content/uploads/2021/05/Proposed-medium-term-activities.pdf) and discussed the future ESUO strategy. ESUO also presented the current and future activities to transform ESUO into a legal entity based on Belgian law. On July 12th, 2021, an important step related to this transformation process has been achieved with the incorporation of the ESUO international non-profit association (ESUO-AISBL) made by notarial deed. During the next upcoming months, additional important steps are foreseen to take place regarding e.g. the process of having the legal personality of the ESUO-AISBL to be granted by Royal Decree.

Screenshot Group picture taken during 15th ESUO general assembly meeting (please note that not all participants are present on the group picture).

ESUO to become an AISBL is considered as an important step towards a sustainable future. Indeed, ESUO is very much hoping to be able to benefit from a wider potential of attracting funding support by pursuing and by further developing existing and new joint activities and partnerships, including with LEAPS, in international matters, for the benefit of all. As part of the portfolio of the FEL analytical infrastructures, ESUO is also strongly hoping for a bright future of the state-of-the-art CLIO IR FEL, for the benefit of all and our society and in a recent letter addressed its support to the CLIO IR FEL facility and its existing and upcoming user community.

More information:
https://www.wayforlight.eu/en/users/esuo/
https://leaps-initiative.eu/

Annick Froideval and Ulli Pietsch

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

For experiments at European XFEL:
Autumn 2021

For experiments at FELIX
Deadline: 15 November 2021

For experiments at FLASH
Deadline: 1 October 2021

UPCOMING EVENTS

Webinar Series in 2021:
Follow the announcements on
https://www.fels-of-europe.eu/

Science@FELs Conference at DESY
20-23 September 2022

PhotonDiag Conference at HZB
4-7 October 2022

Celebration of the 10th Anniversary
FELs of Europe in 2022

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