eli

The Extreme Light Infrastructure ERIC

ANNUAL REPORT

2022–2023

Letter from the

Director General

The Extreme Light Infrastructure (ELI) achieved significant milestones this past year which shape the organisation for the future and make progress on the core mission of ELI to open the Facilities to the scientific community via the Joint User Programme.

One of the notable highlights of the year was the strategic agreement with the Institute of Physics of the Czech Academy of Sciences, which resulted in the integration of ELI Beamlines into ELI ERIC on 1 January 2023. The establishment of the ELI ERIC and pursuant integration of the Facilities into the ELI ERIC launches a new chapter for the research facility. In practice this meant that overnight on New Year's 2023, ELI ERIC gained over 350 staff and all of the assets and liabilities related to ELI Beamlines. The integration of ELI Beamlines into ELI ERIC represents a significant step towards fostering collaboration, harnessing synergies and amplifying ELI's impact in laser-driven research.

The preparations for the integration of ELI ALPS are progressing quickly with the expected integration on 1 January 2024. The goal is to operate the high-power laser facilities as a unified organisation with a single governance and common management structure.

In addition to these achievements, the Joint ELI User Programme has matured significantly. As the experiments of the 1st User Call are being implemented, the 2nd Call for Users was launched in early February 2023. The scope of the available equipment for these state-of-the-art experiments has broadened with the 2nd Call and resulted in a decisive increase in proposals submitted. In total 147 proposals from 27 countries were submitted in both Calls for all 3 ELI Facilities. The User Programme fosters partnerships with external researchers enabling cutting-edge research and ground-breaking science. By nurturing a vibrant user community, ELI facilitates interdisciplinary collaborations, stimulates innovation, and provides a platform for scientists worldwide to explore new frontiers of knowledge.

There are many activities, collaborations, events and lots of work taking place in parallel. Between the ELI ERIC Facilities over 600 staff are working together with dedication that have propelled ELI to the forefront of laser research and its applications. The integration of ELI Beamlines into ELI ERIC, the preparations for the integration of ELI ALPS, and the maturing of the Joint User Programme exemplify ELI's commitment to optimising resources, fostering collaboration, and driving innovation.

I deeply appreciate the efforts of the exceptional individuals and teams at the ELI Facilities who are contributing to these accomplishments and have embraced our strategy to be "One ELI". Thank you for your continued support and dedication to the mission of ELI. This annual report is a testament to our collective impact and inspires future generations to further explore the realms of laser-driven science. Together, we are continuing to push the boundaries of what is possible, advancing scientific frontiers, and making a positive difference in society.

Allen Weeks
ELI ERIC Director General

Extreme Light for
Excellent Science

Table of Contents

01

ELI Organisation

Fundamentals of ELI's Laser Technology

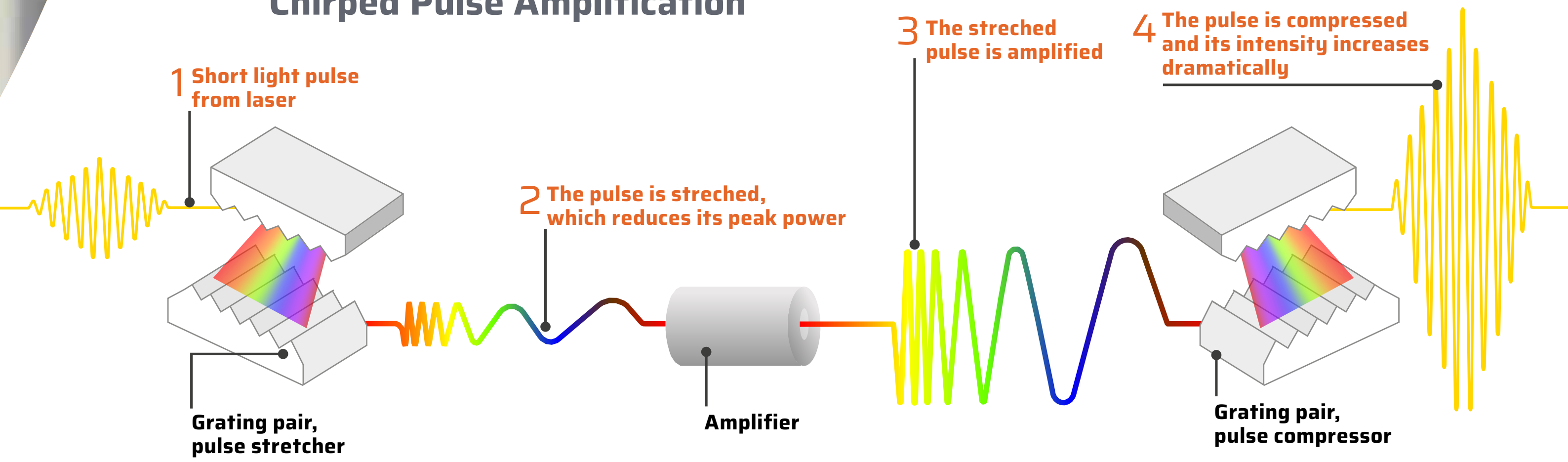
The technology used at ELI, which allows for unprecedented laser intensities and powers, is based on Chirped Pulse Amplification (CPA). CPA involves stretching a short laser pulse in time by delaying its spectral components, amplifying the elongated pulse, and then compressing it again to very short time scales. This technique, for which Gérard Mourou and Donna Strickland were awarded the Nobel Prize in Physics in 2018, enables the production of extreme laser powers on the order of petawatts, which is significantly greater than the combined power of all the power stations in the world.

Chirped Pulse Amplification has revolutionised the field of laser technology, and ELI's ultra-high-power lasers with focusable intensities and average powers surpass existing systems. These lasers will unlock new frontiers in fundamental science, allowing for a deeper understanding of molecular and atomic structures and their dynamic processes.

ELI's Facilities enable scientists to capture snapshots of electron dynamics in various substances in atomic, molecular, plasma, and solid form. The research conducted at ELI will have implications in particle physics, nuclear physics, gravitational physics, nonlinear field theory, ultrahigh-pressure physics, astrophysics, cosmology, and other fields. Additionally, ELI aims to provide compact laser plasma accelerators that can generate ultra-short energetic particle beams and radiation. These secondary sources offer X-ray technologies that can shed light on the complete time history of important reactions such as protein activity, protein folding, radiolysis, chemical bond monitoring, and catalysis processes. This knowledge will contribute to a better understanding and control of key events during chemical bond formation and destruction, which has significant implications for industries such as drug development. Overall, high-power lasers like those at ELI will have a profound impact on both industry and society.

> ***CPA involves stretching a short laser pulse in time by delaying its spectral components, amplifying the elongated pulse, and then compressing it again to very short time scales.***

Chirped Pulse Amplification



ELI ERIC Facilities

The Extreme Light Infrastructure (ELI ERIC) is the **world's largest** and **most advanced collection of high-power lasers**. As an **international user facility** dedicated to **multi-disciplinary science and research applications** ELI provides access to world-class high-power, high-repetition-rate laser systems and enables cutting-edge research in physical, chemical, materials, and medical sciences, as well as breakthrough technological innovations. The ELI ERIC operates as a **single multi-site organisation** with **complementary facilities** specialised in different fields of research with extreme light: ELI Beamlines in Dolní Břežany (Czech Republic) and ELI ALPS in Szeged (Hungary). ELI Nuclear Physics in Măgurele (Romania) is expected to join the ERIC in the near future.

ELI Beamlines, Czech Republic

High-Energy Beam Facility, ultra-intense laser pulses to explore extreme conditions and offer high-energy particles and X-rays

ELI ALPS, Hungary

Attosecond Light Pulse Source, offering unique time-resolved investigation possibilities for both nonrelativistic and relativistic interaction of light with all four states of matter

Multi-site organisation

Complementary Facilities

1st large-scale Research Infrastructure in Central and Eastern Europe

ESFRI **Landmark** project

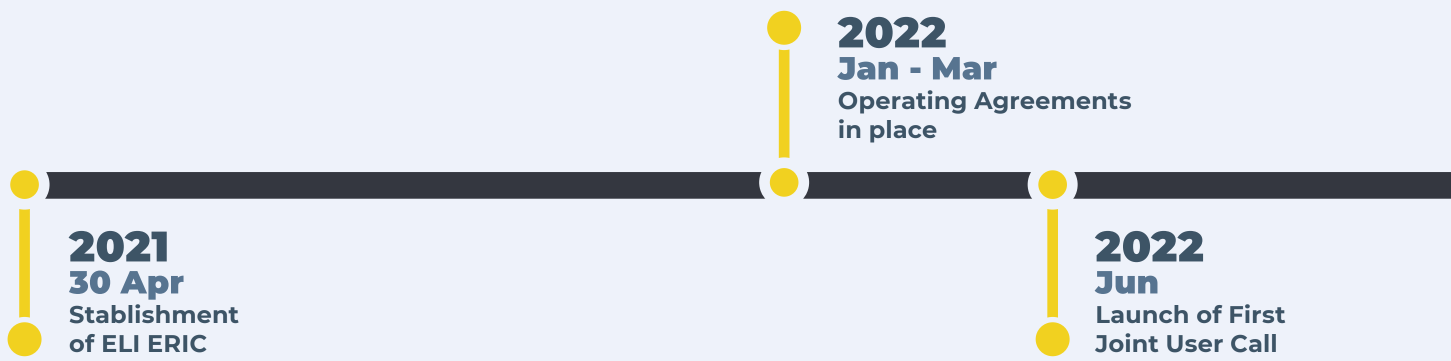
Initial Operations and Integration

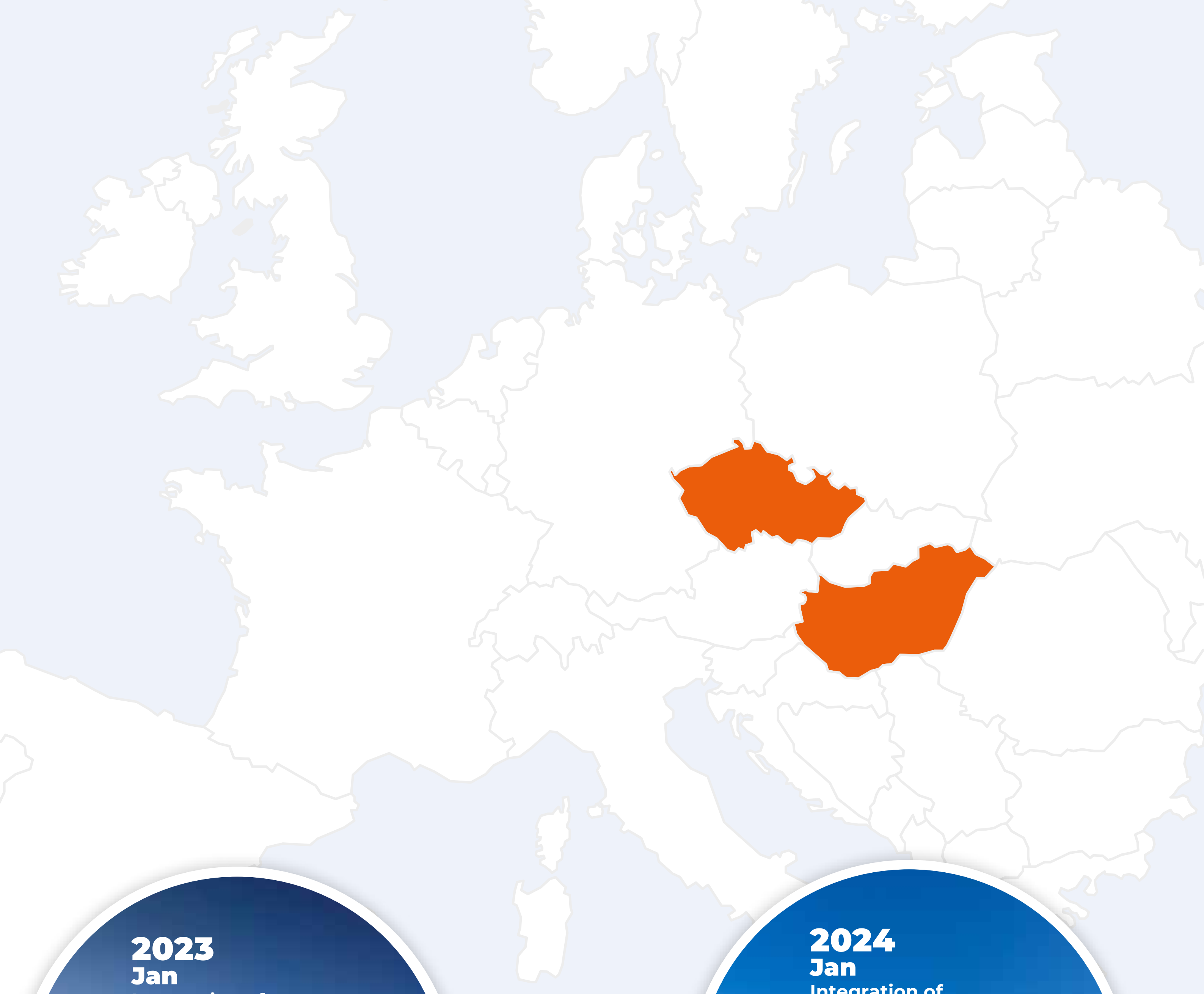
During Initial Operations, the ELI Facilities legally integrate into a single organisation in the framework of ELI ERIC. ELI ERIC will operate the high-power laser facilities ELI Beamlines and ELI ALPS as an integrated organisation, with a unified governance and management structure.

The ELI Beamlines Facility, previously a department of the Institute of Physics (FZU) of the Czech Academy of Sciences, integrated into ELI ERIC on 1 January 2023. This entailed that all assets, including land and buildings, all rights and obligations such as employee contracts and grants connected with the ELI Beamlines Facility, as well as all existing intellectual property rights were transferred from FZU to ELI ERIC. An integration of such scale is complex and unprecedented on a Czech national level. The integration into ELI ERIC ensures long-term operations and scientific developments to maintain the European leadership in laser technology.

The integration of the ELI Facilities to ELI ERIC is being realised by the implementation of a joint management system. This approach translates governance policies to operative processes and procedures in key activity areas such as Access, Scientific Evaluation and Dissemination, Data, Finance and Procurement, Employment, as well as Innovation, Industry and IPR. Further policies such as IT, Environment, Health and Safety, and Communications and joint procedures are in development.

Preparations for the integration of ELI ALPS are in progress with the expected transition at the beginning of 2024. The proposed approach is for ELI ERIC to operate ELI ALPS through a controlling majority ownership in the Hungarian legal corporation. This will enable ELI ERIC to manage the real assets of the facility and own the moveable assets, while also providing the necessary flexibility to realise ELI ERIC's legal presence in Hungary. The integration will effectively minimise administrative and legislative difficulties, ensuring the success of ELI ERIC.





2023
Feb
Launch of 2nd
Joint User Call

ELI Scientific Management

As the ELI Facilities integrate and begin to operate as a unified organisation, aligning scientific activities and defining core scientific goals is key. The scientific leadership of ELI ERIC is charged with making the ELI ERIC Facilities available to the international scientific user community.

Andrew Harrison,

ELI ERIC Director of Science

Andrew Harrison joined ELI ERIC from the Diamond Light Source in the UK. He led Diamond through the transition from construction to operations, ensuring a strategy for long-term sustainability and tremendous growth in the user base. Prior to Diamond, he served as Director General and Associate Director for Science at the Institute Laue-Langevin in Grenoble, France. As a materials scientist and chemist, he has done research at neutron, X-ray and laser facilities throughout his career.

Harrison has participated extensively in scientific policy-making bodies across Europe and internationally, including chairing EIROForum (2012-2013) and as chair of ERF AISBL. He has also contributed to developing the framework for assessing European research infrastructures as the UK delegate for ESFRI (European Strategy Forum for Research Infrastructures) since 2014. Throughout his career, he has contributed to and shaped the research landscape of Europe to deliver scientific excellence in partnership with a variety of stakeholders.

Katalin Varjú,

Science Director of ELI ALPS

Katalin Varjú has contributed to ELI since the beginning of the project. She was active in the preparatory stages of the ELI proposals and co-edited the first Scientific Case for ELI ALPS in 2011. After the establishment of ELI-HU Ltd., she acted as group leader, and later as division head. Since 2019 she has been the Science Director of the ELI ALPS facility, responsible for the implementation and operation of the research infrastructure.

She completed her PhD studies at the University of Kent at Canterbury and the University of Szeged. She holds an associate professorship. As a visiting scientist at Lund University in Sweden (2003-2005), supported by the Marie Curie Programme, she deepened her research into the generation and application of attosecond pulses from high-intensity laser fields, a topic that ultimately connected her scientific career to ELI ALPS.

Her main research interests are in optical and atomic physics: concerning the propagation of femtosecond laser pulses, nonlinear interactions of light with matter, high-order harmonic generation and attosecond pulse (train) production, and its applications to study electron dynamics.

Daniele Margarone,

Director of Research and Operations of ELI Beamlines

Daniele Margarone was appointed Director of Research and Operations of ELI Beamlines in September 2022. He is a recognised scientist in the field of plasma physics and particle acceleration with extensive experience from experiments using high-power lasers.

He completed his PhD at Messina University. Margarone lectured in experimental plasma physics at Queen's University in Belfast and acted as Head of the Department of "Ion acceleration and application of high energy particles" at ELI Beamlines. He joined ELI Beamlines in 2010 and has contributed to the development of the facility from the preparatory phase through the implementation and commissioning of technologies, in particular, the ion accelerator called ELIMAIA.

His main research interests are in the areas of laser-driven ion acceleration, innovative target geometries for ion acceleration, real-time diagnostics of particles and radiation generated in laser-plasmas, generation of brilliant particle streams from nuclear fusion reactions, production of laser-based secondary sources for multidisciplinary applications, including new compact approaches to hadron therapy for cancer treatment and enhancement of cancer cell killing efficacy through the Proton-Boron Fusion reaction.

Joint User Programme

The Joint ELI User Programme plays a crucial role in providing researchers with a centralised access point to the commissioned scientific equipment. It also represents a significant milestone for ELI in bringing together all three Facilities, demonstrating their readiness to conduct groundbreaking science.

The User Programme is an essential activity for ELI as an international User facility. As the ELI Facilities transition from construction to initial user operation, commissioned equipment are made available for cutting-edge experiments. Managed by ELI ERIC, the Joint User Programme provides a single access point to all capabilities offered at the ELI Facilities. Access to ELI is open to scientists from within and outside the ELI ERIC Member countries, following the principles established in the European Union Charter for Access to Research Infrastructures. Access is free, competitive, international, and based on three modes: Scientific Excellence, Mission-based Access, and Proprietary Access.

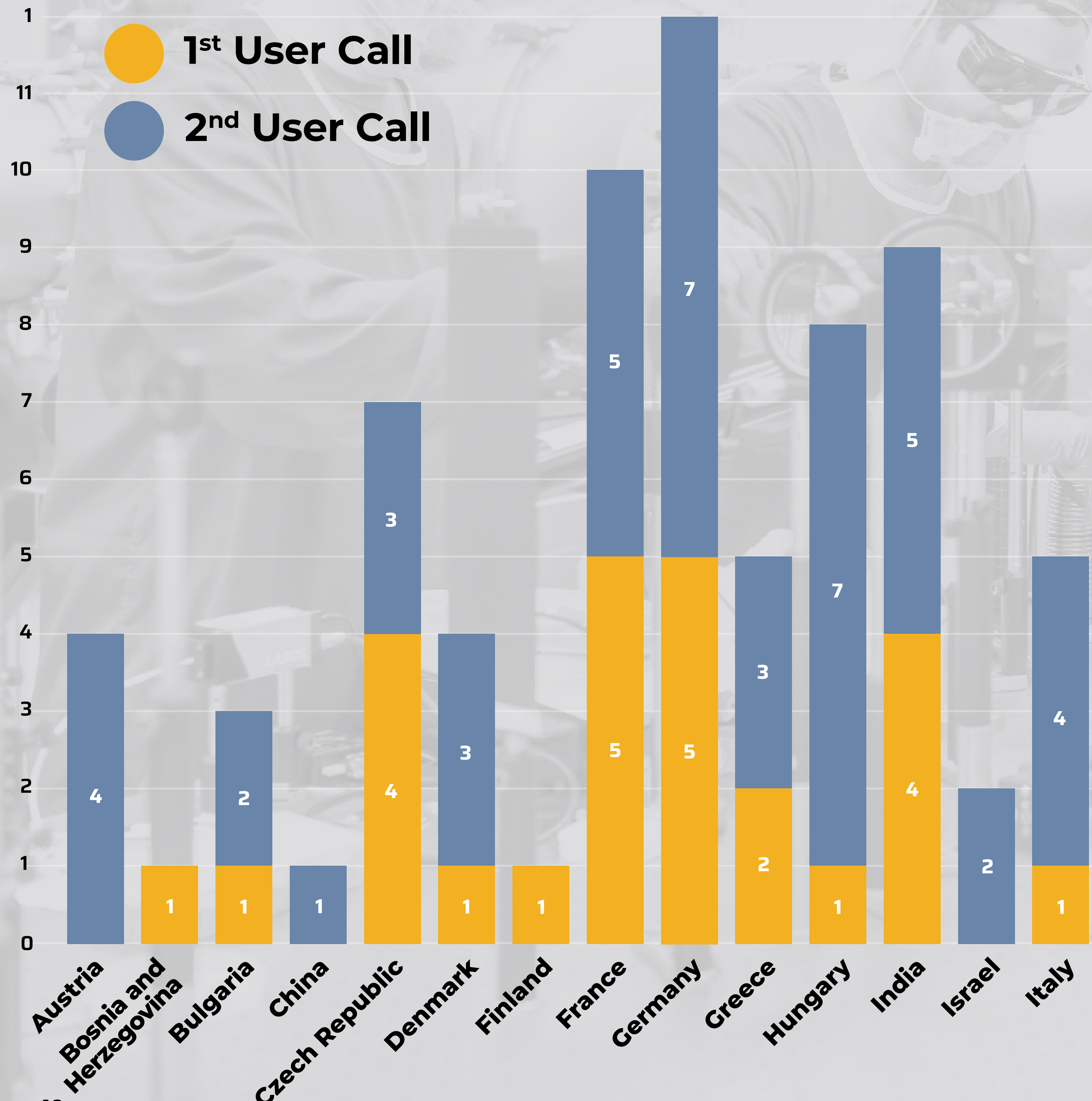
The 1st Joint User Call was launched in June 2022, offering a total of 10 experimental chains. The focus of this Call was on instruments with proven readiness, reliability, and extensive operational experience. Researchers from 20 different countries submitted 45 proposals, and the first experiments at all three ELI Facilities began in November 2022.

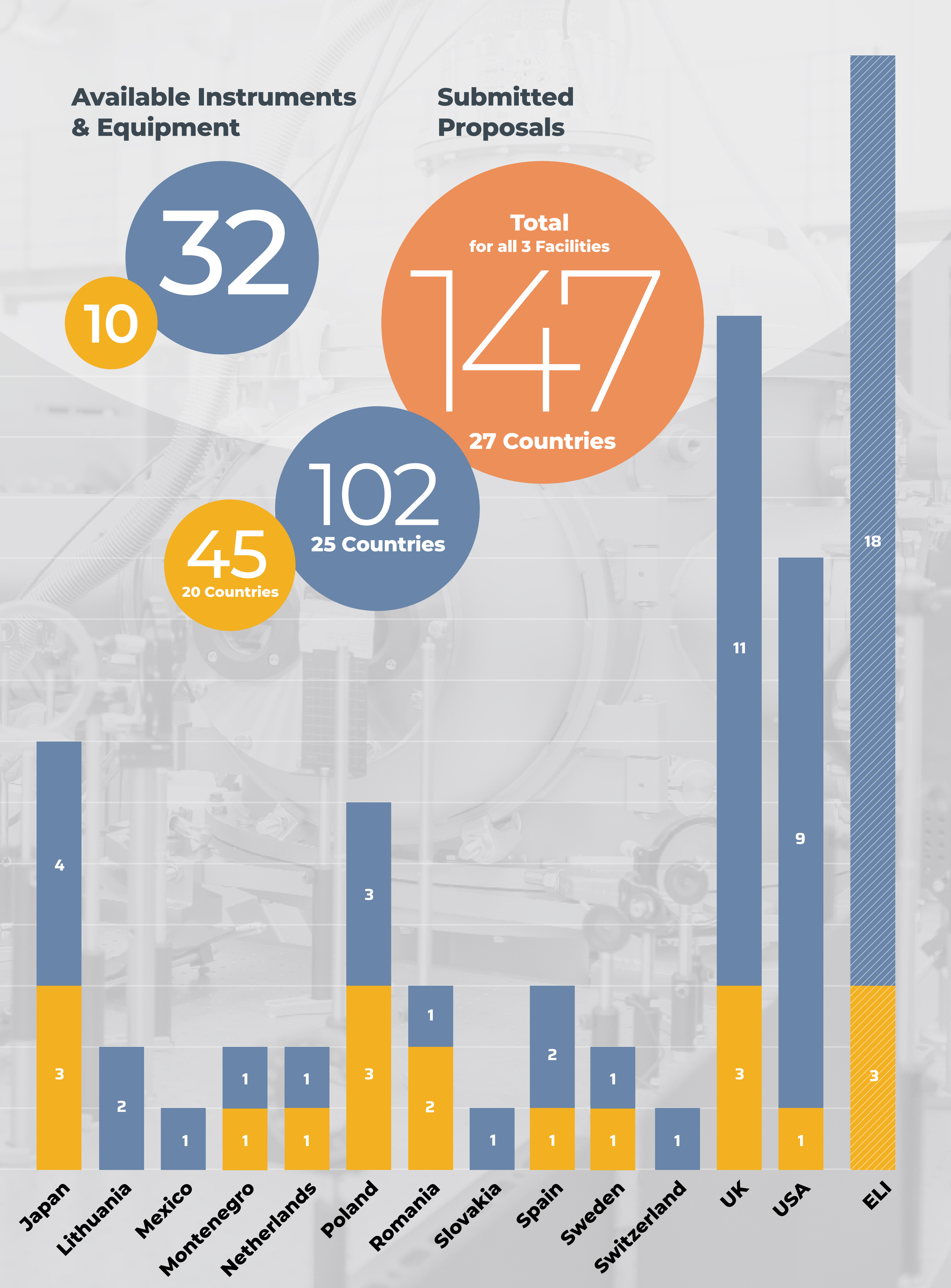
In February 2023, the 2nd Joint Call for Users was announced, expanding the scope of available equipment for state-of-the-art experiments. The offering for this 2nd Call includes 5 primary lasers, 10 secondary sources, 11 endstations, and 6 standalone or experimental platforms. The 2nd Call received 102 proposals from 25 countries. The fields of Atomic, Molecular and Optical Science, Surface and Materials Science, and Accelerators and Particles received the most proposals, along with other areas like bio/life sciences, plasma physics, and Relativistic and Ultrarelativistic Interactions. An international Peer Review Panel will evaluate the proposals. Successful proposal will receive beamtime beginning in Autumn 2023.

The Joint User Programme includes all three of the ELI Facilities, thanks to a close collaboration between ELI ERIC and ELI-NP within the Horizon 2020 funded IMPULSE project. IMPULSE supports the collaboration by providing scientific, technical, and administrative assistance through the implementation of a single point of access and management systems. The Joint User Programme is expected to launch two User Calls per year going forward.

Joint ELI User Programme
At a glance

Country of PIs affiliated Insitute




Available Instruments & Equipment
Submitted Proposals
32
10
Total
for all 3 Facilities
147
27 Countries
102
25 Countries
45
20 Countries
4
3
2
1
1
1
1
1
3
3
1
2
1
2
1
1
1
1
11
3
9
1
18
3
Japan
Lithuania
Mexico
Montenegro
Netherlands
Poland
Romania
Slovakia
Spain
Sweden
Switzerland
UK
USA
ELI

ELI ERIC Facility Staff

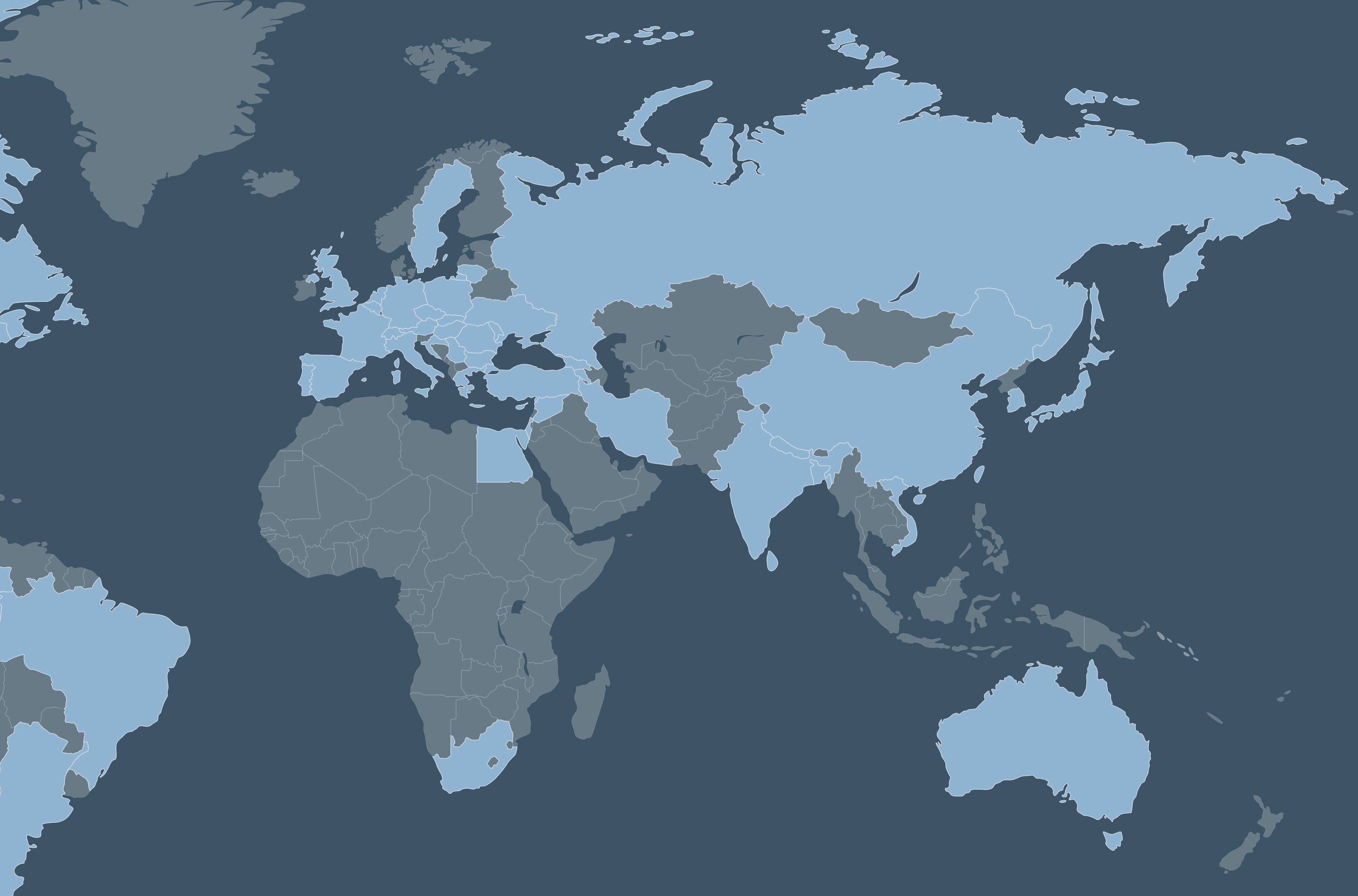
The ELI ERIC Facility staff is made up of the staff located in Hungary and the Czech Republic and includes scientists, researchers, technicians and engineers, facility support staff as well as the administration.

47

Nationalities

627

Combined

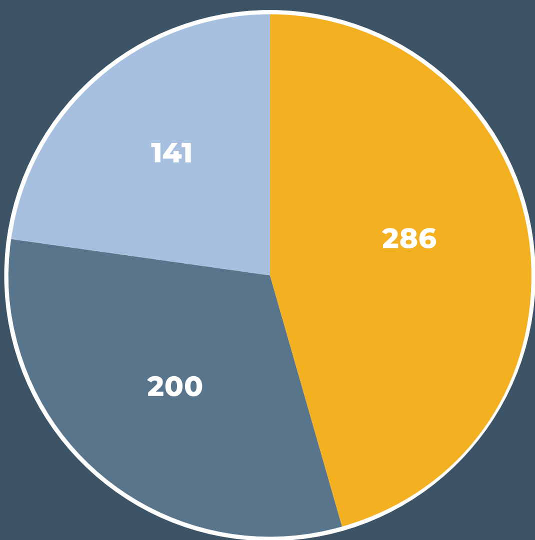


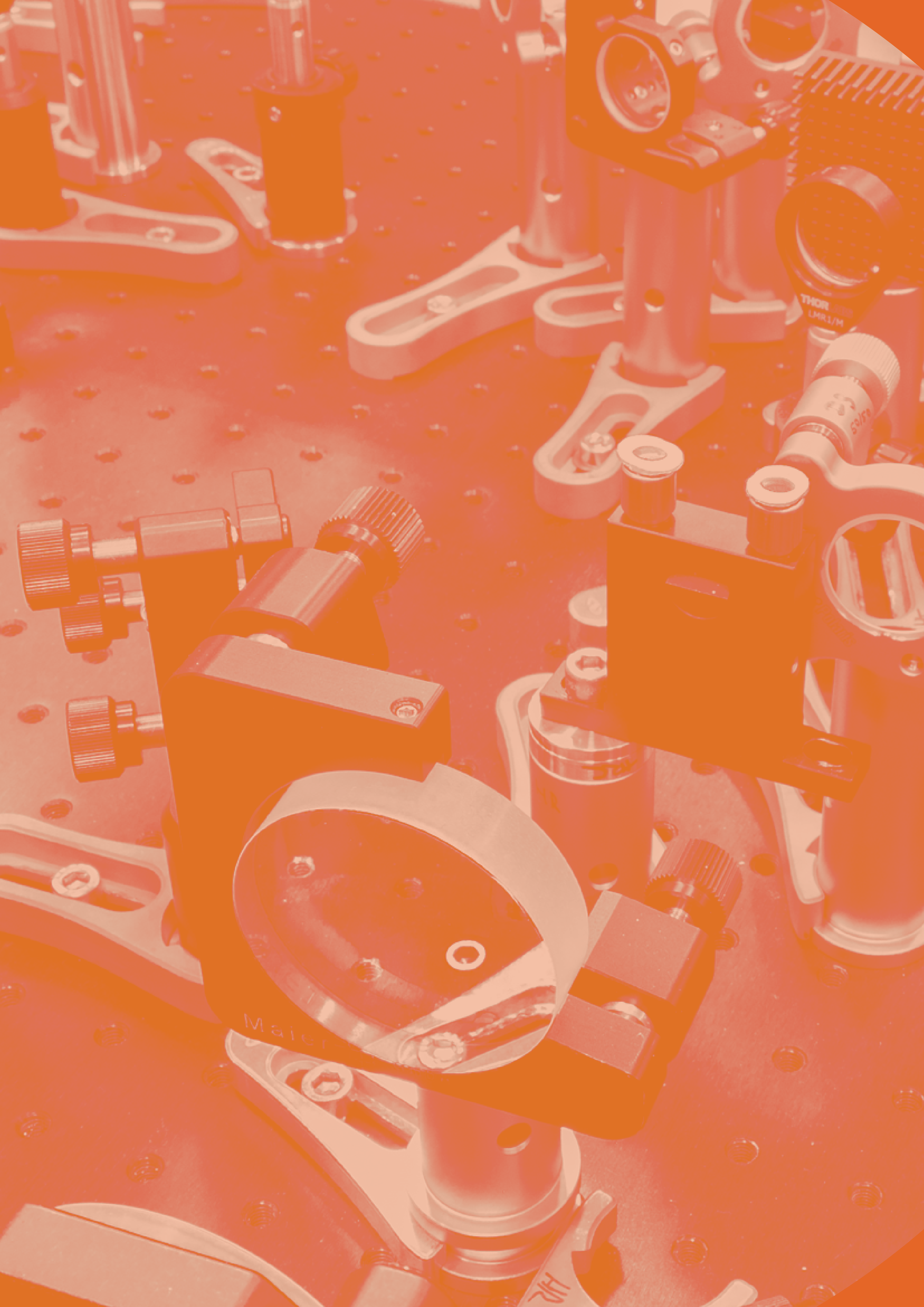
Argentina	2	Croatia	3	Italy	13	South Africa	1
Armenia	1	Cyprus	1	Lithuania	2	South Korea	2
Australia	1	Czech Republic	242	Mexico	1	Spain	2
Austria	1	Egypt	1	Moldavia	1	Sweden	3
Bangladesh	1	France	9	Nepal	2	Switzerland	2
Belgium	1	Georgia	1	Netherlands	1	Syria	1
Brazil	1	Germany	7	Poland	5	Turkey	1
Bulgaria	1	Greece	6	Portugal	1	Ukraine	14
Canada	1	Hungary	225	Romania	2	United Kingdom	6
China	1	India	16	Russia	16	USA	6
Columbia	1	Iran	2	Serbia	5	Vietnam	1
Costa Rica	1	Israel	1	Slovakia	12		

Researchers 286

Technicians/Engineer 200

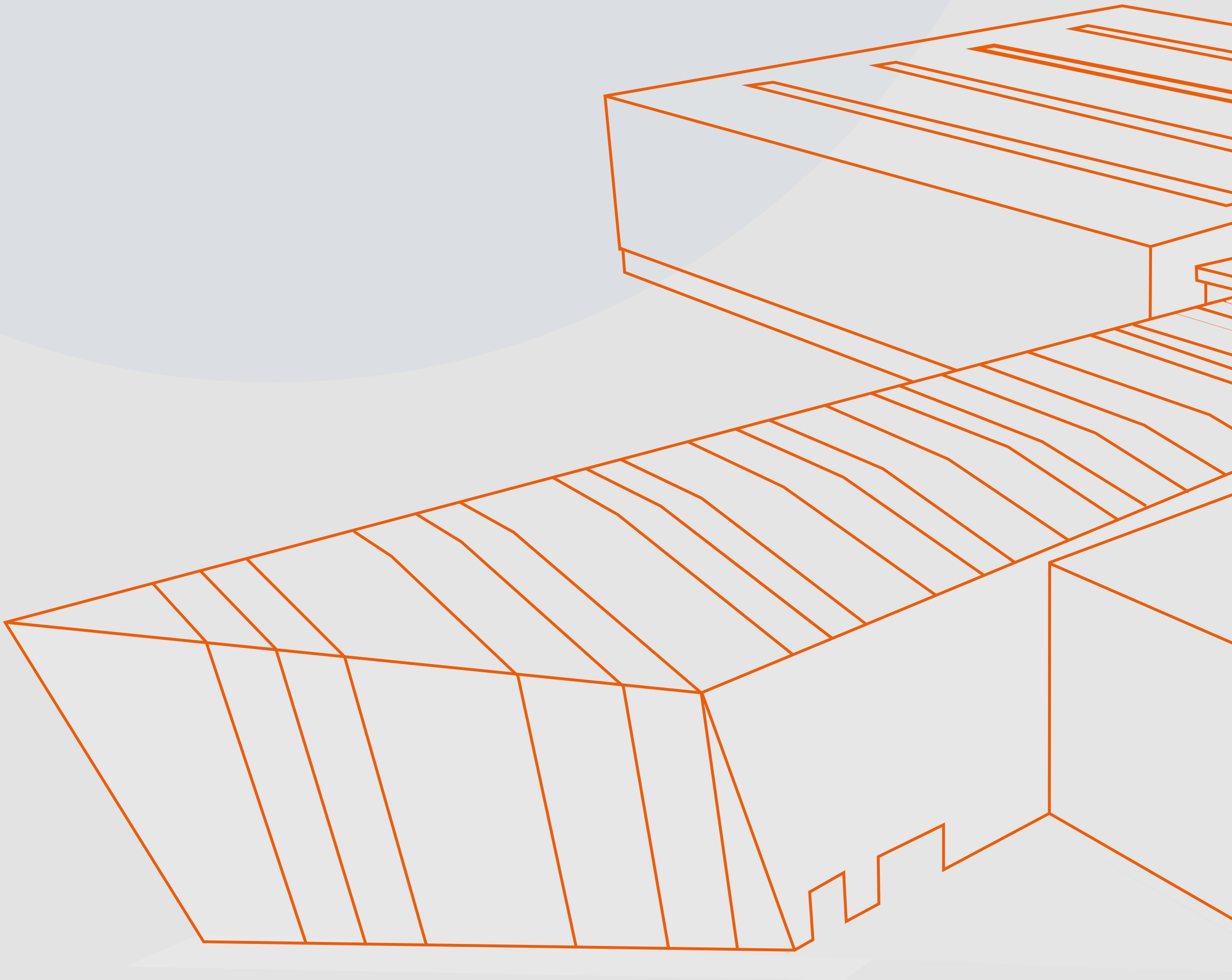
Admin 141





02 Facility Focus

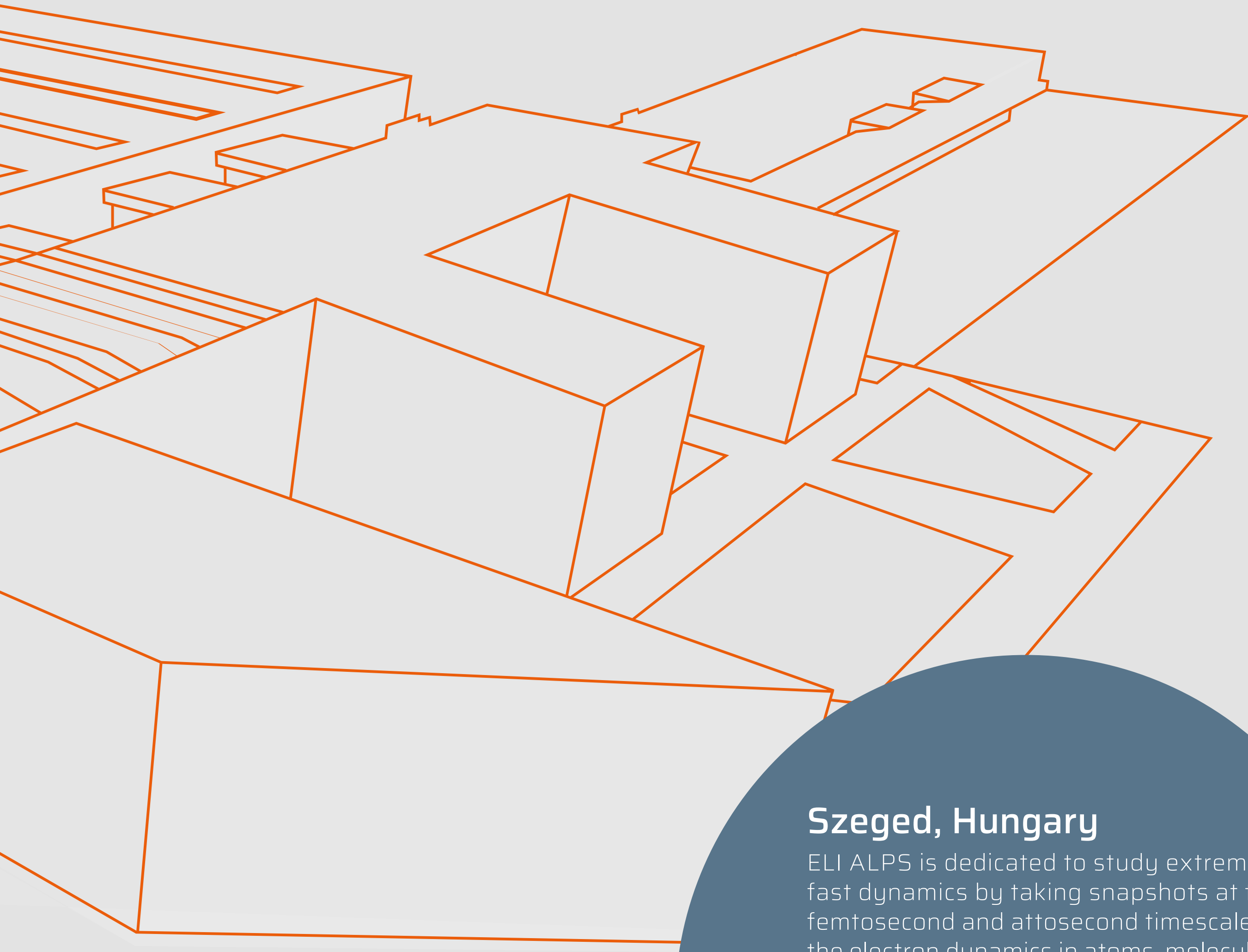
ELI Attosecond Light Pulse Source Facility



The primary mission of the ELI ALPS research facility in Szeged, Hungary is to provide laser and secondary light and particle sources in the form of ultrashort bursts with high repetition rates. Energetic coherent light pulses of few optical cycles are available from the terahertz (10^{12} Hz) to the X-ray (10^{18} — 10^{19} Hz) frequency range. The parallel existence of these secondary sources and state-of-the-art lasers including PW-class lasers within the same facility, offers unique time-resolved investigation possibilities for both nonrelativistic and relativistic interaction of light with all four phases of matter.

The constructed buildings house the laser equipment, secondary sources, target areas, laser preparation, other special laboratories and electrical, mechanical and optical workshops. These state-of-the-art facilities require specialised engineering design and cutting-edge implementation of the latest technology for vibration levels, thermal stability, relative humidity, clean room facilities and radiation protection conditions.

Prof. Dr. Gábor Szabó
is the Managing Director of ELI ALPS, a laser physicist, Professor at the Institute of Physics of the University of Szeged, and former Rector of the University (2010-2018). Prof. Szabó has played a key role in the establishment of ELI ALPS. He actively participated in the development of the facility's scientific strategy and laser infrastructure as a member of the Scientific Advisory Board. He has a wealth of experience in leadership positions, including Deputy State Secretary for R&D and President of the Hungarian Association for Innovation. His areas of experience include ultrafast light pulse generation, ultrafast laser spectroscopy, nonlinear optics, photoacoustic spectroscopy and medical applications of lasers with a focus on applied research, which is reflected by, e.g., the 32 patents he has produced.



Szeged, Hungary

ELI ALPS is dedicated to study extremely fast dynamics by taking snapshots at the femtosecond and attosecond timescale of the electron dynamics in atoms, molecules, plasmas and solids for applications in:

- Ultrafast electron dynamics
- Materials science
- Ultrashort Laser Driven by Particle and X-ray Sources
- Plasma and High-field Physics
- Radiobiological Applications

ELI ALPS Primary Sources

The **SYLOS2** (1 kHz / 32 mJ (super-Gaussian beam profile), 25 mJ (Gaussian) / 7 fs) and **SYLOS Alignment** (10 Hz / 35 mJ / 11 fs) laser systems are currently driving three beamlines (GHHG Long, GHHG Compact and the user-built neutron generation setup), while the installation of two additional beamlines (eSylos, SHHG Sylos) are close to completion. Both laser sources were optically synchronised to all mentioned experimental stations. The SYLOS2 pointing stabiliser was upgraded and also a pulse energy attenuator system was added which can be used for beamline alignment purposes. Additionally, a low-energy output (1 kHz / 0.7 mJ / 7 fs) was realised in the SYLOS2 laboratory, allowing parallel research activities. Internal R&D activities resulted in post-compressing the output of the SYLOS Alignment down to 3.9 fs pulse duration at 12 mJ energy. Post-compression experiments were also carried out with the SYLOS2 system as well, where 4.5 fs pulse duration at 16 mJ energy was demonstrated. The **SYLOS3** system (1 kHz / 120 mJ / 8 fs) is in development, and has recently passed the factory acceptance test, with OPCPA amplification stages demonstrated parameters without pulse compression. The installation of the system at ELI ALPS began in May 2023. The SYLOS Alignment 2 system (50 Hz / 40 mJ / 15 fs) serving the alignment of SYLOS3 driven experiments is under development. The installation of the system will be completed by the end of October 2023.

The ALPS laser team together with the University of Szeged continues to push the frontier of laser science. The publication **Single thin-plate compression of multi-TW laser pulses to 3.9 fs** demonstrated a simple and robust post-compression of the SEA system from 12 fs to 3.9 fs with high efficiency. This will enable a number of new experiments on the frontier of ultrafast and attosecond science, especially when extended to the SYLOS2 system, and is a useful demonstration for the international community. S. Tóth et al., Opt. Lett. **48**, 57-60 (2023)

The **HR-1 laser** (100 kHz / 1 mJ / 7 fs), driving beamlines and endstations, participated in several user experiments of chemical, biochemical or quantum-mechanical nature. Other than experiments, internal R&D is being done in order to improve stability of the laser and beamline parameters. CEP stabilisation is not user-ready yet, but phase tagging is possible. Additionally, a low-energy output (100 kHz / 200 μJ / 35 fs) was realised in the HR laboratory, allowing parallel research activities.

Installation of **HR-2 laser** (100 kHz / target: 5 mJ & 7 fs & CEP / currently: 7 mJ & 280 fs / 6 mJ & 50 fs / 4 mJ & 12 fs & CEP tagging) at ELI ALPS started in December 2022, after manufacturing delays. The system is assembled, but still under commissioning, that is expected to complete by mid-2023.

The **Mid-Infrared Laser (MIR)** is dedicated to drive strong-field interactions in solids and gases at 100 kHz repetition rate, allowing for unprecedented amount of data for proper statistical analysis of low-yield processes driven by 3.2 μm CEP stable few-cycle pulses. Recently, the system has been relocated to a new laboratory. After the implementation of a new seed for its pump laser, the MIR is recommissioned and available for users in two configurations. Both long (40 fs, 150 μJ) and short pulses (20 fs, 70 μJ) can be utilised to drive a crystal-based HHG station or injected into the VMI (velocity map imaging) end-station. Pump-probe capabilities are under development aiming to provide synchronised femtosecond pulses at 1030 and 3200 nm (or 1600 nm).

To enable attosecond pulse generation beyond the water window, it is necessary to develop a high-energy long wavelength ultrafast driving laser at ELI ALPS together with a dedicated attosecond beamline. The **MIR-HE laser** is in development, aimed to provide more than 20 mJ at 3.2 μm or more than 12 mJ at 1.6 μm at a repetition rate of 1 kHz by mid-2023. The technology based on OPCPA is similar to the existing MIR laser however delivering 100 times more energy.

The **THz pump laser** (dual architecture with an Yb and a Ti:Sa arms synchronised better than 10fs RMS jitter) support not just user experiments that are related to THz generation but user projects like creating surface markings, studying biological effects of laser light irradiation or production of special surface structures on metals were carried out as well.

The **HF-PW** laser reached a major milestone in its development by demonstrating 10 J, 25 fs compressed pulses at 10 Hz and became available for beamline commissioning. For slowly ramping up the high intensity interactions, the laser is currently configured to provide the same pulse parameters in single shot operation mode or at 2.5 Hz repetition rate in the HTA (High-shielded Target Area) laboratory. The HF-100 frontend provides at the moment 6 mJ pulses with <25 fs duration at 100 Hz repetition rate and is post-compressed in an XPW stage to <10 fs with 1 mJ output. Ramping up the laser output to the 1 PW level is planned for Q4 2023. Operation of the system has started, where characterisation of pulses under different conditions is performed in the HTA laboratory.

Secondary Sources

The SYLOS-driven **Compact GHHG** beamline has been commissioned, and is user ready. Among other results, it demonstrated continuum XUV generation, a sign of isolated attosecond pulses, using the polarisation gating technique. Recently, the beamline has been upgraded to host a non-linear XUV-XUV experiment to study electron correlations in He with a Reaction Microscope (REMI), in collaboration with a user group.

The SYLOS-driven **Long GHHG beamline** is in commissioning by mid-2023, using 20 m focusing in combination with a single gas cell of variable length (36-70 cm). The first attosecond pulse train characterization has been done with the RABBIT technique.

The **eSYLOS beamline** is in development and will be commissioned during the summer of 2023. The laser beam is focused down to 12 µm spot size in a gas jet/cell having a few 100s µm in length of helium gas or a mixture He &N_2 gases. By increasing the local gas (plasma) density to > $10^{19}/cm^3$, the SYLOS laser is capable of driving an LWFA process at 1kHz repetition rate in the ionised plasma gas. An electron beam from the background plasma will be trapped and accelerated in the laser direction by the plasma wave to 10-50 MeV of energy and a few pico-Coulomb of charge. Simultaneously, a probe laser beam is crossing the plasma for an interferometric/shadowgraphic diagnostic (outside the chamber). Planned user applications of eSYLOS accelerator include radiobiology and ultrafast soft X-ray spectroscopy.

The **SHHG-SYLOS beamline**, in the medium shielded laboratory, targets attosecond pulse generation via the interaction of relativistic intensity few-cycle SYLOS laser pulses with the solid surface of a fast-rotating target. The beamline is equipped with state-of-the-art primary beam diagnostics, plasma diagnostics and beam shaping arrangement. A liquid jet plasma mirror target will provide temporal contrast cleaning of the pulses in an uninterrupted manner, while a passively stabilised high-speed rotating interaction target is estimated to deliver attosecond pulses at kHz repetition rate. An end-station is being designed and will be attached to the interaction chamber for spectral and temporal characterisation of the XUV radiation as well as hosting user defined experiments. The beamline can support user experiments on field driven relativistic plasma physics and is in commissioning.

For the publication **Two-XUV-photon double ionization of neon** an international collaboration was formed including multiple ALPS groups. They used the high harmonic radiation from the SYLOS GHHG-COMPACT beamline to ionize neon gas. The ionization of neon gas to its doubly-charged state with a two-photon process from a high-harmonic beam represents a powerful tool for the field. They also compared to theoretical models, showing how the system can be used to study fundamental atomic processes driven by intense XUV light. E. Orfanos et al., Phys. Rev. A 106, 043117 (2022)

The **HR GHHG Gas beamline** is now permanently equipped with the Reaction Microscope (ReMi) end-station, giving a powerful tool for research in atomic-, molecular- and optical physics. This combination of photon source and diagnostics was already offered in the 1st ELI ERIC User Call – with the experimental campaign already performed – and is available in the 2nd User Call for researchers wishing to exploit the capabilities of a high-flux extreme-ultraviolet source running at 100 kHz repetition rate with the possibility to measure photoionisation events in coincidence mode.

In **High-Flux 100 kHz Attosecond Pulse Source Driven by a High-Average Power Annular Laser Beam** using the HR-1 laser, the ALPS Attosources group developed a system to break an energy frontier for attosecond sources at very high repetition rates. Using an annular laser beam profile, created with low losses, they could efficiently filter out and diagnose only the high-harmonic beam. High repetition-rate sources will be more and more in demand for sensitive science applications. P.Ye et al., Ultrafast Science, 9823783 (2022)

The **HR GHHG Condensed beamline** driven by the HR-1 laser system is equipped with a time-delay compensated XUV monochromator for the selection of single harmonics down to 50 meV spectral resolution, while preserving close to Fourier-limited pulse durations. The beamline is open to users since mid-2022, running experiments utilising its sub-cycle pump-probe capabilities and diverse diagnostic equipment, like the investigation of relative photoemission time delays in low ionisation cross section processes, or XUV transient absorption spectroscopy. The results of commissioning measurements – involving the detailed characterisation of the focusability, spectral bandwidth, overall photon flux and temporal resolution of the generated radiation – represented exceptional tunability on single harmonic pulse properties.

Scaling laws in strong field physics state that the generated high order harmonics spectrum extends with the driving laser wavelength. The **Mid Infrared High Energy (MIR HE) ATTO beamline** is dedicated to providing high order harmonics in the soft X-ray (up to 1.5 keV) regime. It is designed to accommodate MIR-soft X-ray pump probe experiments. The beamline is under development, to be completed by end 2023. Vacuum assembly has been successfully finished. High gas pressure load and first high harmonic generation tests will be done by the summer of 2023.

The **Nonlinear Terahertz (THz) Spectroscopy Facility (NLTSF)** enables time-resolved pump-probe studies using a strong THz pulse to initiate changes (pump) in the sample and a weaker THz pulse to probe them. There was a significant interest in the user community in the NLTSF, made accessible in the commissioning and Joint User Calls. Experimental topics included a broad range from solid-state physics and exotic materials to in vivo biological specimens. After relocating to a new laboratory, the facility was successfully recommissioned, and is available to users. An upgrade of the driving laser was initiated, which will increase the pulse repetition rate and energy.

The **High-Energy THz (HE-THz) source** is designed to study strong-field THz-driven interactions. The HE-THz source was installed, is in commissioning, and already accessible to users as part of the Joint User Programme. The development of the first endstation started, which will enable to THz-XUV pump-probe experiments.

The **SHHG (surface plasma HHG) PW beamline** is set up in the high shielded target area (HTA). The SHHG PW beamline, developed by a partner company, is oriented towards user driven relativistic laser plasma interaction studies on optically flat solid surface, in a regime optimised to the generation of ultra-intense XUV pulses. The SHHG PW is focused on enabling studies on relativistic optics, which demands high temporal contrast, and charge particle acceleration in the reflection mode.

The **ePW beamline** is a GeV **electron accelerator** which will be located in the HTA bunker (commissioning in Q3 2023) . The focusing optic f-number (F#40) implemented in the ePW allows a laser spot size of 40-50 mm which translates into a highly-relativistic laser peak intensity of $\approx 2 \times 10^{19}$ W/cm^2 in the focal volume. The interaction gas cell/jet creates a plasma density and length of about 2×10^{18} cm^{-3} and 1-2 cm, respectively. The expected parameters of ePW are 1-2 GeV energy, 100 pC charge, and 2 mrad divergence. The ePW is planned primarily to be a betatron X-ray source for producing beams of hard X-rays in a broad spectral range 5 keV up to 100 keV. User applications of those X-ray beams include phase-contrast imaging, micro-computed tomography and other application areas of science, technology and medicine etc.

Scientific Endstations

The **Gas Phase Reaction Control (GPRC)** setup can be used at the SYLOS2 low-energy output. The photodissociation and Coulomb explosion experiments can be driven by the 8 fs pulses (890 nm, 1 kHz, 0.75 mJ/pulse) focusing the beam with a spherical mirror for plasma generation in the reaction chamber. The NIR pump/UV-Vis emission probe experiments can be characterised by the detection of the fluorescent light from the generated radicals.

An LIDT **(Laser Induced Damage Threshold)** prototype test station has been designed and developed in house for a better understanding of the LIDT process, that is essential to operate the systems safely and reliably. This necessitates novel metrology tools with redundancy in the measurement protocol. The setup developed under IMPULSE can be used to study LIDT of different reflective system by using pump probe imaging as well as reflectometry studies on optical quality surface material and it can be adapted/upgraded to support R&D in laser machining with ultrashort pulses and studies in ultrashort pulse induced effects in bulk dielectric samples. The test station is mobile and can be set up in different laser laboratories and experimental halls within a few days. With further upgrades more aspects like ultrafast phase changes in materials near damage threshold can be studied. Tackling ultra-short laser induced material modifications require a thorough understanding of the damage dynamics through a combination of time resolved imaging in a pump probe mode and numerical simulation. Full implementation is in process and can supplement user experiments once completed in 2023.

The **Transient Absorption Setup (TAS)** (TAS) at the HR1 laser has the capability to perform operando electrochemistry measurements. With a custom-made electrochemical cell, the electrochemical measurements in both aqueous and non-aqueous media can be performed. During these the atmosphere in the cell can also be altered, and inert conditions can be ensured (Ar purging). The measurements can be performed both in transmission and reflection mode. This allows the separation of bulk and surface related recombination processes within semiconductor electrodes. The electrochemical workstation allows routine electrochemical characterisations such as cyclic voltammetry, electrochemical impedance spectroscopy and is also equipped with a fast scan module. The TAS setup can be used with both ultrashort green (10 fs) and UV pump pulses.

An international collaboration including University of Twente and the ALPS Ultrafast dynamics group studied ultrafast dynamics in semiconductor thin films using pump-probe methods and presented results in **Exciton Dynamics in MoS2-Pentacene and WSe2-Pentacene Heterojunctions**. The dynamics within thin films of such exotic materials are not well known, and this work should improve knowledge and stimulate future developments, with implications on fundamental science and deep-tech. P. A. Markeev et al., ACS Nano 16, 16668-16676 (2022)

The **REaction Microscope End Station** (REMi-ES), is attached to the HR GHHG Gas beamline. The REMI-ES is designed to measure the momenta of charged reaction fragments in coincidence when excited by lasers and extreme ultraviolet sources. The setup is mobile, and in principle can be driven by other sources (commissioning done only for the HR-1 driven GHHG Gas beamline). The REMi-ES is developed for studying many-particle quantum-dynamics of atoms, molecules and small clusters initiated by the interaction with pulsed, ionising laser radiation. The instrument permits kinematically complete measurements of photoionisation fragments (electrons and ions) over the full solid angle and with high momentum resolution.

A Hungarian collaboration, including the ALPS surface science group, explore metals deposited on hexagonal boron nitride – a material with vast potential in optoelectronics in **New insights into thermal processes of metal deposits on h-BN/Rh(1 1 1): A comparison of Au and Rh**. Using low-energy electron diffraction in the NanoESCA end-station at ALPS, they could elucidate thermal properties of the case with rhodium deposited, and the differences from the more standard gold deposits. G. Vári et al., Appl. Surf. Sci. 623, 157041 (2023)

The **NanoESCA station** for studies of photo-electron processes at surfaces has been uniquely coupled with the GHHG Condensed Beamline, and first test experiments using NIR pump and XUV probe pulses have been performed on Rh(111) and on Co(0001) films. The NanoESCA endstation itself has been equipped with a new metal evaporator and a quartz crystal microbalance to measure the evaporation rate. With this the evaporation material can be exchanged without venting the ultra-high vacuum system, allowing faster and smoother transition between different research projects. The endstation is available for both static and time-resolved experiments in surface chemistry and surface physics.

The **UFO (UltraFast Optics) endstation** receives the PW beam after the plasma mirror contrast cleaning stage of the SHHG beamline. The UFO station, designed in-house, is a multipurpose high-field physics endstation that would provide a flexible configuration for supporting diverse user experiments and developmental tests, using a diversity of target configurations including gas, liquid and nano-foil and nano-photonic structured targets. The setup is in the implementation phase, completion expected in 2023.

Supporting activities

Nanoscience activities

A RAITH e-LINE Plus electron microscope and electron beam lithography system (EBL), accessible for electron microscopy and nanolithography is operational with the whole lift-off technological chain and a wire bonder. A Scios 2 HiVac electron microscope and focused ion-beam device (FIB) accessible for imaging (SEM and STEM), milling of thin film cross-sections, direct writing of nanopatterns and preparation of TEM lamellae is operational. An atomic force microscope (AFM) based Neaspec VIS+ scanning near-field optical microscope (SNOM) is available for measuring optical near fields of surfaces upon laser illumination both in reflection and transmission mode and for characterising surface topography with tapping mode AFM. As a result of an in-house R&D project, pump-probe SNOM measurements will be available in 2023. Also the ultrafast ellipsometer will be driven by a short pulsed laser for femtosecond time resolved measurements of optical properties of surfaces.

Radiobiology activities

ELI ALPS' biological laboratories contain six research units: cell culture laboratory, zebrafish laboratory, analytic, molecular biology, and histopathology laboratories, as well as the medical physics laboratory (with an X-ray irradiator and dosimetry systems), all fully operational. The biomedical laboratory supports various investigations on the radio-sensitising effect of nanomaterials, on metabolomic and lipidomic studies at primary and secondary laser sources, and on pharmacology research. For this, zebrafish embryos, the reference source of an X-ray irradiator, a dosimetry system, microscopes, and analytical devices are studied. To support the user projects, the group started to detect the biological processes induced by THz radiation in in vitro and in vivo systems, with particular interest in lipidomic changes. Furthermore, the regeneration enhancement in a zebrafish embryo model offers insight into the molecular background of improved wound healing in human keratinocytes and fibroblast cells and in THz exposed tissues using different omics. Using zebrafish embryos, the effects of ionising radiation with different LET sources and radiation modifying agents at the macro- and micro-morphological and functional levels, as well as molecular activation, damage, and repair are examined. With this a novel vertebrate model

for research on the biological effects of different radiation qualities and for intercomparison of the effects of accelerator-based and laser-driven particle beams with ultra-high spatial and temporal resolution can be proposed.

The **IFIR-LDP** (Irradiation facility for interdisciplinary research with laser driven particles) is a multipurpose, modular irradiation facility, using ELI ALPS' laser-driven particle beams, designed to provide the necessary experimental setup for assorted applications such as radiobiology, dosimetry, radiation chemistry, material science and space science, as well as for the development and testing of laser-driven particle sources for such applications. The facility includes the necessary beam shaping and monitoring and positioning systems, a micro-environment control system, instruments for observation of the desired phenomena, as well as a complete and versatile dosimetry system.

The IFIR-LDP end-station is under commissioning and will be completely functional by summer 2023. After commissioning, further developments to expand the application possibilities are envisioned.

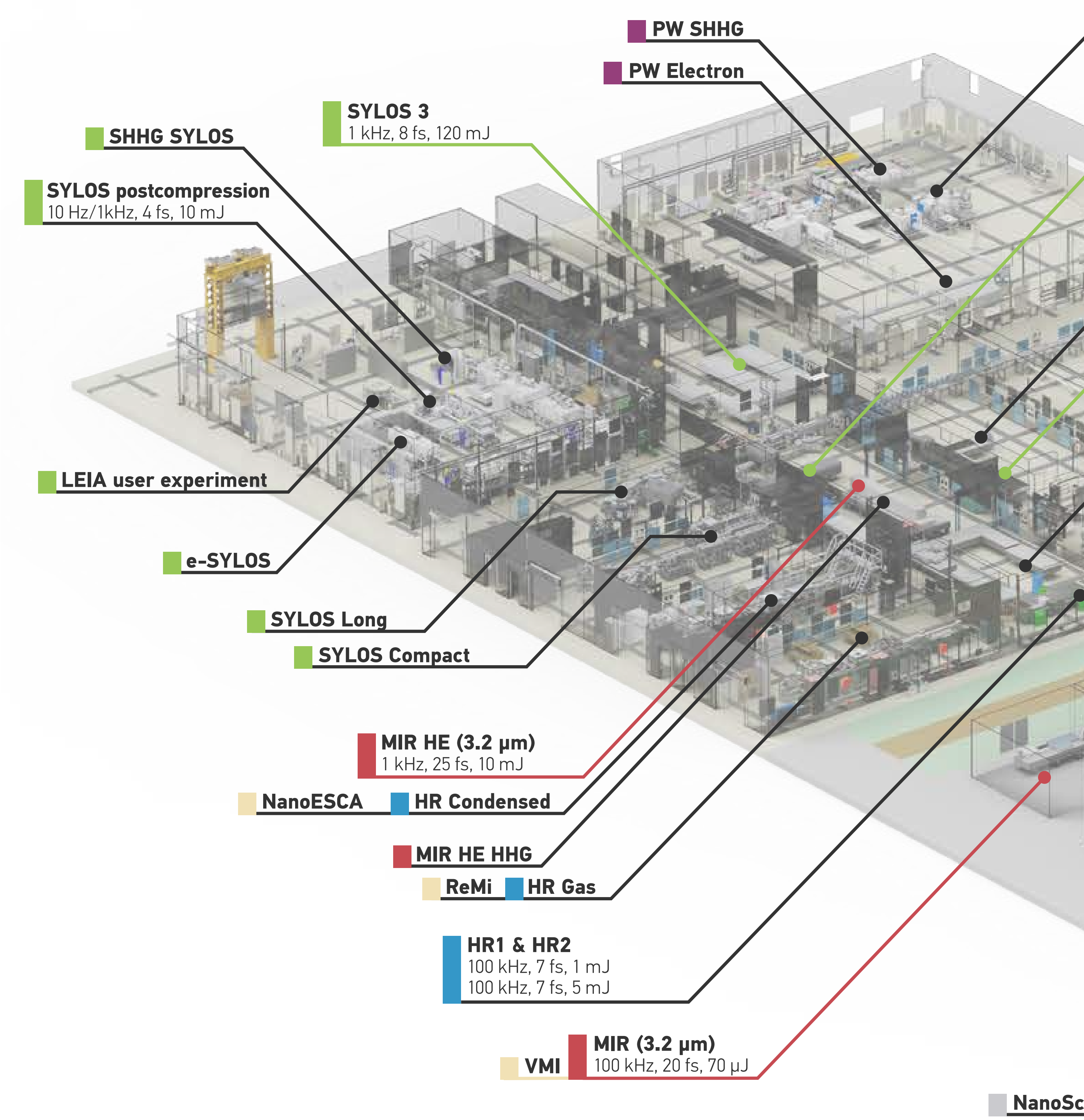
Simulation activities

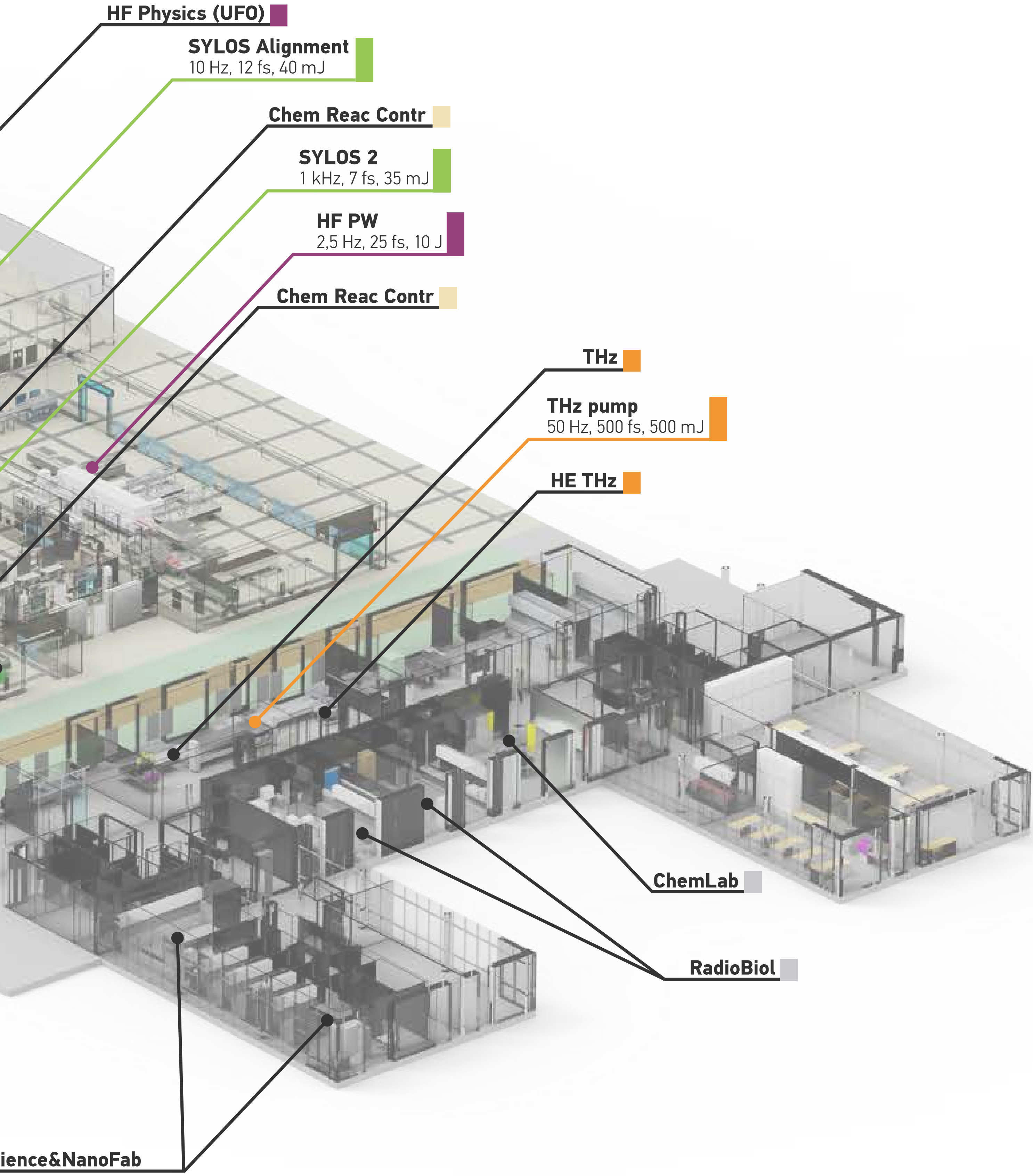
The Theory, Simulation and Computational Materials Science Group offers a combination of computational tools (e.g. DFT, TDDFT, numerically exact TDSE, Floquet methods, complex scaling methods, optimised lower-dimensional model potentials, phase space methods, FEM, MCTDHF, Molecular Dynamics, nonequilibrium Green's functions methods), to support and improve experimental and analysis techniques. The simulation activities work in close cooperation with the experimentalists and support user projects and a variety of national and international projects (ex. IMPULSE, PaNOSC, etc.).

Several beamlines and endstations have been developed to investigate relativistic and ultra-relativistic intensity femtosecond laser interaction with plasma targets. The in-house expertise in Particle-In-Cell (PIC) simulations can complement experiments and provide insight into the ultrafast sub-cycle charge dynamics which are often difficult to access via laboratory experiments. These simulation tools have been tested in the interaction conditions to identify optimised operating conditions and evaluate radiation-related hazards expected in the beamlines. Beyond that, the activities on relativistic plasma physics simulate the evolution of laser plasma fields and help to reveal and understand physical mechanisms, which could otherwise not be diagnosed experimentally.

The current simulation capabilities at ELI ALPS, enabled by the in-house High-Performance Computing (HPC) facility, range from: ultrafast imaging of charge migration and charge transfer, time-resolved evolution of electronic band-structure, ultrafast spin-transfer and magnetisation, THz spectroscopy and valley dynamics in semiconductors, high harmonic generation in atoms, molecules, solids and surfaces, optoelectronics, photovoltaics, photodetectors and light-emitting devices, biomedical applications such as drug design, laser-driven charged particle acceleration, high energy photon emission via Thomson or Compton scattering, incoherent x-ray generation via betatron radiation, exotic high intensity laser-matter interactions, strong-field ionisation, quantum optics, photon statistics of HHG, and nanostructures interacting with light.

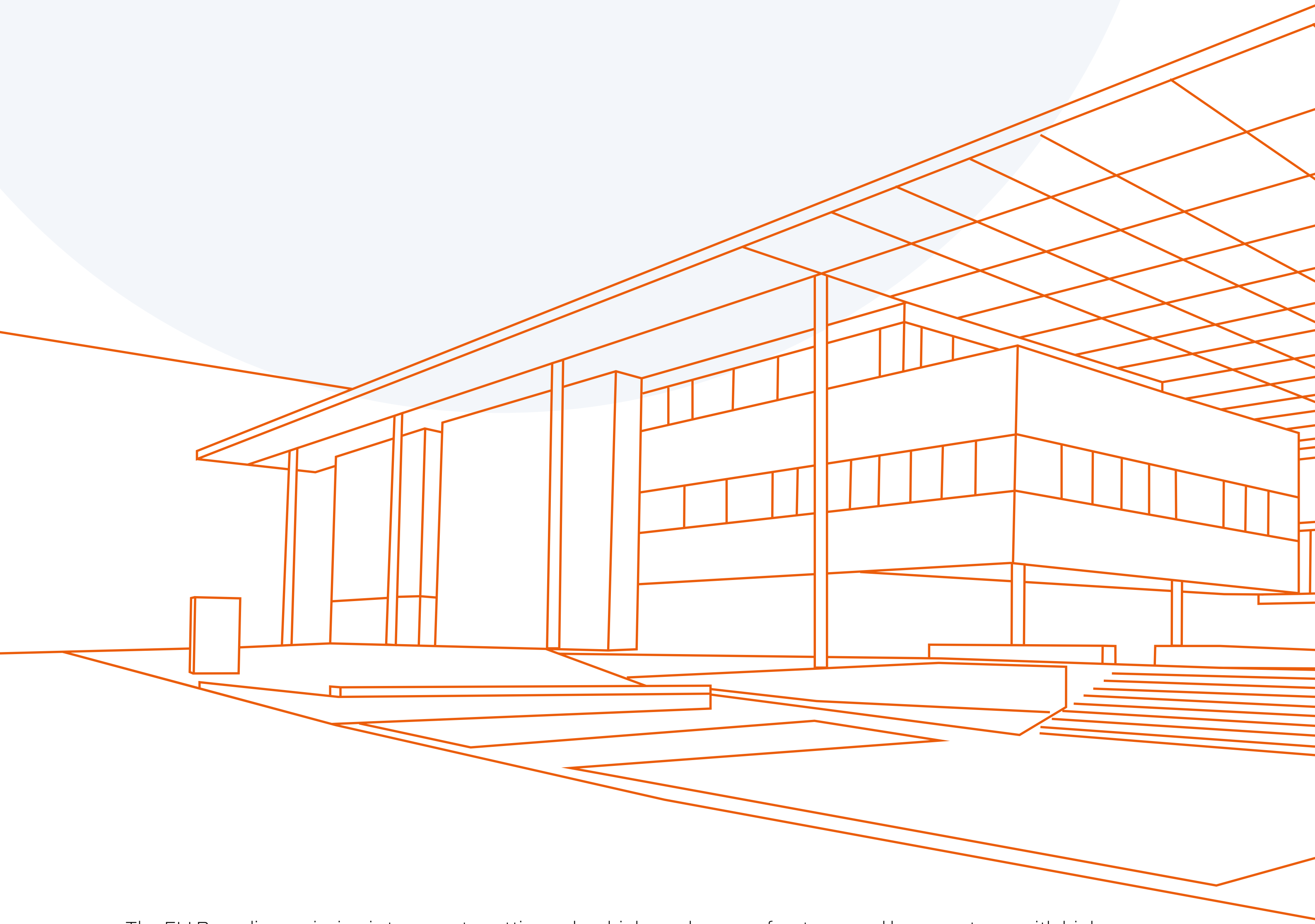
ELI ALPS Facility Layout





HF Physics (UFO)
SYLOS Alignment
10 Hz, 12 fs, 40 mJ
Chem Reac Contr
SYLOS 2
1 kHz, 7 fs, 35 mJ
HF PW
2,5 Hz, 25 fs, 10 J
Chem Reac Contr
THz
THz pump
50 Hz, 500 fs, 500 mJ
HE THz
ChemLab
RadioBiol
ience&NanoFab

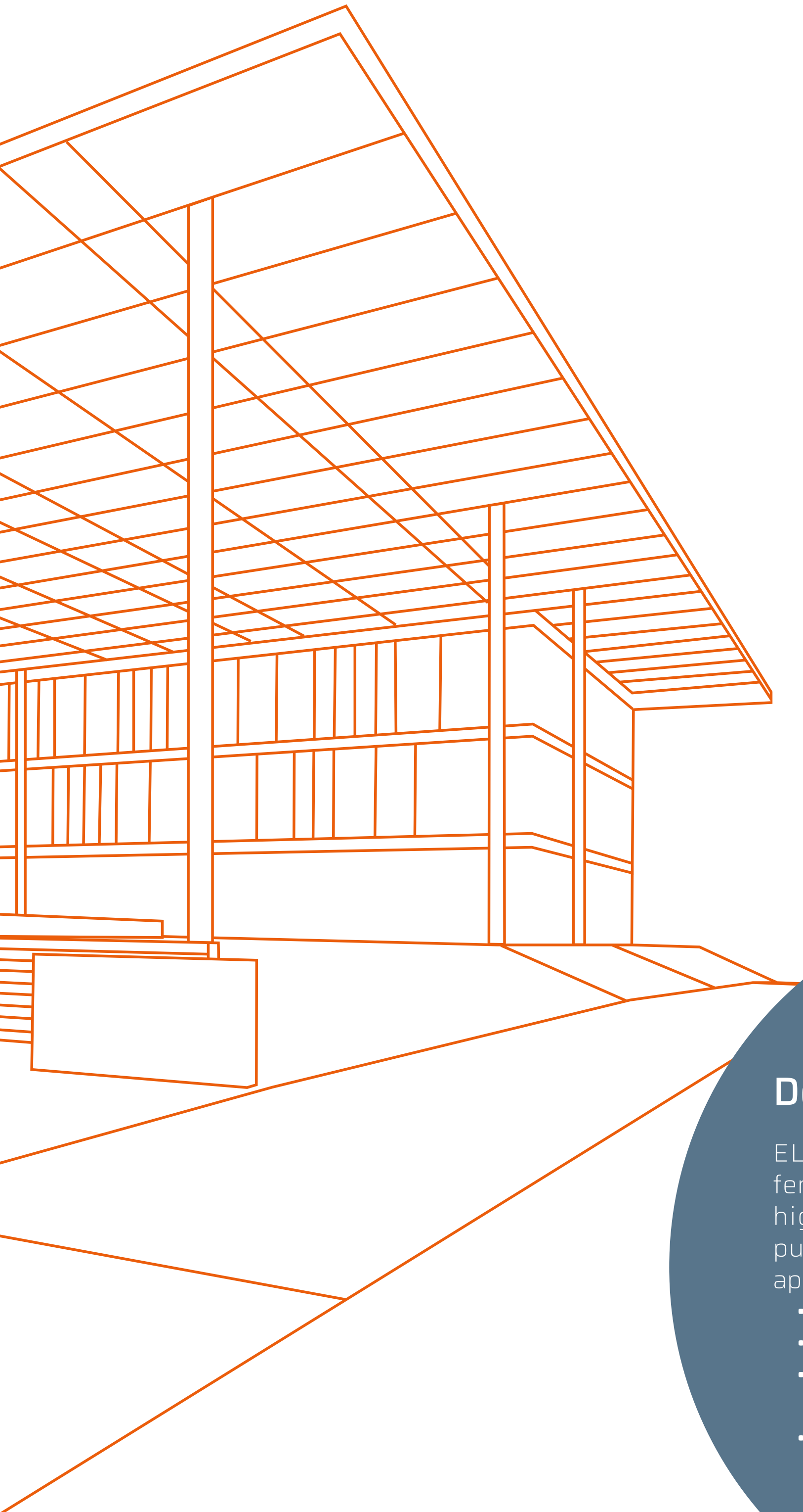
ELI Beamlines Facility



The ELI Beamlines mission is to operate cutting-edge, high-peak-power femtosecond laser systems with high-energy, high-repetition-rate capability, and secondary sources (X-rays and accelerated particles) with unique capabilities. This enables pioneering research in interaction of light with matter (plasma) at ultrahigh laser intensities. This is of large importance for front-edge high-field physics, nuclear fusion, and laboratory astrophysics, and also for materials science, biology, chemistry, medicine and other disciplines with strong multidisciplinary application potential.

ELI Beamlines hosts several primary sources and secondary sources as well as a variety of support laboratories, workshops, and other equipment required for efficient operations. The main focus of the activities aims to enhance the user access for the available experimental stations and complete commissioning activities for the other equipment and experiment chains. Additionally, the staff dedicated to operations of the primary and secondary sources are gaining further experience during commissioning in cooperation with a range of partners in order to better exploit the systems and technologies and demonstrate technical readiness of the high-power laser facility.

Roman Hvězda
is the Facility Director of ELI Beamlines and has been the Deputy Director of the Institute of Physics of the Czech Academy of Sciences for ELI and HiLASE projects and head of ELI Beamlines Division since 2014. He holds degrees in engineering and economics from Czech Technical University, RWTH Aachen (Germany), and the National Graduate Institute for Policy Studies (Japan). With a background in technology companies, policy formulation at the Czech Ministry of Education, and managerial experience, Hvězda's focus lies in fostering cooperation between research institutions and the private sector, knowledge and technology transfer, and managing large-scale research organisations. He joined the ELI Beamlines project in 2010 and has been instrumental in its success and growth.



Dolní Břežany, Czech Republic

ELI Beamlines operates high-peak-power femtosecond laser systems with high-energy, high-repetition-rate capability and short-pulse secondary sources for multidisciplinary applications in:

- Particle Acceleration (Ions and Electrons)
- Biomolecular Applications
- X-ray Sources Driven by Ultrashort Laser Pulses
- Plasma and High-field Physics

ELI Beamlines Primary Sources

The **L1-ALLEGRA laser** (Target design: 100 mJ, <20 fs, 1 kHz; current performance 30 mJ, 15 fs, 1 kHz) has been developed in house by the ELI Beamlines laser team. The concept of the laser is based entirely on amplification of frequency chirped picosecond pulses in an optical parametric chirped pulse amplification (OPCPA) chain consisting of a total of seven amplifiers. The OPCPA amplifier stages are pumped by precisely synchronized picosecond pulses generated by state-of-the-art thin-disk-based Yb:YAG laser systems.

The **L2-DUHA Laser** (Dual-beam Ultra-fast High energy OPCPA Amplifier) (Target 2024: 2 J, 25 fs, 80 TW, 20 Hz, Target 2026: 3 J, 25 fs, 120 TW, 50 Hz) is designed to provide 100 TW-level pulses at a high repetition rate (50 Hz) at 820 nm, falling between L1-ALLEGRA and L3-HAPLS in terms of peak power. L2-DUHA is the newest of the ELI Beamlines laser systems and is currently in development with expected completion in the first half of 2024. L2-DUHA is based on DPSSL-pumped OPCPA and offers advantages in terms of average power handling and contrast. In addition, the L2-DUHA laser has a synchronised mid-IR 5 mJ, 30 fs auxiliary output centered around 2.2 μm.

The **L3-HAPLS laser** (The High-Repetition-Rate Advanced Petawatt Laser System) (Target design: >30 J, <30 fs, 10 Hz, 1 PW, current performance 13.3 J, 27.3 fs, 3.3 Hz, 0.5 PW). This system was developed at the Lawrence Livermore National Laboratory, with ELI Beamlines cooperating on the development of the PW pulse compressor, the short-pulse diagnostics, and the short-pulse part controls and timing. The L3 HAPLS pump engine with design pulse energy of 200 J employs two Nd-doped glass amplifiers operating at 10 Hz and cooled by helium gas. Each amplifier is pumped by high power laser diode arrays, each providing an 800-kW peak power. These are the highest peak-power pulsed laser diode arrays in the world.

The **L4-ATON laser** system is designed to generate an extremely high and unprecedented peak power of 10 PW (Petawatt) in pulses with duration of 150 fs, pulse energy 1.5 kJ and repetition rate 1 shot per minute. At the long-pulse operation is now providing pulses with energy 1.2 kJ, duration 0.5 - 10 ns and repetition rate 1 shot per minute, which is more than one order of magnitude higher compared to other present-day kJ-class lasers. The system architecture is based on chirped amplification (CPA) in several successive stages of optical parametric amplifiers, followed by direct amplification in two types of Nd:glass laser discs., The laser was built by the consortium of National Energetics (USA) and EKSPLA (Lithuania), with major contribution of ELI Beamlines, which developed the 10 PW compressor and participated in development of numerous subsystems including the OPCPA preamplifiers, diagnostics or integrated electronic control system. The compressor has dimensions 18x4.5x3.6 m and weights 55 tons.

Dual-output kilohertz pump laser for high-energy picosecond OPCPA
A dual-output thin-disk picosecond laser operating at 100W with 1 kHz repetition rate is reported. By electronically adjusting the amplitude of the optical seed pulses injected into the laser cavity, the energy extracted from the gain medium can be shared between two pulses. Amplified double pulses are subsequently spatially separated into two independent beams by a fast Pockels cell, compressed in one common compressor, and frequency doubled with ~70% efficiency. This approach significantly decreases strain on the optics, as well as nonlinear effects. J. Novák et al., Optics Letters 47, 4869 (2022)

Secondary Sources

High harmonic generation (HHG): The HHG beamline uses high-order harmonic generation in gas to produce a stable source of coherent femtosecond pulses in the XUV spectral range. At this time the beamline is set to a 5 m focal length (although other lengths can be considered) and is ready to run with different noble gases with conversion efficiencies up to 5×10^{-6} for argon. The source supports 2nd harmonic generation before the HHG and can thus be operated in two colour ($\omega+2\omega$) mode, or by the 2nd harmonic only. HHG is a kHz source of ultra-short EUV pulses emitted with low-divergence in a coherent collimated beam of photons with energies in the range 10 eV - 120 eV. HHG operates at wavelength 5 - 120 nm with 10^9 - 10^{12} photons per shot.

Allegra Laser For Acceleration (ALFA) is the first user-oriented laser plasma electron accelerator of its kind, being based on the unique capabilities of the high average power, high repetition rate (1 kHz) L1-Allegra laser. ALFA enables users to carry out laser-matter interaction experiments at relativistic intensity (~5×10^{18} W/cm^2) and very high repetition rate (1 kHz). In addition, it delivers ultra-short electron beams (few fs) at a tunable frequency (up to 1 kHz) and with tunable energy (a maximum of 50 MeV).

The Plasma X-ray Source (PXS): This is an incoherent source of hard X-ray radiation operating with the in-house developed L1 Allegra. X-ray radiation is in the spectral range of 3 - 77 keV. Using an off-axis parabola, the laser beam is focused onto a continuously restoring solid-density target, enabling long-term 1 kHz operation of the beam line. The beam delivery chamber and the plasma interaction chamber are separated by an anti-reflection (AR)-coated quartz window to suppress contamination of the beam transport system by debris. The X-ray output port has three output Beryllium windows: two for user end stations and one for the X-ray emission monitor.

The **Betatron/Compton beamline** will use the L3 PW-class, 10 Hz repetition rate laser and the L2 100 TW-class, 50 Hz laser. After completion in 2024, it will provide X-ray photons from keV up to a few MeV energies. An intense laser pulse propagating in an under-dense plasma can drive a relativistic plasma wave in which electrons can be injected and accelerated to relativistic energies, being trapped in the ion cavity and oscillating across the cavity axis at a period called the betatron period, thus emitting synchrotron-like X-ray radiation with peak brightness of the order of 10^{22} ph/0.1% BW/s/mm^2/mrad^2. The **Compton source** operates by colliding a relativistic electron bunch and an intense laser pulse.

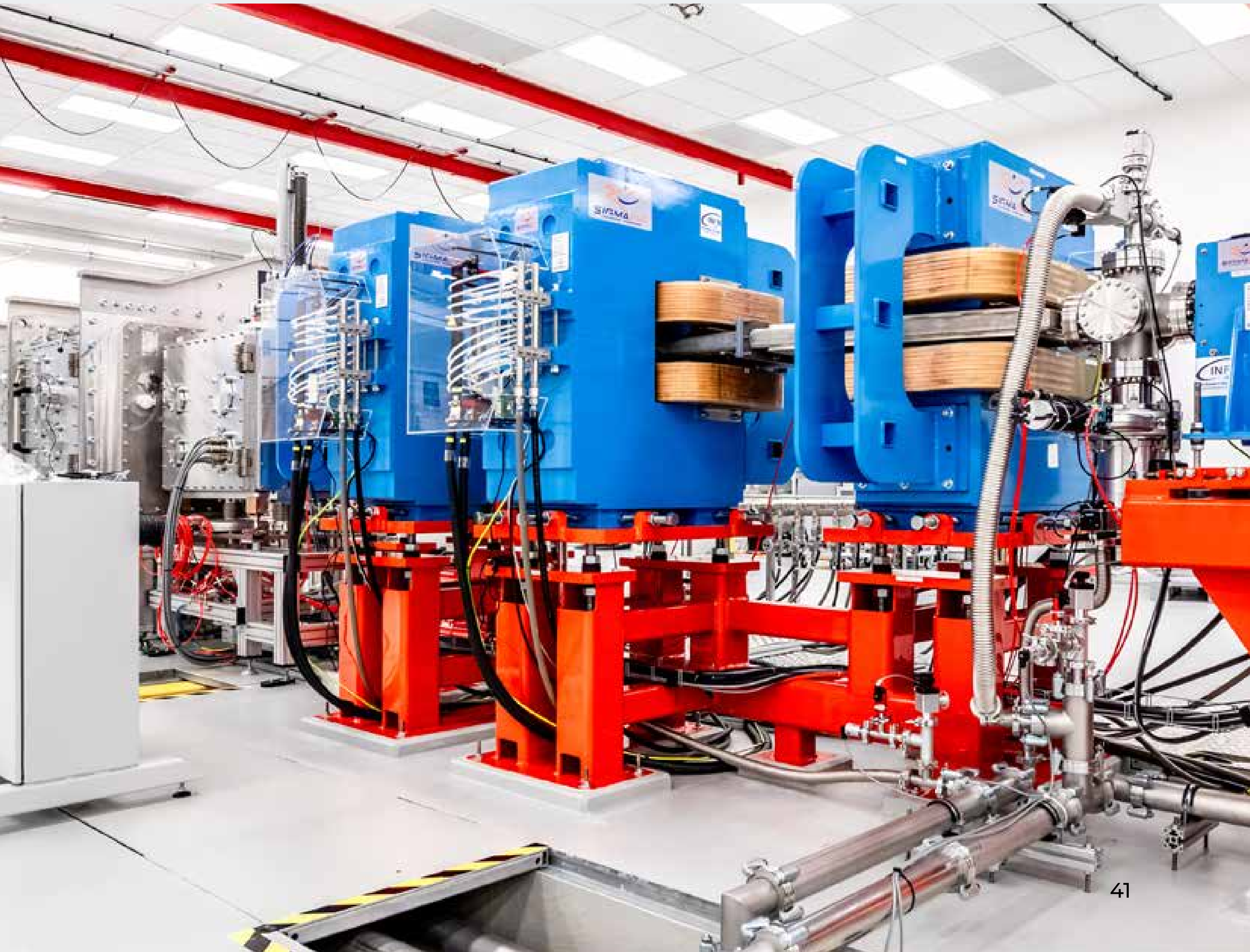
The **ELI Multidisciplinary Applications of laser-Ion Acceleration (ELIMAIA)** beamline is dedicated to user experiments based on ion acceleration or applications of ion beams in multidisciplinary fields. The PW-class, high repetition rate L3-HAPLS laser is focused down onto solid targets to reach ultrahigh laser intensities (>>10^{21} W/cm^2) and generate proton beams with unique features such as ultrashort bunch duration (<ns), high current per pulse (>10^{11}), and high cut-off energy (up to 100 MeV).

The ELIMAIA Laser-Plasma Ion Accelerator: Technological Commissioning and Perspectives

Technological commissioning of the Laser-Plasma Ion Accelerator section of the ELIMAIA user beamline. The high-peak, high-average power L3-HAPLS laser system was used with an energy of ~10 J and pulse duration of ~30 fs on target, both in single-pulse and high repetition-rate (~0.5 Hz) mode. The laser pulse was tightly focused to reach ultrahigh intensity on target (~10^{21} W/cm^2) and sustain such laser- plasma interaction regime during high repetition-rate operations. The capability and reliability of the ELIMAIA Ion Accelerator was successfully demonstrated. F. Schillaci et al., Quantum Beam Sci. 6, 1 (2022)

Electron Beam Accelerator (ELI-ELBA) beamline serves both fundamental sciences and applications. As electron acceleration technique, ELI-ELBA experiments are based on Laser Wake Field Acceleration (LWFA), which is at the state of the art capable of producing very energetic (1 - 10 GeV) ultra-short (fs) electron beams by its extremely high accelerating gradients (>100 MeV/mm). At the same time, ELBA will use the L2 100 TW-class, 50 Hz laser and will be offered to users as an experimental platform for basic science studies in the area of high-field physics, such as quantum electrodynamic processes (QED).

The **Laser Undulator Illuminating Source (LUIS)** beamline will deliver (after completion in 2024) incoherent undulator XUV radiation photon (e.g. in the 'water-window' spectrum) to users from material and biological sciences. Furthermore, the beamline aims at improving the electron beam performances to reach the requirements determined by SASE free-electron laser operation. Realisation of this research program will open the way to build a new-generation compact laser-driven FEL, providing the user community an highly desired tool for medicine, biology and material science.



Scientific Endstations and Experimental Platforms

The **Multipurpose station for Atomic, Molecular and Optical science and Coherent Diffractive Imaging (MAC):** a Multi-purpose chamber for AMO (Atomic, Molecular, and Optical) sciences and CDI (Coherent Diffractive Imaging), connected to the HHG secondary source. It can house different types of targets and can be equipped with a range of diagnostic tools. The design of the MAC vacuum chamber is similar to that of the LAMP chamber in the AMO station at LCLS and the CAMP chamber now located at FLASH, DESY. At present the following spectrometers and detection systems are operational or in the commissioning pipeline: Electron and ion Time of Flight spectrometers (in house development) and the Velocity Map Imaging with ns gated imaging detector.

The **Hard X-ray endstation TREX**, is a modular station for Time Resolved Experiements (scattering, diffraction, spectroscopy, pulse radiolysis and imaging) with X-rays, connected to the PXS secondary source. The combination of X-ray pulses with sub-picosecond duration and perfectly synchronized and tunable UV-VIS-IR „pump" pulses is the foundation for the development of the end station for X-ray scattering and diffraction (XRD), X-ray absorption spectroscopy (XAS) and phase contrast imaging. Due to the modular design of this TREX area we will be able to switch rapidly between the main experimental modes and even to move parts of the experimental set up to other locations, e.g the Betatron beamline.

Time-resolved Spectroscopic Ellipsometry (trELIps) and Transient Current Technique (TCT):
trELIps with femtosecond time resolution is a technique for monitoring ultrafast changes in the dielectric function of a material after the excitation by an ultrashort laser pulse. The technique is based on the pump-probe approach.

The **TCT** is a tool for the characterisation of ultrafast semiconductor detectors. The technique is based on the recording and analysis of the transient current pulse, originating from the drift of charge carriers generated by ultrashort laser pulse in the electric field inside a biased sensor. The signal can be measured at different conditions with various parameters such as bias voltage, laser pulse energy, position of the charge generation and temperature.

2.4-Å structure of the double-ring Gemmatimonas phototrophica photosystem
Phototrophic Gemmatimonadetes evolved the ability to use solar energy following horizontal transfer of photosynthesis-related genes from an ancient phototrophic proteobacterium. The electron cryo-microscopy structure of the Gemmatimonas phototrophica photosystem at 2.4 Å reveals a unique, double-ring complex. This structural and functional study shows that G. phototrophica has independently evolved its own compact, robust, and highly effective architecture for harvesting and trapping solar energy. P. Qian et al., Science Advances 8, (2022)

Femtosecond Stimulated Raman Spectroscopy (FSRS) and Ultrafast Transient Absorption (TA):
FSRS is an experiment that allows monitoring Raman active vibration of molecules with sub-ps time resolution. When used with reactions that can be triggered, ideally photo-triggered, it is a powerful tool to follow reaction dynamics and structural changes with high time resolution and high acquisition speed.

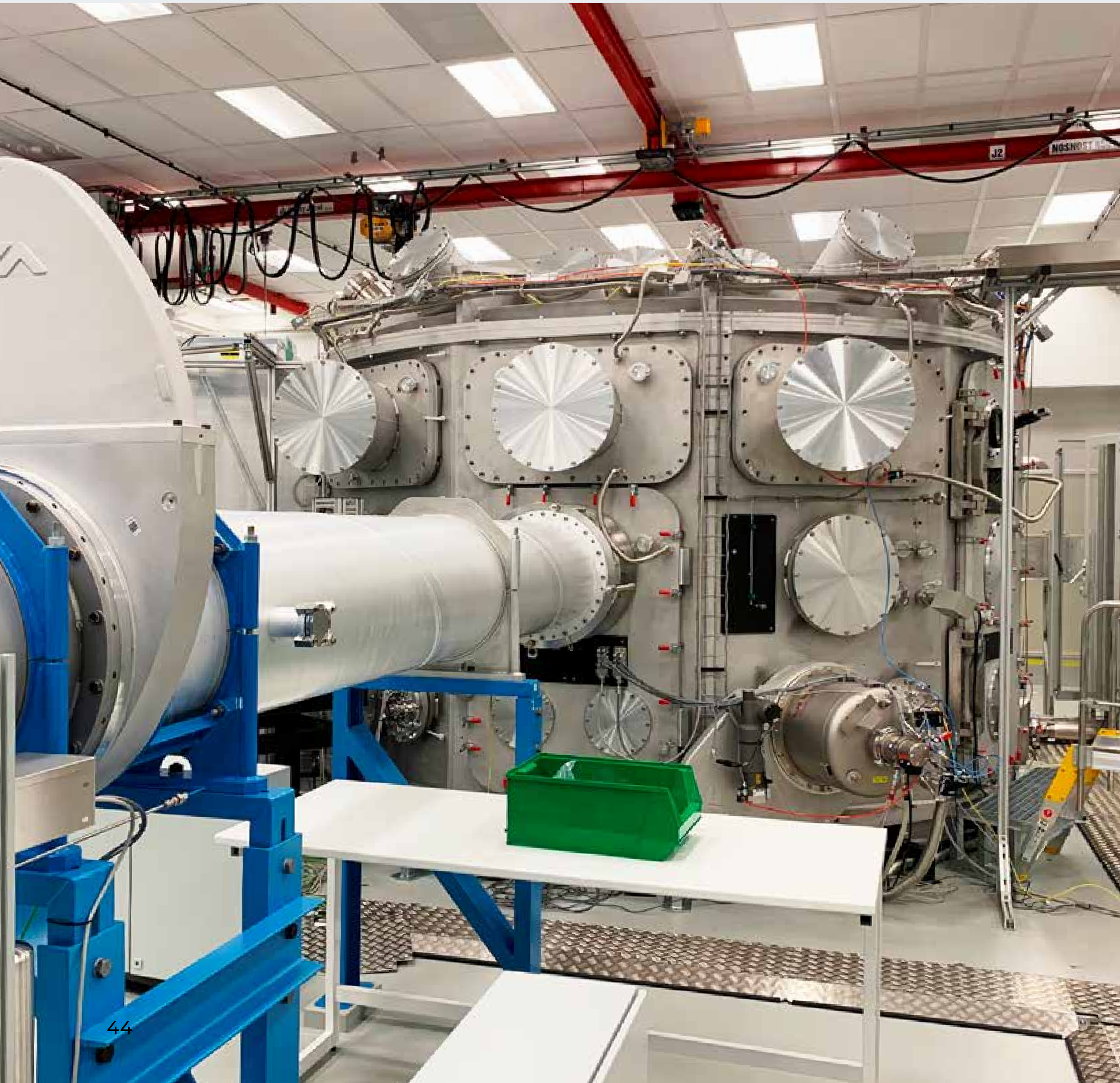
The purpose of the **TA** setup is to measure laser-induced transient change of absorption of liquid and solid samples at UV/VIS/NIR spectral region at room temperature. Resolvable timescales range from tens of fs to 0.5 ms.

The **ELIMED** station will enable users to carry out pre-clinical research for future applications in cancer therapy, such as irradiation of biological cells with short bunches of protons/ions and ultra-high-dose rate (also known as "flash radiotherapy"), accelerated by the L3-HAPLS laser. ELIMED has been designed and built by the National Institute for Nuclear Physics (LNS-INFN). ELIMED is equipped with online absolute and relative dosimetry devices and an ion irradiation system that can be used for applications in various disciplines, such us biology, medicine, material science and analysis. It has also implications in cultural heritage and archeology.

The **Plasma Physics Platform (P3)** is a unique multi-functional experimental infrastructure designed to perform laser-plasma and laser-matter interaction research predominantly on the following topics: High energy density physics (HEDP), Inertial Fusion Energy (IFE), Warm dense matter (WDM), Plasma optics (PO), Laboratory astrophysics (LA) and Ultra-high intensity interaction (UHI). P3 unique infrastructure includes up to 5 synchronised laser beams (from fs to ns pulse duration), a large versatile vacuum chamber (~45 m^3), a pulsed power device for magnetic field generation (>50 Tesla), a a Betatron source for diagnostic purposes, an optical switchyard and manipulation station (MOB) including delay lines, frequency conversion, leakage optics for pulse characterisation, adaptive optics, etc.

Nonlinear Compton scattering in time-dependent electric fields beyond the locally constant crossed field approximation

Exploring Locally Constant crossed Field Approximation (LCFA) in detail for photon emission by a spinless particle in a strong time-dependent electric field. These kinds of electromagnetic fields, in contrast to the comprehensively studied case of a plane wave, are not crossed. We develop an approach for calculating photon emission probability in a generic time-dependent electric field, establish the range of applicability of LCFA, and calculate the corrections to it. E. G. Gelfer et al., Phys. Rev. D 106, 056013 (2022)



Research & Development

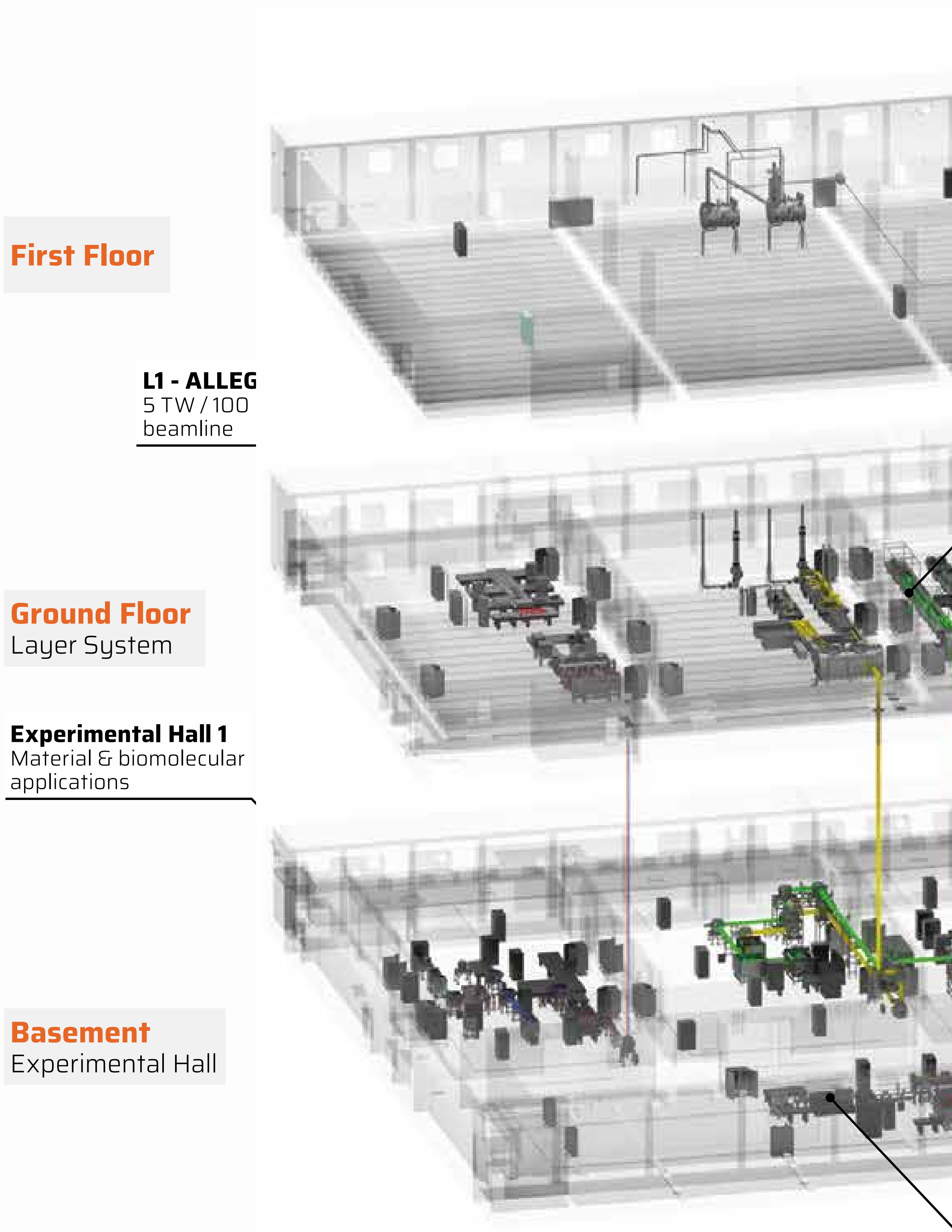
The High Field Initiative (HiFI) R&D project was established to be the leading project in the high-field science. It emphasises synergies between theory and experiments and building a strong theoretical group to develop new ideas for experiments, in parallel conducting extensive computer simulations. The project advances knowledge of laser accelerated electrons and ions as well as high energy photon generation. It aims at studying novel regimes when radiation friction and quantum electrodynamics processes, such as electron-positron pair creation and vacuum polarisation, become significant.

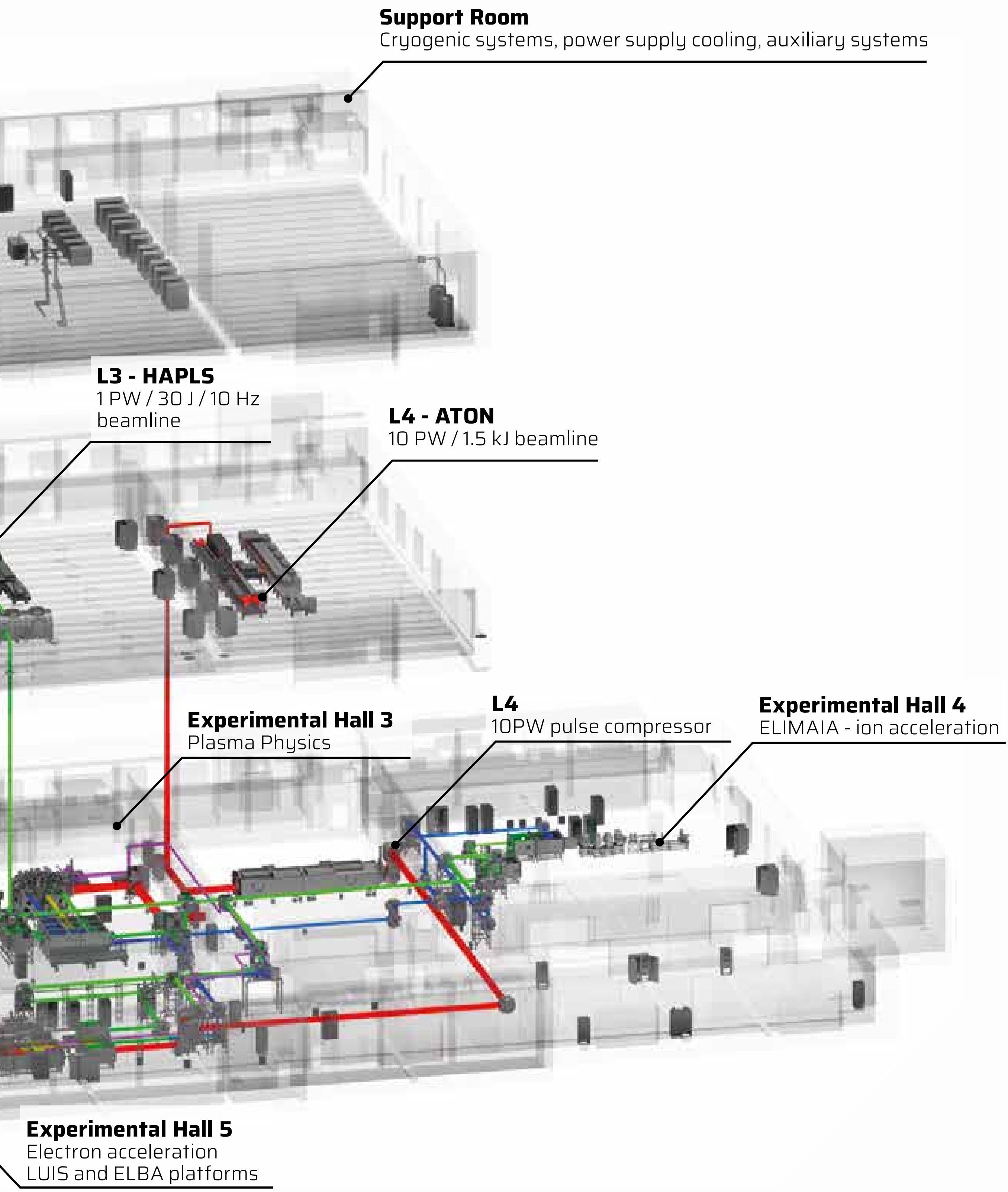
Electron-positron pairs and radioactive nuclei production by irradiation of high-Z target with γ-photon flash generated by an ultra-intense laser in the λ3 regime

Monte Carlo simulations of the interaction of laser-driven γ photons and high-energy charged particles with high-Z targets with focus on Lead. The results reveal an ultra-short, ultra-relativistic collimated positron population, describing their energy spectra, angular distribution, and temporal profile. Because of the short pulse duration, the γ photon, electron-positron, and neutron sources could find applications in material science, nuclear physics, laboratory astrophysics, and injectors in laser-based accelerators of particles. D. Kolenatý et al., Phys. Rev. Research 4, 023124 (2022)

The **ELIBIO** project explores new frontiers in light and optics to create breakthrough science in biology, chemistry and physics. An essential goal of the project is to understand photon-material interactions in extremely intense X-ray fields where new physics can be expected. The experiments explore fundamental questions in the physics of photoemission and electron dynamics in the relativistic regime with X-rays. The new knowledge in studies on structure, function and dynamics in cells, organelles, and biomolecules is used to perform experiments that were impossible so far. The research team of ELIBIO is formed at the interface between two complementary research centres, ELI Beamlines oriented to photon physics and BIOCEV oriented to biomedical and biotechnological research.

ELI Beamlines Facility Layout




Support Room
Cryogenic systems, power supply cooling, auxiliary systems
L3 - HAPLS
1 PW / 30 J / 10 Hz
beamline
L4 - ATON
10 PW / 1.5 kJ beamline
Experimental Hall 3
Plasma Physics
L4
10PW pulse compressor
Experimental Hall 4
ELIMAIA - ion acceleration
Experimental Hall 5
Electron acceleration
LUIS and ELBA platforms

03

Partners and Collaborations

Partners & Collaborations

Collaboration is a driving force for scientific research, as it fosters cross-disciplinary exchange, accelerates discovery, and maximises the impact of collective expertise. In this era of interconnectedness, where scientific questions are increasingly multifaceted, collaboration has become essential for success in research facilities, enabling scientists to pool resources, share ideas, and tackle grand challenges that would be otherwise insurmountable. ELI fully embraces collaboration with a diversity of partners and collaborators to unlocking new frontiers and ushering in a new era of scientific advancement.

78

Institutes

23

Countries

Ongoing Collaborations

Romania

ELI Nuclear Physics (ELI-NP) in Magurele, Romania, is focused on laser-based nuclear physics. It will host two machines, a very high intensity laser, where beams from two 10 PW lasers are coherently added to get intensities of the order of 10^{23}–10^{24} W/cm^2, and a very intense, brilliant gamma beam obtained by incoherent Compton back scattering of a laser light off a brilliant electron beam from a conventional linear accelerator. Applications include frontier fundamental physics, new nuclear physics, astrophysics, nuclear materials and radioactive waste management. ELI-NP has made significant progress with the 10 PW lasers, demonstrating short pulses at full energy and recently focusing those pulses to a high intensity on solid targets.

ELI-NP is an active partner and contributor in IMPULSE. IMPULSE serves as a bridge between the ELI Facilities and enables strong collaboration and convergence at all levels. Within the framework of the IMPULSE project collaborations are ongoing, in particular with regards to the joint user programme but also in numerous scientific and technical areas as well as on innovation and communication. ELI-NP recently hosted an event on the standardisation of metrology procedures for lasers and secondary sources (STAMPLASS) which is a key activity for the laser community and will benefit ELI as a whole. Reliable solutions and accepted protocols for the metrology of high-peak power, high-repetition rate lasers and secondary sources are critical for enabling excellent research and user access at ELI.

In a decision made during ELI ERIC's 8th General Assembly (GA) Meeting on 13 June 2023, Romania was accepted as a Founding Observer to ELI ERIC. This is an important development in the relationship between ELI ERIC and the ELI-NP Facility which Romania is hosting. This decision opens a new chapter in the alliance, laying the groundwork for the facility to integrate into the ELI ERIC organisation over the next three years.

Czech Republic

Within the Czech Republic, ELI Beamlines cooperates closely with the large laser centers, **PALS**, Institute of Plasma Physics and **HiLASE**, Institute of Physics both part of the **Czech Academy of Sciences**. The collaborations range from joint projects, joint development of new technology to exchange of scientific staff. There are also long-term collaborations with universities, the **Czech Technical University** and **Charles University**, for joint education of students and specific scientific cooperation. The processing of huge amount of data generated at ELI Beamlines is done in cooperation with the national center for computing and data storage infrastructure, **CERIT-SC Center** at the **Masaryk University** in Brno. Several high-tech Czech companies co-developed components of the technology at Beamlines, in particular **Delong Instruments** in Brno, **Streicher** in Plzeň, **CRYTUR** in Turnov and **ATEKO** in Hradec Králové. Another significant collaboration with the **Institute of Photonics and Electronics** of the Czech Academy of Sciences develops of 3D-printed foam targets. These targets have gained considerable importance in the last few years for dedicated laser-plasma interaction experiments in controlled plasma environments. ELI Beamlines also collaborates with the **Institute of Archaeology** of the Czech Academy of Sciences on non-destructive testing of archeological monuments.

Denmark

ELI collaborates with **Aarhus University** (and other partners) on one of the IMPULSE Flagship experiments on XUV Tuning, studies of collective dynamics at the nanoscale using intense, tunable XUV pulses from High-Harmonic Generation. The extension of the applicability of the developed method covers a wider range of targets and XUV energies, and introduces pump-probe capabilities. The ability to tune ultrashort VUV-XUV pulses to selected absorption edges gives unique capabilities to study properties and functions of nano-engineered samples. The equipment which will be employed includes the L1 Allegra Laser, the E1 HHG beamline and the MAC experimental station, Multipurpose end station for AMO (Atomic, Molecular and Optical) and CDI (Coherent Diffractive Imaging).

France

ELI ALPS collaborates with various partners in France to develop advanced laser-driven technologies. The collaboration with **SourceLab** was initiated to create a reflection-based PW laser-driven SHHG beamline capable of generating high-energy XUV-Xray pulses. The focus is on achieving single-shot operation and potentially increasing the repetition rate in the future. The collaboration with **Laboratoire d'Optique Appliquée** (LOA) at **Ecole Polytechnique**, was aimed at developing a Solid High-Harmonic Generation (SHHG) beamline driven by the SYLOS laser family. This beamline would generate high-energy attosecond pulses for studying nonlinear short-wavelength processes in different states of matter. **ARDOP** is assisting ELI ALPS in implementing the SYLOS laser-driven SHHG beamline for pump-probe-based laser plasma metrology and XUV experiments. **Amplitude**, a leading manufacturer of PW-class lasers, collaborates with ELI ALPS to develop high-repetitionrate high-field light sources, aiming to achieve few-cycle 2 PW pulses at 10 Hz. Additionally, ELI Beamlines and **CELIA-CNRS** collaborate Proton-Boron Fusion using high-power lasers.

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Germany

The German Ministry of Education and Research (BMBF) have funded an initiative at ELI ERIC on Laser Induced Fusion. The initiative aims to explore opportunities and determine priorities for work on enhanced scientific insights and technological development towards laser-fusion based energy, and in particular the role ELI might play. A kick-off workshop with representatives of ELI and the German research community will be organised in autumn 2023. ELI ALPS is engaged in collaborative projects with several partners in Germany. The Nonlinear ATTO project conducted by ELI ALPS in collaboration with FORTH (Greece) and the **University of Freiburg** and **MPI für Kernphysik in Heidelberg**, aims to perform double ionization of helium and attosecond spectroscopy in molecules using the SYLOS Compact GHHG and Reaction Microscope (ReMi) endstation. The time-resolved NanoESCA experiments, in partnership with the **Technical University of Kaiserslautern**, focus on surface science and the study of hexagonal boron nitrate. Additionally, ELI ALPS and **Class 5 Photonics** are jointly developing a mid-infrared OPCPA source and an attosecond beamline to achieve water window to X-ray harmonics. These collaborations highlight cutting-edge research in various scientific domains, such as attosecond spectroscopy, surface science, and mid-infrared optics. **Helmholz Zentrum Dresden Rossendorf (HZDR), Technische Universität Darmstadt (TUD) and Ludwig-Maximilians-Universität München (LMU)**, are all partners in the IMPULSE project and contributing on a variety of aspects. TUD is developing new targetry capabilities with the creation of a Macropixel and Macropixel-based particle and radiation detector. HZDR and LMU are contributing to the development of metrology diagnostics, procedures, and planning of cross-calibrations campaigns on specific topics, specifically, LMU is cooperating with Beamlines in developing characterisation techniques by carrying out measurements of the spatial-temporal coupling effect using the L3-HALPS laser beam. HZDR is also contributing to the development of the user management process and data management as well as a flagship experiment.

Greece

Collaborators at **FORTH** designed and developed a unique gas-source-based high-harmonic generation beamline driven by the SYLOS laser to achieve high XUV flux in form of attosecond pulse trains and single attosecond pulses. In consecutive user campaigns FORTH researchers have demonstrated nonlinear XUV processes. A second user campaign for the fabrication of periodic subphase structures using Mid-IR laser radiation was also implemented.

Hungary

ELI ALPS, in collaboration with various partners, is pushing the boundaries of research and development. The **University of Szeged's National Laser-Initiated Transmutation Laboratory** joins forces with ELI ALPS to create advanced laser-based neutron sources, facilitating applications in medical and materials science, nuclear resonance spectroscopy, neutron imaging, and cultural heritage exploration. The **Biological Research Centre** collaborates on multidimensional optical spectroscopy workstations and investigates the impact of strong THz fields on light-induced processes. The **Wigner Research Centre** contributes to the development of femtosecond time-resolved Raman spectroscopy, novel laser-based particle acceleration methods, and the ultrafast nanoscience program. **ATOMKI** aids in developing particle detection instrumentation, while the **University of Pécs** designs THz sources for ELI ALPS. These collaborations have yielded significant progress in respective fields, marked by successful user experiments and advancements in research capabilities.

Italy

The **INFN-LNS** in Catania has been working on the design and implementation of the ELIMED beamline for ion beam transport, dosimetry and sample irradiation systems for ELI Beamlines over the past 10 years. ELIMED will be a core technology to conduct clinically relevant research in the field of cancer therapy and will be used as a flagship experiment at ELI Beamlines on the Flash and Ultrahigh Dose-Rate Radiobiology with Laser Accelerated Ions for Medical research (FLAIM) within the IMPULSE project. The **CNR-IFN** in Milano and Padova has collaborated on the design of two of the ELI ALPS attosecond beamlines and contributed to their implementation, which after commissioning, resulted in the first attosecond pulses at ELI ALPS with its own equipment in 2019. Design and commissioning of a time-compensated monochromator for high-order harmonics was provided to both ELI ALPS and ELI Beamlines. The joint work with the ELI Facilities has been continuing in the form of user experiments and the development of an XUV polarimeter device in the framework of the IMPULSE project. **Elettra Sincrotrone Trieste** has collaborated with ELI Beamlines in the implementation of the HELL platform and in the field of technology transfer. Assistance in the development at ELI ALPS of a Personnel Safety System (PSS) and of several organisational aspects was provided. Key technologies for enhanced experiments, enabling excellent user access and fostering ELI's innovation impact are the contributions within the IMPULSE project. ELI Beamlines also cooperates with **CNR-INO** in Pisa for high-power laser diagnostics to optimise the LWFA performances and further activities including contributions to the ELIMAIA commissioning. There is also cooperation with Italian partners in EuPRAXIA.

Japan

Engagement with Japan has increased with several visits by Japanese delegations of Ambassadors, scientific attachés, and scientists to both ELI ERIC Facilities. A workshop on ELI-Japanese opportunities for closer collaboration in laser science and technology was held in as a satellite event to the 2023 OPIC meeting in Yokohama. An agreement has been signed between ELI NP, **Okamoto Optics** and the **Institute of Laser Engineering of Osaka University (ILE)** to establish a high-power laser optics center that will make or repair optical components for NP and the wider community of laser facilities. **ILE Osaka** also collaborates with ELI Beamlines on the topic of Proton-Boron Fusion using high-power lasers.

Lithuania

EKSPLA and **Light Conversion**, the two leading Lithuanian laser manufacturers formed a consortium in 2014 to deliver the 1 kHz SYLOS laser for ELI ALPS. The joint work of these three organisations keeps pushing the boundaries of state-of-the-art OPCPA technology, invented at Vilnius University Laser Research Center by Lithuanian research group of prof. A.Piskarskas and prof. A.Dubietis, as of today. The collaboration recently resulted in the SYLOS 3 system, which produces unprecedented set of parameters - 120 mJ, 8 fs pulses at 1 kHz. SYLOS 3 will be the driving source for attosecond pulse generation permitting cutting-edge 4D imaging, as well as a supreme particle acceleration driver reaching exceptionally large XUV/X-ray intensities leading to extreme short wavelength science, all of which opens up new possibilities for discoveries in industrial, biological and medical applications. At ELI Beamlines, EKSPLA was part of the consortium delivering the L4 laser contributing with the front end pump lasers, as well as the long pulse front-end laser, in addition to providing the capacitor banks for the kilojoule amplifiers.

Poland

There is strong cooperation between ELI and a variety of institutes and partners in Poland. The Polish scientific community has been an active collaborator of ELI with contributions in the ELI Preparatory Phase and ongoing collaborations such as joint experiments and the construction of unique instruments, as well as student training and exchanges. In Spring 2023 an ELI ERIC information day was organised at the Henryk Niewodniczański **Institute of Nuclear Physics Polish Academy of Sciences (IFJ)** with participants from the **ELI-Polska Consortium**. Current collaboration and ongoing projects include the construction of a Time Projection Chamber (ELITPC) as a collaboration between **Warsaw University** and the ELI-NP Facility. In addition, ELI Beamlines has a long-term project with Polish research centre **Solaris** focusing on X-ray spectroscopy. These efforts have led to compelling results in joint scientific publications, user and R&D experiments and developments in research topics such as laser-plasma diagnostics, magnetic fields, and Proton-Boron Fusion. ELI Beamlines collaborates extensively with the **Institute of Plasma Physics and Laser Microfusion in Warsaw** on laser-accelerated high-energy electron beams, one of the key secondary sources, using a wide range of focal lengths of the focusing optics.

Spain

The **Spanish Center for Pulsed Lasers (CLPU)** in Salamanca has been an longstanding collaborator of ELI with ongoing cooperations in particular in IMPULSE. CLPU is actively contributing to the standardisation of metrology procedures for lasers and secondary sources and published a paper on the metrology of laser-driven ions. To strengthen ELI's relationship and connections to the scientific community in Iberia several activities were held in the past including engagement with the Spanish Industry Liaison Office and diplomats. ELI Beamlines and CLPU collaborate within projects like RADNEXT and EUPRAXIA and the COST action Probono on the Proton-Boron Fusion using high-power lasers and on development of new generation of the laser-driven Proton source.

Sweden

Collaborators at **Lund University** designed and developed a unique gas-source-based high-order harmonic generation beamline driven by the SYLOS laser. Its uniqueness comes from its size, since its beam path is more than 70 m long. Based on loose focusing geometry the main target is to achieve high-flux attosecond pulses in the sub 100 eV to observe non linear XUV-XUV processes, while keeping the option for XUV-IR and XUV post generated pulse pump-probe experiments. In a user campaign they performed detailed studies on the conversion efficiency of the harmonics, with a comparative study of the harmonic yield from different cell lengths and target pressures. ELI Beamlines also collaborates with the **Uppsala University** in methods development and exchange of equipment in the areas of molecular dynamics and material science. The main exchange of equipment is the placement of a laser system from Uppsala in the E1 experimental hall that has allowed to move rapidly into user operation.

Switzerland

Bilateral agreements between the Swiss Research Ministry (SERI) and the respective Research Ministries of Hungary and the Czech Republic are being established to provide financial support for existing and future cooperation between ELI and Swiss organisations that include **Eidgenössische Technische Hochschule Zürich (ETH Zürich)**, **Paul Scherrer Institute (PSI)** and **École polytechnique fédérale de Lausanne (EPFL)**. ELI has engaged with the **Swiss Society for Photon Science (SSPh)** for the dissemination of information about ELI among Swiss researchers.

USA

ELI Beamlines is involved in several collaborative projects with partners from different institutions. In collaboration with the **University of California, San Diego** and funded by the U.S. National Science Foundation and the Czech Science Foundation, the goal is to generate dense gamma-ray beams similar to those produced by stellar objects like pulsars. Reproducing this phenomenon on Earth requires creating a dense cloud of high-energy photons, a challenging task that has yet to be achieved. A collaboration with the **University of Michigan** and **Lawrence Berkeley National Laboratory**, focuses on strong field quantum electrodynamics (QED) plasma physics. The project aims to develop tools for modelling experiments at high-power laser facilities, where extreme electromagnetic fields can accelerate particles and generate matter-antimatter pairs. One of the IMPULSE Flagship experiments is an international collaborative **MULTI-LPI-P3** which aims for the characterisation of shocked material with a variety of diagnostic tools using synchronised multi-beam configurations. The pulse-shaping capabilities of the L4n driver beam allows to access EOS off the Hugoniot, thereby providing new insight into complex, dynamic states of matter under extreme conditions. Focus on L4n capabilities with Visor SOP diagnostics. It uses of one of the User Assisted commissioning experiments. Prof. Robert Baker from **Ohio State University** (OSU) is working on ultrafast, high-intensity laser science as part of the Fulbright John Von Neumann Distinguished Award in STEM at ELI ALPS. His collaboration aims to develop new techniques for studying electron dynamics in solar energy conversion materials and foster international research collaborations through the NSF NeXUS programme. ELI also collaborates with OSU within the program Extreme Light in Intensity, Time, and Space (X-lites) funded by the National Science Foundation through International Network-to-Network Collaborations (AccelNet) programme.

United Kingdom

ELI ALPS collaborates with partners in the United Kingdom to advance laser-driven technologies. Experts of **John Adams Institute (JAI)** work with ELI ALPS to implement the eSYLOS and ePW electron beamlines, generating X-rays for applications in betatron imaging, flash radiobiology, and volumetric material inspection. ELI ALPS also collaborates with **Queen's University Belfast (QUB)** to develop a world-first 1 kHz ultra-short and tunable positron source using the eSYLOS beamline's electron output. QUB specialises in laser-driven positron sources and their applications in material scanning and defect detection. Additionally, ELI Beamlines collaborates with QUB on the Flash and Ultrahigh Dose-Rate Radiobiology with Laser Accelerated Ions for Medical research (FLAIM) flagship experiment, investigating ion acceleration with a PW-class laser at ELIMAIA for medical purposes including on ELIMAIA implementation and also on the ELIMED commissioning. The experiment involves on-target laser and ion diagnostics, as well as dedicated ion beam transport and also innovative all-optical beam transport system based on the "coil target" technology developed within the IMPULSE project.

IMPULSE

Project information

Project acronym: IMPULSE

Project full name: Integrated Management and reliable operations for User-based Laser Scientific Excellence

Grant Agreement number: 871161

Beginning of project: November 2020

End of project: April 2024

Total budget: ~ 20,000,000 EUR

Website: impulse-project.eu/

The IMPULSE project aims at achieving a quick and effective transition of the Extreme Light Infrastructure from construction into sustainable, unified operations. IMPULSE addresses the key scientific, technical, organisational, and management requirements of this transition, building user communities and expanding the ELI member consortium. Though IMPULSE focuses primarily on ELI, its results will impact all European high-power laser facilities.

As IMPULSE entered the second half of the project period the non-scientific work packages continue to build on administrative and support functions which will serve as the basis for the future integrated management system of ELI ERIC. The scientific and technical work is also ramping up with activities dedicated to defining joint technical standards and procedures for example in metrology, identifying synergies in particular areas such as a joint spare parts database and training as well as services related to users and access to the Facilities.

IMPULSE has initiated a variety of activities not just between the ELI Facilities but for all project partners. One of the main goals of the project is to strengthen the exchanges and connections between the partners and establish a network of collaborators which all together drive science and innovation with laser technologies.

ELI ERIC (Extreme Light Infrastructure European Research Infrastructure Consortium)

ELI ALPS (ELI-HU Kutatási és Fejlesztési Nonprofit Közhasznú Korlátolt Felelősségű Társaság)

ELI-NP (Institutul National De Cercetare-Dezvoltare Pentru Fizica Si Inginerienucleara-Horia Hulubei)

TUDA (Technische Universitat Darmstadt)

STFC (Science and Technology Facilities Council)

LMU (Ludwig-Maximilians-Universität München)

CLPU (Consorcio Para El Diseno, Construccion, Equipamiento y Explotacion Del Centro De Laseres Pulsados Ultracortes Ultraintensos)

CNR (Consiglio Nazionale delle Ricerche)

ELETTRA (Elettra Sincrotrone Trieste)

HZDR (Helmholtz-Zentrum Dresden-Rossendorf)

IST (Instituto Superior Tecnico)

INFN (Istituto Nazionale di Fisica Nucleare)

QUB (The Queen's University of Belfast)

FORTH (Idryma Technologias Kai Erevnas)

EU Projects

ERIC Forum

The European Research Infrastructure Consortium (ERIC) legal framework was introduced in 2009 to support the establishment and operation of large-scale European Research Infrastructures. The ERIC community has expanded in 10 years with 26 established ERICs. The variety and diversity of ERICs make them important players in European scientific excellence that respond to various societal challenges. They also support science diplomacy, and create bridges between research communities within Europe and worldwide.

The ERIC Forum implementation project ended in 2021 and was followed by the ERIC Forum 2 launched in 2023. The overarching goal of this project is to further structure the cooperation between ERICs, support the implementation of the ERIC regulation and ERICs services, and consolidate the integration of the ERICs in the ERA. ELI ERIC is a participating member and the ELI ERIC Director General was elected as Vice-Chair in October 2022.

EuPRAXIA

EuPRAXIA is the first European project that develops a dedicated particle accelerator research infrastructure based on novel plasma acceleration concepts and laser technology. EuPRAXIA is one of the projects on the European Strategy Forum on Research Infrastructures (ESFRI) Roadmap of 2021. EuPRAXIA aims at realising the first laser plasma user facility worldwide, demonstrating feasibility and gaining operational and user experience.

IMPRESS

Coordinated by the Consiglio Nazionale delle Ricerche (Italy), IMPRESS is a new EU-funded scientific project launched in February 2023 with the ambition to revolutionise the field of transmission electron microscopy (TEM). It aims at co-developing and delivering new and sophisticated instrumentation, methods and tools, which will change how transmission electron microscopes are used by both well established and new scientific communities. IMPRESS brings together 19 partners from 11 European countries, comprising scientists, companies, experts in the field of electron microscopy and research infrastructures, who will collaborate to address needs that are not yet satisfied by commercially-available electron microscopes.

ELI ERIC will be involved in a Pre-commercial Procurement (PCP) activity for the design, development and testing of an interoperable platform for TEM, the co-development of novel experimental techniques for in situ/operando/correlative using the study of laser-induced phase transformations in materials used as photoconductive switches.

Laserlab-Europe

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

ELI collaborates with Laserlab-Europe on various levels including activities such as workshops but also specifically on the development of a laser science and technology landscape analysis of Europe which is supported by IMPULSE. A joint event was hosted during ICRI 2022 for key stakeholders and a joint report is being finalised. ELI ERIC is also collaborating with Laserlab-Europe on the recently submitted Lasers4EU proposal.

PaNOSC

The Photon and Neutron Open Science Cloud (PaNOSC) is a European project aiming at making FAIR data a reality in 6 European Research Infrastructures (RIs), developing and providing services for scientific data and connecting these to the European Open Science Cloud (EOSC).

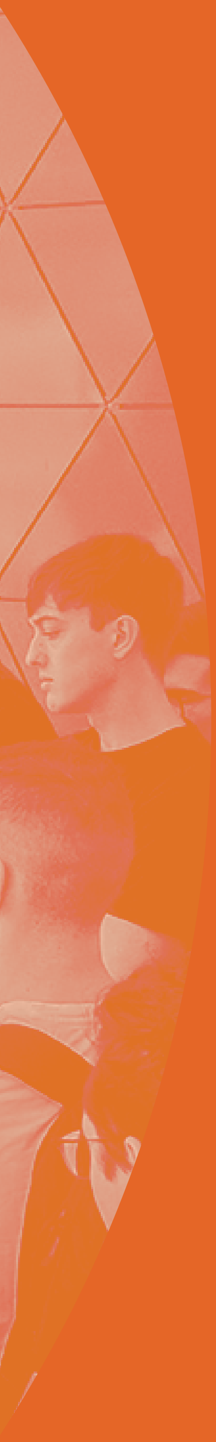
Completed at the end of 2022, the main objective of PaNOSC was to ensure that the PaNOSC partners consisting of RIs on the ESFRI roadmap make their data open and available to the EOSC. While two of the participating RIs (ESS and ELI) are only completing construction and entering into operations, respectively, they are ready to publish Open Data from the beginning of User Mode, thanks to their Open Data policies based on the PaNOSC policy framework and the implementation of data catalogues.

The PaNOSC project . ELI ERIC contributed on a variety of levels and hosted the PaNOSC Summer School in Szeged, Hungary.

THRILL

The THRILL (Technology for High-Repetition-rate Intense Laser Laboratories) project received more than ten million euro of funding in the framework of the European Union's HORIZON EUROPE program. The project aims at providing new designs and high-performance components for high-energy high-repetition-rate lasers, enabling the technical readiness level required to specify and build the needed devices. This work improves the performance, the energy efficiency and reliability in operation of such lasers at the partnering research institutions. Nine companies and research institutes participate in the project

The project is not only pushing technology, it is also offering an outstanding opportunity to train a qualified workforce for RIs and industry. With this in mind, the structure of THRILL promotes synergies, fast transfer to industry and integrated research activities at the European level.



04 Outreach and Engagement

ELI User Meeting and Scientific Engagement

The User Meeting is a core activity in the annual calendar for ELI. The meeting is an opportunity to engage with and strengthen the interaction between ELI and the scientific user community.

The first Joint ELI User Meeting was held on 2-4 November 2022 with a central Plenary Day on 3 November. The meeting brought together nearly 400 participants from all over the world for both in-person and hybrid sessions. The joint programme on 3 November introduced the current status and update from each of the facilities, as well as ongoing and planned user experiments for a better overview of their respective scientific focus and capacities. Satellite workshops offered an opportunity for each of the facilities and research groups to go into more detail on specific topics and fields. Organising the meeting across all three facilities demonstrates the potential for scientific impact that ELI has to drive laser science and technology not just in central Europe but worldwide.

Beyond the ELI User Meeting, scientific and technical staff engage with a plethora of scientific conference, workshops, seminar etc. presenting results, exchanging with the community and raising awareness about ELI. To name a few, ELI scientists participated in the 9th International Conference on Ultrahigh Intensity Lasers (ICUIL 2022), the International Conference on Attosecond Science and Technology (ATTO 2022), SPIE Optics + Photonics 2022, OPIC, MP3, I.FAST, CLEO, EPS, MUST 2022, HPLSA, ICLO, Proton-Boron Workshop, ERICE Summer School, EGI2022 and ICRI (International Conference on Research Infrastructures). ELI was represented at trade and technology fairs, such as Laser World of Photonics and Big Science Business Forum.

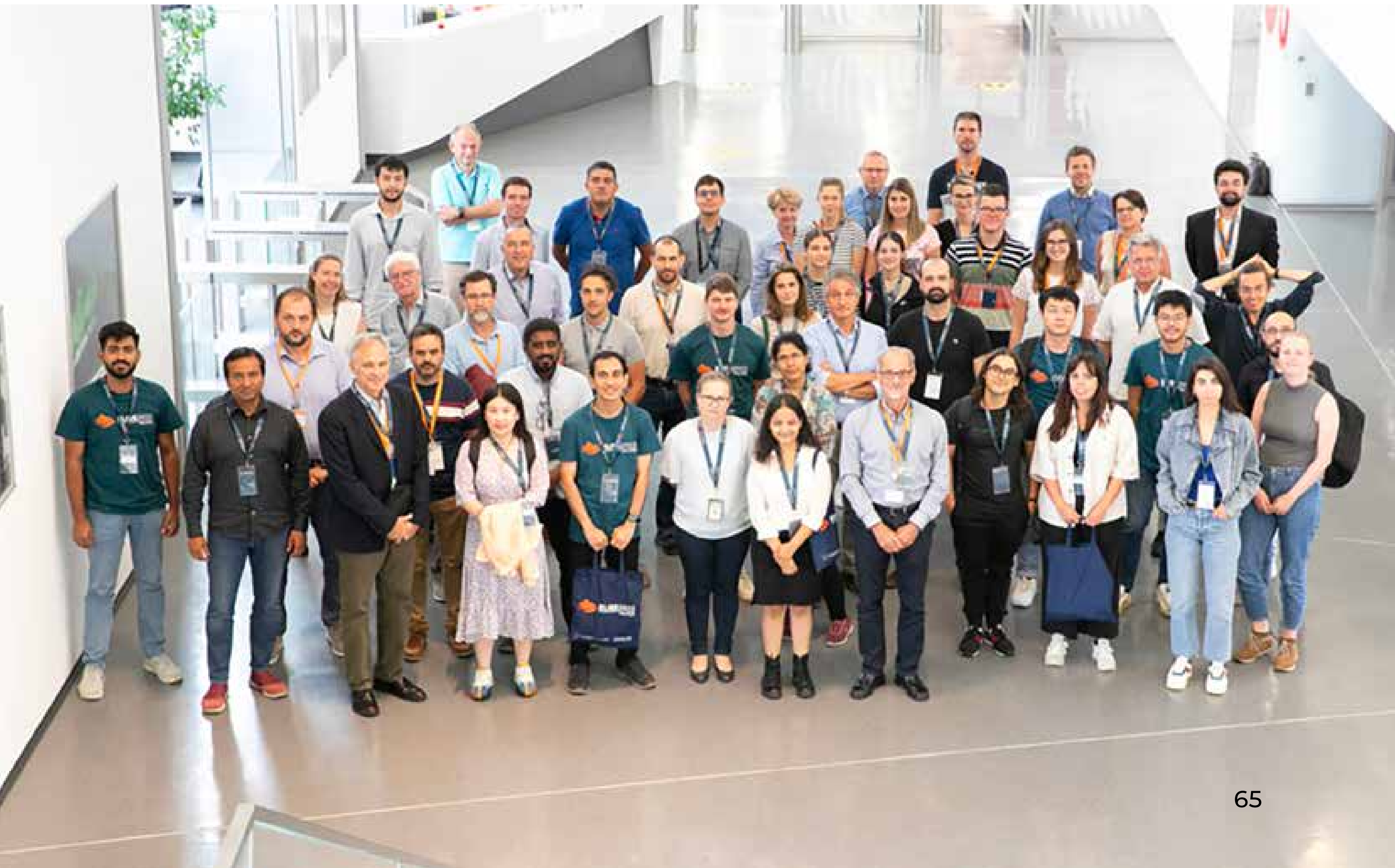
ELISS2022
ELI Summer School | 30 Aug – 2 Sep 2022
Szeged, Hungary

ELI Summer School

The main aim of ELISS, is to provide young scientists with comprehensive information about high-intensity laser pulses and laser-driven particle/radiation sources, while presenting the unique research capabilities of ELI.

The ELI Summer School, already in the seventh edition, was hosted at ELI ALPS Research Institute (Szeged, Hungary) from 30 August to 2 September 2022, jointly organised by ELI Beamlines and ELI ERIC as a hybrid event. The school attracted young scientists interested in the physics of laser and ultra-fast dynamics. A diverse group of almost 40 participants arrived for ELISS 2022 in person while more as 100 joined online. The programme involved 15 speakers covering lectures, overview presentations of the facilities and insights from user experiments. ELISS is an opportunity for students to interact directly with speakers and lectures, as well as ELI scientists and staff.

ELISS has been a very popular event for students and early-stage researchers, offering insight about the research opportunities at ELI and also serving as an important outreach activity contributing to building the future user community of ELI. Student participants from this year represented a variety of European nationalities and institutions but interest reaches far beyond the European Research Area with participants from all over the world taking advantage of the hybrid streaming option offered.



General Public Outreach

Outreach activities ramped up at the ELI Facilities this past year as the pandemic restrictions waned. This made it possible to welcome a large and diverse number of visitors and also reach new audiences. The ELI Facilities organised many events open to young scientists, students and the general public in 2022. Altogether, the ELI Facilities in Hungary and the Czech Republic welcomed over 6000 visitors.

Science for All: Open Days at the ELI Facilities

The ELI Facilities provide opportunities for local and national audiences to have a glimpse behind the scenes of a world-scale research infrastructure and get to know more about the science that is performed in the labs on a daily basis. In 2022, both ELI ALPS and ELI Beamlines joined the programmes of the International Day of Light in May and the European Researchers' Night at the end of September. Young and adult science enthusiasts were invited to participate in a wide range of light-inspired talks, experiments and playful activities, such as VR and clean room experiences, scientific T-shirt challenge, laser chess, optical tricks, and many more - attracting hundreds of visitors to both events.

Student and Teacher Programmes – Reaching Younger Audiences

The ELI Facilities engage in a handful of activities to generate interest around physics and scientific careers in general amongst the younger audiences through visitor programmes, student competitions, science camps and thematic lectures. ELI Beamlines invites university students to their Laser Days, while ELI ALPS teams up with the University of Szeged for the Day of Physics. ELI Beamlines also has special programmes, the Science Challenge and Talent Academy to give high school students the opportunity to learn more about the science behind ELI and offer hands-on experiences.

In June 2022, ELI ALPS organised its first-ever Summer Camp event for Hungarian high school students. The week was filled with educational lectures, interesting activities and experiments, and visits to several parts of the facility. ELI ALPS also hosts a Teachers' Course which aims to inform teachers about the specific knowledge and methods that could be incorporated into their physics classes. More than 20 teachers were introduced to the research activities of ELI in August 2022, and the event proved to be an effective tool for multiplying ELI's impact on the local curriculum in the field of physics.

Pop-science and Social Media Outreach

Besides all the self-generated activities to popularise science and laser physics amongst the different groups of the general public, ELI was invited to participate in the ICRI Citizens Programme with a special evening at the Vida Science Centre in Brno, Czech Republic, during the Vida After Dark event to showcase all the interesting attributes of light, lasers, the science behind them, and the ways people can harness this knowledge in their everyday lives. With nearly 6200 square metres the Vida Science Centre offers a variety of hands-on experiences to explore science for all audiences.

ELI also continued engaging audiences through the most popular social media platforms reaching more than 13'000 followers on Facebook, Twitter, LinkedIn, Instagram and Youtube altogether. To multiply the impact of these activities, the ELI Facilities started to align their strategies, closely cooperating and adding up their contents to create a unified, effective, and attractive digital presence towards various target groups. Altogether, nearly 350 social media posts were created by the ELI Facilities in 2022.

Outreach Activities

The ELI ERIC Facilities offer a variety of programmes to raise awareness about the science and research performed at ELI. Public outreach serves as a vital conduit for sharing discoveries, and showcasing the relevance and impact of the research being performed at ELI. The outreach activities not only inform and educate, but also inspire curiosity, foster a deeper understanding of scientific concepts. The programmes strengthens the relationship between science and society and cultivate support for ELI and research infrastructures.

190

events

Various activities for different audiences:

- Visitor centre
- Laboratory visits
- Facility tours
- Conferences
- Workshops
- Seminars
- Education and training events
- Open house
- University days
- Science Fairs

6130

visitors

The ELI ERIC Facilities welcome a diverse range of visitors, from scientists, partners, stakeholders, ambassadors, political decision-makers, industry, university students, secondary schools, elementary school and kindergartens as well as regional stakeholders and general public among many others.

05
Innovation

Innovation Activities

Innovation lies at the core of ELI ERIC's mission as a research facility. ELI ERIC is developing a sustainable innovation ecosystem that nurtures innovation and facilitates collaboration with industry partners. With this goal, ELI established a network of industrial liaison officers (ILO), explored the introduction of innovative procurement practices, proprietary user access for industry, internal funding mechanisms to promote innovation, and established internal and external advisory bodies.

Enhancing Research Excellence and Know-How for Applications

At ELI, a primary goal is to utilise cutting-edge research to foster innovative solutions for practical applications. ELI provides a unique platform for the development of know-how and IPR valorisation by coordinating research and development of relevant technologies, coordinating the joint training of scientific and technical personnel, and by promoting collaboration between ELI and other leading research centers and with industry.

Expanding the User Community:

Innovation activities at ELI also focus on expanding the user community including industry. By providing opportunities for world-class education and training, ELI attracts talented students and postgraduates to engage with its facilities capitalise on acquired skills for the future. This not only enriches the research environment but, also cultivates a culture of innovation and actively contributes to joint projects between ELI and industry.

Socio-Economic Impact:

Innovation goes beyond academic achievements. The importance of creating socio-economic impact by translating research outcomes into practical applications is essential. By collaborating with industrial partners, ELI aims to bridge the gap between excellent research and industrial implementation. This approach fosters long-term economic growth, job creation, and technological advancement.

Examples of Innovation Potential

- ELI generates ultrashort pulses from laser-driven XUV and X-ray sources, as well as from the primary infrared lasers which can be used for materials research into the structure, dynamics and function of materials ranging from isolated atoms to complex biological samples and solid-state materials. ELI is equipped with a bio lab and other types of equipment to perform such experiments.
- ELI continuously seeks new and innovative designs of high-performance components for its high-energy high-repetition-rate lasers. These components include cutting-edge optics with the aim to achieve improved performance and reliability in operation. ELI is developing innovative spherical mirrors and off-axis parabolic mirrors to focus or defocus the laser beam. These optical components include different types of mirrors with special properties to keep the spectral, energy and phase properties of light pulses unchanged during propagation, as well as optical gratings that perform dispersion tasks.
- ELI enables laser-driven particle acceleration driven by ultra-short high-energy laser pulses, which generate stable beams of charged particles with good properties and high energies for a lot of applications, i.e. low toxicity radiotherapy of tumors, non-invasive material analysis, and development of new kinds of high-energy accelerators.
- Experiments in inertial fusion laser-driven energy generation can be performed by the high-repetition-rate laser system on the kilo-Joule level available at ELI. This experiment can serve as a testbed for many physics & technology issues as well as a training environment for the next generation of laser-plasma physicists.

06 Governance

ELI ERIC Governing Bodies

ELI ERIC General Assembly

The General Assembly (GA) of ELI ERIC is made up of delegates and experts from every member and observer country. The GA appoints the Director General (DG) and Chair, and - among others - approves the annual actvitiy plans and budgets of the ELI ERIC Facilities. The GA and DG are supported by independent advisory bodies, the Administrative and Finance Committee (AFC) and International Scientific and Technical Advisory Committee (ISTAC).

Chair: Caterina Petrillo, Area Science Park, University of Perugia

Founding Members

Czech Republic
Lukáš Levák (Delegate), Ministry of Education, Youth and Sports
Jan Řídký (Delegate), Czech Academy of Sciences
Marek Vyšinka (Expert Advisor), Ministry of Education, Youth and Sports
Michael Prouza (Expert Advisor), Czech Academy of Sciences

Hungary
László Bódis (Delegate), Ministry of Culture and Innovation
Zsolt Fülöp (Delegate), National Research Infrastructure Committee

Italy
Sandro De Silvestri (Delegate), National Research Council
Alessandro Boero (Delegate), Ministry of University and Research
Eugenio Nappi (Expert advisor), National Institute for Nuclear Physics
Giorgio Rossi (Expert advisor), Università degli Studi di Milano

Lithuania
Gediminas Račiukaitis (Delegate), Vilnius Center for Physical Sciences and Technology
Aidas Matijošius (Delegate), Laser Research Center Vilnius University
Tadas Juknevičius (Expert advisor), Ministry of Education, Science and Sport of Lithuania

Founding Observers

Bulgaria
Milena Damyanova (Delegate), Ministry of Education and Science
Lubomir Kovachev (Delegate), Bulgarian Academy of Sciences

Germany
Eckart Lilienthal (Delegate), Federal Ministry of Education and Research
Sebastian Schmidt (Delegate), Helmholtz-Zentrum Dresden-Rossendorf
Bernadette Klose (Expert advisor), DLR Project Management Agency
Barbara Schramm (Expert advisor), Helmholtz-Zentrum Dresden-Rossendorf

Administrative and Finance Committee (AFC)

The AFC advises the GA on all matters relating to administrative and legal issues and financial management. The AFC Chair is appointed by the GA. The AFC oversees all major administrative and financial functions of ELI, such as the definition of the procurement and financial rules and gives advice and recommendations for decisions to the ERIC GA.

Chair: László Jakab

AFC Delegates

Jan Buriánek, Ministry of Education, Youth and ports, Czech Republic
Petr Lukáš, Nuclear Physics Institute, Academy of Sciences, Czech Republic
László Lengyel, National Research, Development and Innovation Office, Hungary
Lívia Sinkó, Ministry of Culture and Innovation, Hungary
Ileana Gimmillaro, Elettra - Sincrotrone Trieste S.C.p.A., Italy
Antonella Tajani, National Research Council, Italy
Artūras Malysis, Ministry of Education, Science and Sport, Lithuania
Akvilė Andrulytė, Research Council of Lithuania
Zornitsa Georgieva, Ministry of Education and Science
Bernadette Klose, DLR Project Management Agency, Germany
Barbara Schramm, Helmholtz-Zentrum Dresden-Rossendorf, Germany

International Scientific Advisory Committee (ISTAC)

The ISTAC is made up of independent expert scientists and advises the GA on scientific matters and other matters of importance for ELI. The members of the ISTAC and its Chair are appointed by the GA. The ISTAC independently assesses the scientific goals and the overall plans of ELI ERIC, and advises on the scientific objectives of ELI ERIC. The 14 leading experts in the field of laser science offer independent advice on all strategic issues, scientific and technical activities to the ELI ERIC management and GA, including making recommendations on the user programme of the ELI Facilities.

Chair: John Collier, Central Laser Facility - Science and Technology Facilities Council, UK

Members

Angela Bracco, Università di Milano/National Institute for Nuclear Physics
Francesca Calegari, Center for Free-Electron Laser Science
Colin Danson, AWE Aldermaston
Marta Fajardo, Istituto Superior Tecnico
Roger Falcone, University of California, Berkeley
Sylvie Jacquemot, École Polytechnique
Wim Leemans, Deutsches Elektronen-Synchrotron
Claudio Masciovecchio, Elettra (Fermi)
Mauro Nisoli, Politecnico di Milano
Ulrich Schramm, Helmholtz-Zentrum Dresden-Rossendorf
Thomas Tschentscher, European XFEL
Arünas Varanavicius, University of Vilnius
Jon Zuegel, University of Rochester


25.262
23.7344

07 Finance Report

Notes to the Financial Statements as of 31 December 2022

General Content

The Extreme Light Infrastructure European Research Infrastructure Consortium (ELI ERIC) was established by Commission Implementing Decision (EU) 2021/960 on 30 April 2021.

Extreme Light Infrastructure (ELI ERIC) (hereinafter referred to as 'ELI ERIC'), Company ID: 10974938, Tax No.: CZ10974938, with its registered office at Za radnicí 835, 252 41 Dolní Břežany, was established for an initial period of twenty years, which may be extended by decision of the General Assembly.

The Founding Members of ELI ERIC are the Czech Republic, Hungary, Italy and Lithuania. Bulgaria and Germany are Founding Observers.

ELI ERIC is registered in the Register of Legal and Natural Persons maintained by the Czech Statistical Office.

Purpose of Establishment

ELI ERIC operates high-performance laser systems, beamlines and experimental stations and manages access to them by users from the scientific community and industry.

ELI ERIC is operated on a non-profit basis. It may carry out limited economic activities, provided that such activities are closely related to its principal tasks and do not jeopardise the achievement thereof.

Basis for preparation of the Financial Statements and information on accounting methods

When keeping the books and preparing the financial statements, ELI ERIC proceeded in accordance with Act No. 563/1991 Coll., on Accounting, as amended, with Decree No. 504/2002 Coll., which implements certain provisions of Act No. 563/1991 Coll., on Accounting, as amended, for entities whose main activity is not business if they account in the double-entry accounting system and with Czech accounting standards No. 401–414, for entities that account in accordance with Decree No. 504/2002 Coll., as amended.

To ensure and process accounting, accounting records were made in the economic information system Money S4 by Solitea a.s. Electronic accounting data files are duplicated on the SPRINx cloud solution operator's backup server and backed up daily. The initial documents are archived in a separate accounting archive of ELI ERIC.

The accounting period is the calendar year.

Valuation method:

- Tangible assets and inventories, with the exception of assets created by own activity, are valued at acquisition prices
- Tangible assets created by own activities are valued at own costs, composed of:
  - Direct material
  - Direct wages
  - Overhead costs
- Cash and securities are valued at their nominal values
- ELI ERIC uses the replacement cost to measure inventory surpluses
- In addition to the acquisition costs, the secondary acquisition costs (transport, customs, postage, VAT without deductibility) are included in the cost of acquiring the purchased stocks. Accounting for the acquisition and disposal of stocks is carried out in accordance with method 'A'
- The entity does not have assets valued according to Section 25(1)(k)
- Short-term financial assets are measured at fair value.

Method used to convert data in foreign currencies into Czech currency:

ELI ERIC uses the CNB's daily exchange rate for the valuation of assets and liabilities denominated in foreign currency. Only realised exchange rate gains and losses are accounted for during the year. Assets and liabilities denominated in foreign currency are converted at the official CNB exchange rate as of 31 December of the given year at the balance sheet date. Exchange rate differences from the valuation of financial accounts, receivables, liabilities, loans and financial assistance are recognised on the date of the financial statements through profit or loss in the account of exchange rate differences.

The method for drawing up the depreciation plan for fixed assets and the depreciation methods used to determine the accounting depreciation are based on the useful life of the asset. Accounting depreciation is calculated for the first time for the month following the month in which the assets were put into use. The detailed depreciation plan is precisely set for individual items in relation to SKP (Standard Classification of Production) and CZ-CPA.

The notes below show values for the previous year of 2021 and for the current year of 2022. ELI ERIC started its operations in July 2021, so year 2021 represents six months of operations, which reflects in the profit and loss account values whereas year 2022 represents operations for the entire calendar year.

All financial values in this note to the Financial Statements of 2022 has been converted to EUR using CNB´s year end rate 1 EUR = 24,115 CZK

Additional information to the Balance Sheet

Fixed assets, as of the balance sheet date at acquisition costs and historical prices:

Fixed assets	2021 (k€)	2022 (k€)
Buildings and structures	0	0
Machinery and equipment	35	35
Software	0	0
Land	0	0
Tangible fixed assets in progress	0	1,584
Intangible fixed assets in progress	0	49
Advances paid on tangible fixed assets	0	14
Accumulated depreciation for fixed assets	-6	-20
Total	**29**	**1,663**

The value of equipment remained unchanged from 2021 at 35 k€ with the accumulated depreciation in amount of 20 k€. Tangible and intangible assets increased in value to a total of 1,647 k€. They represent assets that will be in the commissioning phase next year. Advance payments were made on tangible fixed assets to be delivered by February 2023.

On 18 October 2022, the Institute of Physics of the Czech Academy of Sciences (IoP), a public research institution, and ELI ERIC signed a series of agreements organising the transfer of the ELI Beamlines Facility, which had been operated as a division of IoP until then, to ELI ERIC. Under this transaction, it was agreed that all assets and liabilities (including movable and immovable assets), contracts and agreements, rights and duties, activities, employees, intellectual property rights associated with ELI Beamlines will be transferred to and placed under the ownership of ELI ERIC. According to the terms and conditions of this transaction, the transfer of ELI Beamlines happened as of 1 January 2023. As of this date, ELI ERIC is the only owner and operator of ELI Beamlines Facility.

The transfer of the land and buildings was registered with the Cadastral authority already in November 2022, with effect on 1 January 2023 to ensure smooth transition of activities between IoP and ELI ERIC. Accordingly, land, building and all other transferred assets will be registered in the accounting books of ELI ERIC in 2023.

Receivables

The total receivables on the balance sheet date amount to 3,979 k€, including the following significant items:

Receivables	2021 (k€)	2022 (k€)
Operational advances granted	0	5
Other receivables	2	561
Excess VAT deduction	306	3,413
Membership fees	515	0
Total	**823**	**3,979**

There is a significant increase of Other receivables that mainly includes the advance paid to ELI HU non-profit Kft to partly cover operating costs for the 1st quarter costs of 2023 in agreement with the Operating Agreement signed in 2022 between ELI ERIC and that ELI-HU Non-profit Kft. This advance will be settled after the 1st quarter of 2023. Excess VAT deduction is to refund VAT from Czech Republic for December 2023 in amount of 118 k€ and from Hungary for the second half of 2022 in amount of 3,295 k€. There are no membership fees due at year end 2022.

Short-term financial assets

Total short-term assets amount to 8,511 k€ on current accounts with ČSOB a.s.

Short-term assets	2021 (k€)	2022 (k€)
Cash on accounts	2,456	8,511
Petty cash	371	
Total	**2,456**	**8,511**

Other assets

	2021 (k€)	2022 (k€)
Prepaid expenses	5	177
Accrued revenues	37	882
Total	**41**	**1,059**

Prepaid expense of 2022 besides the current year-end prepayment mainly includes prepaid software licenses for next periods in amount of 170 k€. Accrued revenues represent expected revenue from H2020 Project Impulse in amount of 882 k€.

Liabilities

The entity records liabilities to employees, suppliers and authorities that were paid on due dates in 2022.

Liabilities	2021 (k€)	2022 (k€)
Accrued costs	166	104
Liabilities to suppliers in the main activity	15	690
Liabilities to employees	56	88
Liabilities to social security and health insurance institutions	29	36
Liabilities due to other direct taxes	11	16
Other liabilities	1	3
Deferred revenue	0	202
Total	**277**	**1,138**

Accrued costs for 2022 have to do with the untaken holiday entitlement of employees in all jurisdictions where ELI ERIC has activities and employs people. Liabilities towards trade suppliers with the due date over 30 days are in amount of 3 k€, all other supplier liabilities are under due date of 30 days. Liabilities to employees are related to liabilities to social security and health insurance as well as other direct taxes linked to payroll for December 2022. Deferred revenue of 202 k€ is linked to the early payment of the membership contribution of 2023 by the Lithuanian member..

Funds

Funds as of the balance sheet date amounted to 14,074 k€

Funds	2021 (k€)	2022 (k€)
Funds due to legal succession of ELI Delivery Consortium	1	2
Fund for EU Horizon 2020 projects	473	106
ELI ERIC members' contribution fund	2,599	13,940
Provisions	0	25
Total	**3,073**	**14,074**

These are mainly funds of membership contributions in amount of 13,940 k€ and EU projects in amount of 2,599 k€ that are intended for use in the next period. Provision in amount of 25 k€ has been made for 15% withholding tax from bank deposits.

Additional information on the Profit and Loss Statement

Costs and revenues of ELI ERIC for the years 2021 and 2022 differ significantly. This is due first to the fact ELI ERIC, which was established in 2021, operated only July to December 2021, but only to the long-term plan of ELI ERIC to integrate the ELI Beamlines Facility in the Czech Republic and ELI ALPS Facility in Hungary in accordance with the Statutes of ELI ERIC. To that aim, the Institute of Physics of the Czech Academy of Sciences (IoP) and ELI-HU non-profit Kft concluded separate Operating Agreements with ELI ERIC on the operation of the ELI Beamlines and ELI ALPS Facilities, respectively, at the beginning of 2022. On the basis of those agreements, IoP and ELI-HU non-profit Kft made available these ELI Facilities to ELI ERIC and ELI ERIC provided the necessary funding for their operations.

Furthermore, it should be noted that the agreements organise the cooperation of these entities with ELI ERIC to plan and prepare the legal and management integration of these Facilities into ELI ERIC. Within that framework, it was agreed that the ELI Beamlines Facility would be integrated into ELI ERIC as of 1 January 2023 and it is targeted that the ELI ALPS Facility will be integrated into ELI ERIC as of 1 January 2024.

The profit or loss was established as the difference between the costs and revenues of the main and other activities and is shown in the Profit and Loss Statement. The profit or loss of the main activity for 2022 is 0 CZK. There was no other activity in 2022.

Revenues	2021 (k€)	2022 (k€)
Members of ELI ERIC	1,898	31,070
EU projects	503	2,390
Other income - legal succession of ELI DC	6	0
Interest on deposits	37	169
Exchange rate gain	14	729
Other	2	0
Total	**2,459**	**34,358**

Source analysis of costs	2021 (k€)	2022 (k€)
Institutional	1,919	31,964
EU projects	540	2,394
Total	**2,459**	**34,358**

Cost type breakdown	2021 (k€)	2022 (k€)
Personnel costs	786	1,535
Other goods and services	187	2,391
Equipment	30	54
Travel expenses	17	136
Operating costs of ELI BEAMLINES	1,439	17,854
Operating costs of ELI Alps facility	0	12,387
Total	**2,459**	**34,358**

Personnel data

Changes in headcount	2021	2022
New hires	18	5
Terminations	0	1

Breakdown of personnel costs	2021 (k€)	2022 (k€)
Gross wages of employees	624	1,193
Statutory social security and health insurance	162	342
Other social expenses	1	1
Total	**786**	**1,535**

No remuneration, advances or loans were paid to the members of the bodies of ELI ERIC in the 2022 accounting period.

The management of ELI ERIC is not aware that the members of the statutory, supervisory, or other bodies designated by the Statutes or by virtue of their function, or their family members, have participated in commercial contracts or in other contractual obligations that have been concluded during the accounting period or in the preceding period.

Other information

ELI ERIC:

1. Is not encumbered by loans.
2. Does not organize any public charity under a special law.
3. Has no financial or other liabilities not included in the Balance Sheet at the time of its compilation.
4. Auditor's remuneration – the total remuneration of the auditor for 2022 was below the materiality level.
5. Significant events after the financial statements date and which should be listed in these Notes:

On 28 March 2023, the ELI Beamlines network experienced a ransomware attack. The attack exploited misused user credentials of an employee. Around 200 servers and 150 workstations were impacted and the attack had severe impact on the operations of the Facility for at least 2 weeks. Server and network infrastructure were gradually restored in a safe mode and critical services are available. As a result of the attack, part of the company data was encrypted, but there is no evidence of data extraction. It does not appear either that data required for the organisation to comply with its statutory and legal reporting requirements has been lost.

Impact on the laser control system network and user operations was limited due to separation between the networks used for research infrastructure operations and administration. However, it is expected that the attack will have some delaying effect on commissioning activities and R&D milestones. At this stage, it is however not anticipated that this will have an impact on the liabilities of the organisation.

In terms of follow-up actions, countermeasures have been taken based on the conclusions and recommendations of external experts. A deep security analysis is being carried out to determine a long-term strategy minimising cybersecurity risks at ELI Beamlines.

Balance Sheet
as of December 31st, 2022

ASSETS		Row number	Balance on the first day of accounting period (k€)	Balance on the last day of accounting period (k€)
A. Long-term Assets		**1**	**29**	**1 663**
I. Intangible Fixed Assets		**2**	**0**	**49**
1	Inangible research and development outcomes	3	0	0
2	Software	4	0	0
3	Valuable rights	5	0	0
4	Low-value intangible fixed assets	6	0	0
5	Other intangible fixed assets	7	0	0
6	Unfinished intangible fixed assets	8	0	0
7	Advanve payments for intangible fixed assets	9	0	0
II. Tangible Fixed Assets		**10**	**35**	**1 633**
1	Land	11	0	0
2	Works of art and collections	12	0	0
3	Buildings and structures	13	0	0
4	Equipment, furniture and fixtures	14	35	35
5	Perennial crops	15	0	0
6	Breeding and draught animals	16	0	0
7	Low-value tangible fixed assets	17	0	0
8	Other tangible fixed assets	18	0	0
9	Unfinished tangible fixed assets	19	0	1 584
10	Advanved payments for tangible fixed assets	20	0	14
III. Long-term Financial Assets		**21**	**0**	**0**
1	Shares - controlled / controlling entities	22	0	0
2	Shares - substantial influence	23	0	0
3	Debenture loans until maturity	24	0	0
4	Loans to organizational units	25	0	0
5	Other long-term loans	26	0	0
6	Other long-term financial assets	27	0	0
IV. Accumulated Depreciations to Fixed Assets		**28**	**-6**	**-20**
1	Accumulated depreciations - intangible research outcomes	29	0	0
2	Accumulated depreciations - software	30	0	0
3	Accumulated depreciations - valuable rights	31	0	0

4	Accumulated depreciations - low-value intangible fixed assets	32	0	0
5	Accumulated depreciations - other intangible fixed assets	33	0	0
6	Accumulated depreciations - buildings and constructions	34	0	0
7	Accumulated depreciations - equipment, furniture and fixtures	35	-6	-20
8	Accumulated depreciations - perennial crops	36	0	0
9	Accumulated depreciations - breeding and draught animals	37	0	0
10	Accumulated depreciations - low-value tangible fixed assets	38	0	0
11	Accumulated depreciations - other tangible fixed assets	39	0	0

ASSETS		Row number	Balance on the first day of accounting period (k€)	Balance on the last day of accounting period (k€)
B. Short-term Assets		**40**	**3 321**	**13 550**
I. Inventory		**41**	**0**	**0**
1	Material in store	42	0	0
2	Material in transit	43	0	0
3	Work-in-progres	44	0	0
4	Semi-finished products	45	0	0
5	Finished products	46	0	0
6	Animals	47	0	0
7	Merchandise in store	48	0	0
8	Merchandise in transit	49	0	0
9	Advance payments for inventory	50	0	0
II. Receivables		**51**	**823**	**3 979**
1	Trade receivables	52	0	0
2	Exchange bills receivable	53	0	0
3	Receivables for discounted notes	54	0	0
4	Advance payments made	55	0	5
5	Other receivables	56	2	1
6	Receivables from employees	57	0	18
7	Receivables from social security and health insurance	58	0	0
8	Income tax receivables	59	0	0
9	Other direct taxes receivables	60	0	0
10	VAT receivables	61	306	3 413
11	Other taxes and fees receivables	62	0	0
12	Receivables for subsidy and other dues from state	63	0	0

13	Receivables for subsidy from municipalities	64	0	0
14	Receivables from shareholders and partners in an association	65	0	0
15	Receivables from long-term deposits and options	66	0	0
16	Receivables from issued bonds	67	0	0
17	Other receivables	68	515	542
18	Estimated accrued expenses	69	0	0
19	Adjustment to receivables	70	0	0
III. Short-term Financial Assets		**71**	**2 456**	**8 511**
1	Petty cash	72	0	0
2	Liquid valuables (stamps and vouchers)	73	0	0
3	Bank accounts	74	2 456	8 511
4	Shares and similar securities	75	0	0
5	Bonds, debentures and similar securities	76	0	0
6	Other securities	77	0	0
7	Cash in transit	78	0	0
IV. Other Assets		**79**	**41**	**1 059**
1	Prepaid expenses	80	5	177
2	Accrued renenues	81	37	882
TOTAL ASSETS		**82**	**3 350**	**15 212**

LIABILITIES		**Row number**	**Balance on the first day of accounting period (k€)**	**Balance on the last day of accounting period (k€)**
A. Own Resources		**83**	**3 073**	**14 049**
I. Equity		**84**	**3 073**	**14 049**
1	Own equity	85	0	0
2	Funds	86	3 073	14 049
3	Gains and losses from revaluation of assets	87	0	0
II. Profit and loss for the period		**88**	**0**	**0**
1	Profit / loss account	89	0	0
2	Profit / loss in distribution	90	0	0
3	Retained earnings, accumulated loss from previous years	91	0	0
B. External resources		**92**	**277**	**1 163**
I. Provision / Reserves		**93**	**0**	**25**
1	Provisions / reserves	94	0	25
II. Long-term Liabilities		**95**	**166**	**104**
1	Long-term bank loans	96	0	0
2	Issued bonds	97	0	0

3	Liabilities from rent	98	0	0
4	Long-term advance payments received	99	0	0
5	Long-term notes payable	100	0	0
6	Estimated accrued expenses	101	166	104
7	Other long-term liabilities	102	0	0
III. Short-term liabilities		**103**	**110**	**832**
1	Trade suppliers	104	15	690
2	Exchange bills payable	105	0	0
3	Advance payments received	106	0	0
4	Other payables	107	0	1
5	Wages payable	108	56	88
6	Other payables to employee	109	0	0
7	Payables to social security instutitions and public health insurance companies	110	29	36
8	Income tax payables	111	0	0
9	Other direct tax payables	112	11	16
10	VAT payables	113	0	0
11	Other taxes and fees payable	114	0	0
12	Payables for subsidy and other dues to state	115	0	0
13	Payables for subsidy to municipalities	116	0	0
14	Shares / securities payable	117	0	0
15	Payables to shareholders and partners in an association	118	0	0
16	Payables for long-term deposits and options	119	0	0
17	Other payables	120	1	1
18	Short-term bank loans	121	0	0
19	Credit for discounted notes	122	0	0
20	Short-term bonds issued	123	0	0
21	Own bonds issued	124	0	0
22	Estimated accrued expenses	125	0	0
23	Other short-term financial assistance	126	0	0
IV. Short-term liabilities		**127**	**0**	**202**
1	Accrued expenses	128	0	0
2	Deferred revenues	129	0	202
TOTAL LIABILITIES		**130**	**3 350**	**15 212**

Profit and Loss Statement
as of December 31, 2022

		Figures at balancing day		
		Main activity (k€)	Economic activity (k€)	Total (k€)
		1	2	3
A. EXPENSES				
I. Purchase and Services Consumption		**31 448**	**0**	**31 448**
1	Consumption of material, energy	55	0	55
2	Cost of goods sold	0	0	0
3	Repairs and maintenance	0	0	0
4	Travel expenses	128	0	128
5	Hospitality	94	0	94
6	Other services	31 172	0	31 172
II. Change in inventory of own products and capitalization		**-651**	**0**	**-651**
7	Change in inventory of own products	0	0	0
8	Capitalisation of material, goods and services	0	0	0
9	Capitalisation of fixed assets	-651	0	-651
III. Personel Expenses		**1 535**	**0**	**1 535**
10	Wages and salaries	1 193	0	1 193
11	Legal social insurance	342	0	342
12	Other social insurance	0	0	0
13	Legal social security expenses	1	0	1
14	Other social security expenses	0	0	0
IV. Taxes and Fees		**0**	**0**	**0**
15	Taxes and Fees	0	0	0
V. Other Expenses		**1 986**	**0**	**1 986**
16	Contractual fines and interest on late payments	0	0	0
17	Receivables written off	0	0	0
18	Expenses Interest	74	0	74
19	Foreign exchange losses	1 903	0	1 903
20	Gifts	0	0	0
21	Shortages and damages	0	0	0
22	Other operating expenses	9	0	9
VI. Depreciation, Assets Sold, Provisions and Adjustments		**39**	**0**	**39**
23	Depreciation of fixed assets	14	0	14
24	Net book value of fixed assets sold	0	0	0
25	Cost of revenue from stock	0	0	0
26	Net book value of material sold	0	0	0
27	Creation and use of reserves and provisions	25	0	25
VII. Contributions Granted		**0**	**0**	**0**

28	Membership fees	0	0	0
VIII. Income Tax		**0**	**0**	**0**
29	Income tax	0	0	0
EXPENSES TOTAL		**34 358**	**0**	**34 358**

		Figures at balancing day		
		Main activity (k€)	Economic activity (k€)	Total (k€)
		1	2	3
B. REVENUES				
I. Operation Subsidies		**2 390**	**0**	**2 390**
1	Operation subsidies	2 390	0	2 390
II. Contributions Received		**31 070**	**0**	**31 070**
2	Contributions received among organisational units	0	0	0
3	Contributions received (gifts)	0	0	0
4	Membership fees received	31 070	0	31 070
III. Revenues from sales of own products and services		**0**	**0**	**0**
IV. Other Revenues		**898**	**0**	**898**
5	Contractual fines and interest on late payments	0	0	0
6	Payments for receivables written off	0	0	0
7	Intererst income	169	0	169
8	Foreign exchange gains	729	0	729
9	Funds	0	0	0
10	Other revenues	0	0	0
V. Revenues from Assets Sold				
11	Revenues from long-term intangible and tangible assets sold	0	0	0
12	Revenues from securities and shares sold	0	0	0
13	Revenues from material sold	0	0	0
14	Revenues from short-term financial assets	0	0	0
15	Revenues from long-term financial assets	0	0	0
REVENUES TOTAL		**34 358**	**0**	**34 358**
C. PROFIT (+) / LOSS (-) BEFORE TAX		**0**	**0**	**0**
D. PROFIT (+) / LOSS (-) AFTER TAX		**0**	**0**	**0**

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Acknowledgment:

Many thanks to the staff at the ELI ERIC Facilities, ELI ALPS and ELI Beamlines, for contributing and supporting the compilation of this report.

Photo credits:
ELI ERIC
ELI-HU Non-Profit Ltd.

The production of this report has been supported by the IMPULSE project which receives funding from the European Union Framework Programme for Research and Innovation Horizon 2020 under grant agreement No 871161.

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