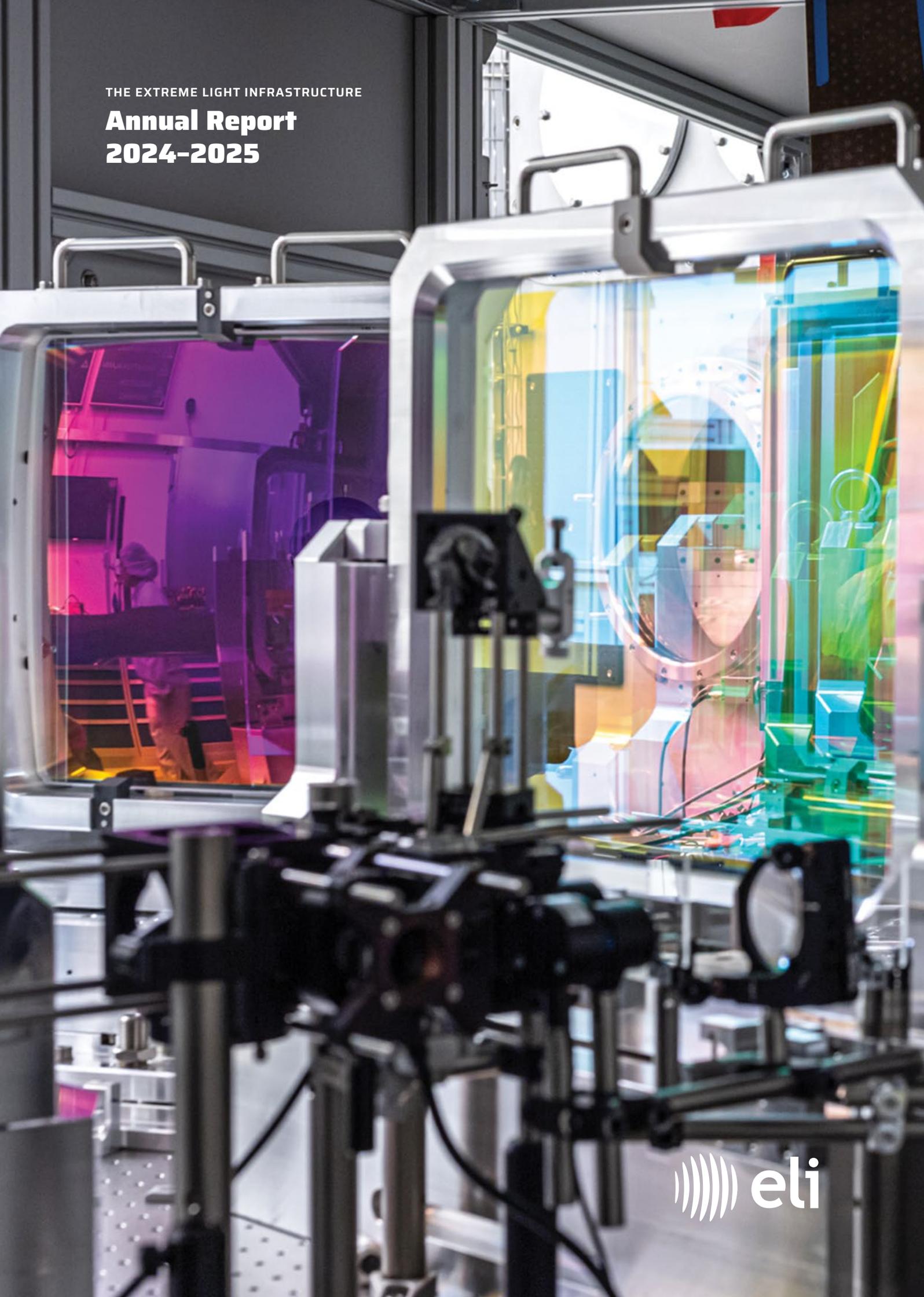


THE EXTREME LIGHT INFRASTRUCTURE

Annual Report 2024-2025



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THE EXTREME LIGHT INFRASTRUCTURE

Annual Report 2024-2025





Letter from the Director General

As we look back on the last year, ELI continues to advance with strong momentum and a shared vision for our facilities. This past year marked an important phase, as ELI fully transitioned into operating as a single integrated organisation—bringing together the ELI ALPS and ELI Beamlines Facilities under one governance and management system. This has already enhanced coherence, operational efficiency, and our ability to deliver on our core mission.

»As a unified organisation, ELI is positioned to deliver world-class science, tackle global challenges through laser-based research, and serve as a hub for international collaboration and scientific excellence.«

At the heart of ELI's activities remains the commitment to serving the international scientific community. The Joint User Programme has matured significantly, completing its 6th Call in spring 2025. With over 1400 users from 38 countries submitting 563 proposals of which 369 were allocated beamtime the User Programme is now a recognised platform. The more than 200 experiments which have already been implemented are also showcasing the excellent science being performed at the facilities. Many of the scientific highlights performed within the framework of the User Programme are featured in this report. Equally notable was the launch of ELI's first mission-based access call, with a focus on Inertial Fusion Energy (IFE), a step toward addressing global challenges like sustainable energy through strategic, long-term scientific collaboration.

In parallel, ELI continued to evolve as an international research infrastructure. Bulgaria transitioned into a Full Member, following a successful Observer phase, which marked an important milestone in the expansion of ELI's member base and set a precedent for other countries to join. Significant efforts to engage new countries and strengthen partnerships have been made with the successful conclusion of agreements with leading institutions across Canada, Switzerland, the United States, Poland and beyond. The success of the User Programme and increasing strategic partnerships showcase the growing demand for the scientific opportunities enabled by ELI.

The facilities have seen continued investment and progress. The commissioning of key systems continues, and new capabilities like the ELIAS large-scale optics coating laboratory and the Gammatron hard X-ray beamline have entered operation, as well as the attosecond and low-energy ion acceleration and neutron generation beamlines. These additions ensure ELI remains at the forefront of laser-based science, from attosecond physics to laser-driven particle acceleration and radiobiology.

Looking ahead, the focus lies on excellence in science and service to the ELI users, strengthening ELI as an organisation, and extending ELI's reach and impact in Europe and beyond. I am proud of what we have achieved together, and excited for what lies ahead!

I thank our staff, users, partners, and funders for their continued dedication and trust in our mission.

Allen Weeks
ELI Director General



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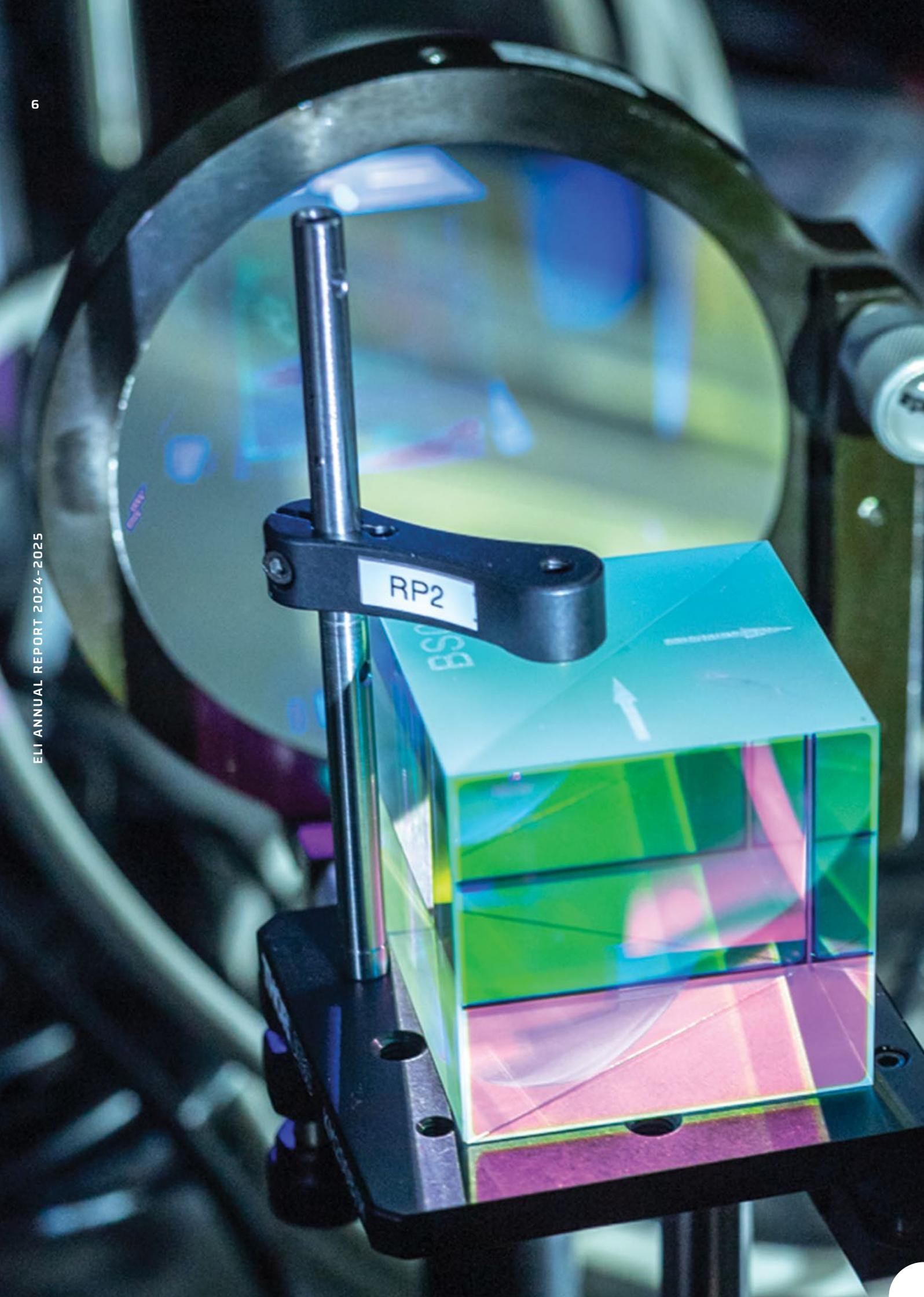
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Extreme Light Infrastructure

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ELI in a Nutshell

The Extreme Light Infrastructure (ELI) is an international research infrastructure with the world's largest and most advanced collection of high-power and high-repetition-rate lasers. As the leading user facility dedicated to multi-disciplinary science and research applications of ultra-intense and ultra-short laser pulses, ELI offers unprecedented capabilities in intense light-matter interactions.

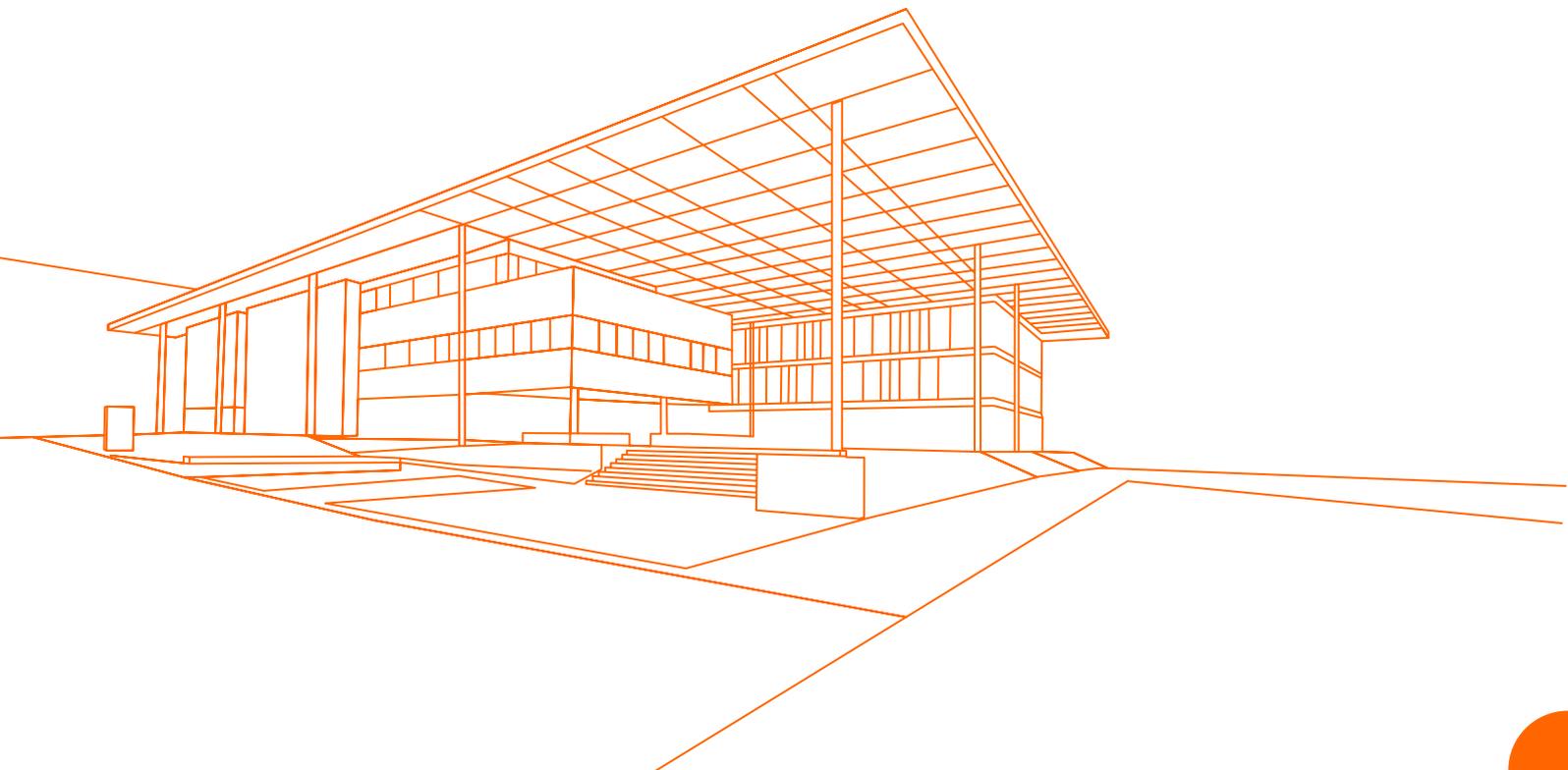
ELI's Mission

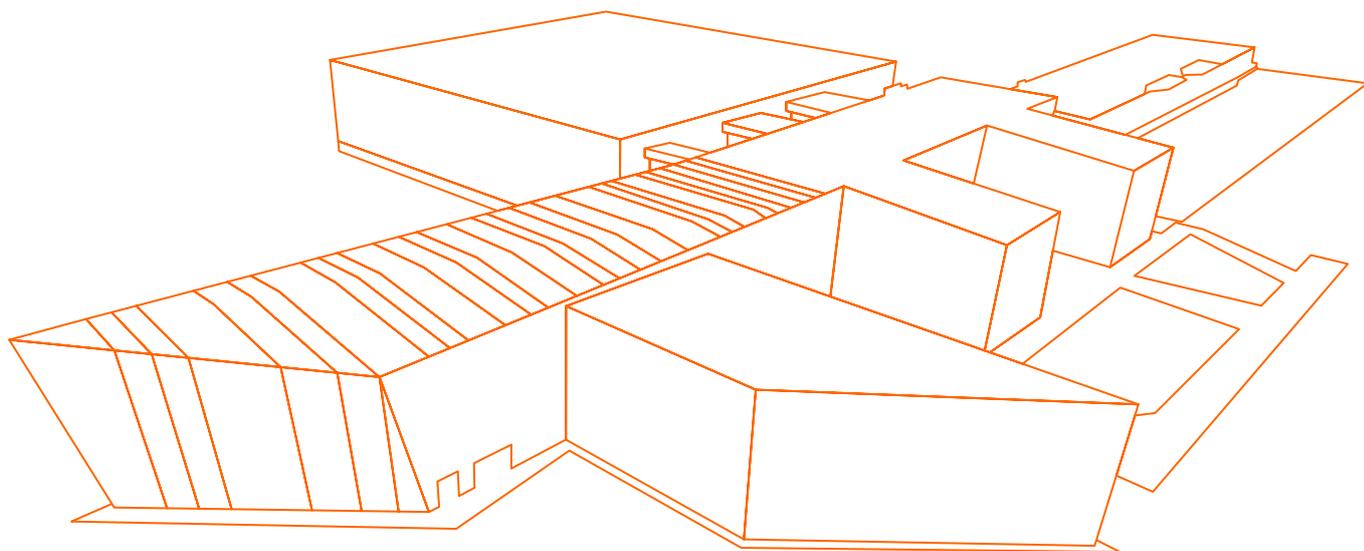
ELI provides the international scientific community with access to a broad range of instruments and technologies enabling cutting-edge research in fundamental science, applied research, and breakthrough technological innovations across physical, chemical, materials, and medical sciences.

An Integrated Organisation

Operating as a unified, multi-site organisation, ELI integrates complementary facilities, each specialised in fields of extreme light research:

- **The ELI Beamlines Facility**, in Dolní Břežany, Czech Republic, focuses on ultra-intense, high-power lasers for particle acceleration, plasma physics, and advanced materials research.





- **The ELI Attosecond Light Pulse Source Facility** located in Szeged, Hungary, specialises in ultrashort laser pulses, enabling studies of electron dynamics and ultrafast phenomena at unprecedented timescales.

From Nobel Prize to Experimental Reality at ELI

ELI's foundational technologies and research are already closely associated with two Nobel Prizes in Physics:

- **2018:** Gérard Mourou and Donna Strickland, for Chirped Pulse Amplification (CPA), fundamental to ELI's laser technologies.
- **2023:** Pierre Agostini, Ferenc Krausz, and Anne L'Huillier, for pioneering experimental methods generating attosecond pulses, central to ELI ALPS's scientific capabilities.

ELI is at the forefront of global research, driving scientific discovery and technological advancement in collaboration with the international research community. The User Programme offers a single access point to a broad range of instrumentation at the ELI facilities. With user communities spanning Europe, North America, Asia, and beyond, ELI serves as a hub for international collaboration, scientific excellence, and innovation, empowering researchers worldwide to address society's greatest challenges.

Integrated Operation

The Extreme Light Infrastructure (ELI) continues to expand its reach and capabilities in 2025. The expansion of ELI's diverse sources and instruments continues, with commissioning and ramp-up efforts ongoing. The User Programme is gradually making more of ELI's laser systems and experimental instruments available to the scientific community, solidifying the organisation's leadership both in terms of breadth of instrumentation and state-of-the-art capabilities.

The ELI User Programme has achieved significant progress with the completion of the 6th Call for Users. In addition to the open excellence-based access, the inaugural call for mission-based access was launched in 2024, with a focus on Inertial Fusion Energy (IFE).

Concurrently, the ELI facilities are undertaking upgrades to their building infrastructure to optimise operational efficiency. As the organisation transitions into steady-state operations, ELI is diversifying its portfolio of activities and has set up a framework to effectively monitor its progress, ensuring evidence-based insights into the performance of ELI as a research infrastructure and its core mission, as well as its broad socio-economic impact.

Operation as a single, integrated organisation, with both ELI ALPS and ELI Beamlines under common governance and management, are underway. Further efforts to consolidate, harmonise, and streamline management processes remain a key priority for the organisation, along with the introduction of a new ERP (Enterprise Resource Planning) software solution. Public engagement, outreach initiatives, and educational programmes continue to grow as well.

Establishment of ELI as a European Research Infrastructure Consortium

30 April
2021

Operating Agreements in place

December
2022

Launch of Joint User Programme

June
2022

Integration of the ELI Beamlines Facility

January
2023

Launch of 2nd Joint User Call

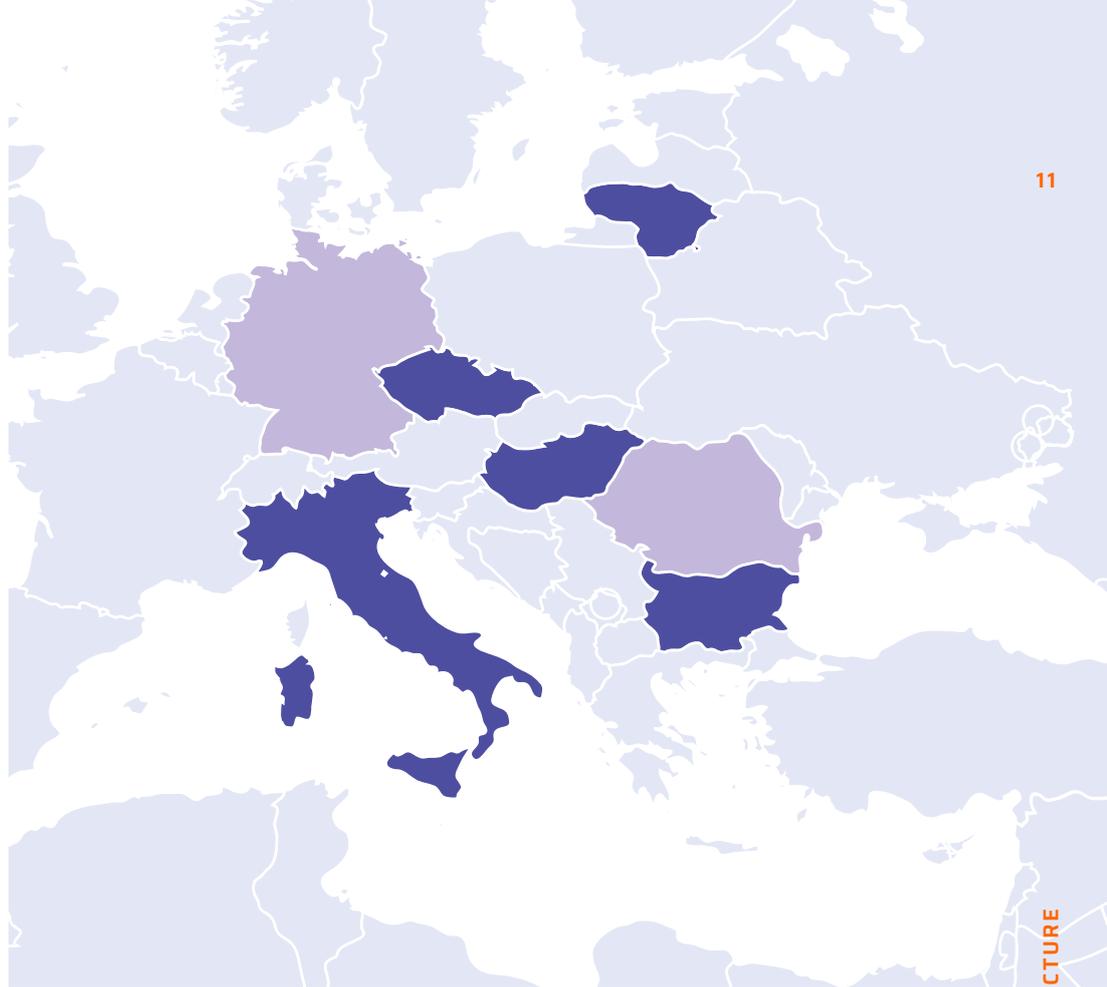
February
2023

Launch of 3rd Joint User Call

October
2023

- Members
- Czech Republic
- Hungary
- Italy
- Lithuania
- Bulgaria

- Observers
- Germany
- Romania



ELI's Member Base

Expanding the ELI member base ensures ELI's long-term sustainability. With its statutory seat in the Czech Republic and research facilities in both Dolní Břežany (ELI Beamlines Facility) and Szeged, Hungary (ELI ALPS Facility), ELI brings together a growing consortium of countries. The Czech Republic and Hungary are joined by Italy and Lithuania as Founding Members, with Bulgaria becoming a Full Member as of 1 January 2025. Germany participates as an Observer, and Romania, which hosts a third ELI facility, joined ELI as a Founding Observer from 1 January 2024. This growth not only ensures diverse national contributions but also amplifies ELI's role as an international research infrastructure.

Integration of the ELI ALPS Facility / Romania joins as a Founding Observer

January 2024

Launch of 4th Joint User Call

March 2024

Launch of 5th Joint User Call

September 2024

Mission-based Access in Inertial Fusion Energy launch

December 2024

Bulgaria joins as a Full Member and Germany is a Full Observer

January 2025

Launch of 6th Joint User Call

March 2025





Bulgaria Transitions to Full Membership

Bulgaria's transition from Founding Observer to Full Member from 1 January 2025 is a significant milestone for ELI as well as the country's laser research capabilities. Bulgaria is the first country to transition from Observer to Full Member, setting a precedent for other countries to join the ELI member base.

During its three-year observership, Bulgaria significantly enhanced its national laser research infrastructure. New cutting-edge laboratories and major upgrades at the Bulgarian Academy of Sciences and Sofia University have enabled Bulgaria to actively engage in high-impact international laser research.

Bulgaria's membership strengthens ELI's member base and positions Bulgaria as a key contributor to this rapidly advancing field of laser science and technology. This membership not only opens pathways for Bulgaria to contribute to cutting-edge research but also fosters the development of international collaborations. The opportunities afforded by this transition will further consolidate Bulgaria's scientific infrastructure while reinforcing Europe's leading position in this important field.

»Bulgaria has a long tradition in laser technology and research and the full membership in ELI is a critical step forward for our national scientific community. This move allows us to fully participate in groundbreaking research and development projects while contributing to the future of laser science in Europe.«

 Deputy Minister **Prof. Nikolai Vitanov.**

Germany Renews Commitment to ELI with a Joint Declaration

Germany reaffirmed its commitment to ELI with a renewed Observer status beginning January 2025, for a two-year term. This formalised engagement is grounded in the Joint Declaration of Intent signed between the governments of Germany, Czechia, and Hungary, outlining a shared vision for deepened scientific cooperation and support for Germany's potential future full membership in ELI.

The agreement highlights key areas of collaboration, including laser-induced fusion, ultrafast science, and accelerator-based medical applications, fields in which both Germany and ELI have strong complementary expertise. The three parties have committed to ongoing joint initiatives, including research programmes, workshops, and community-building events, with annual progress evaluations informing the path toward full German membership. German institutes are among ELI's strongest partners and the diversity of activities additionally strengthens the cooperation.

Strengthening Ties with Romania and Towards an Integration of ELI NP

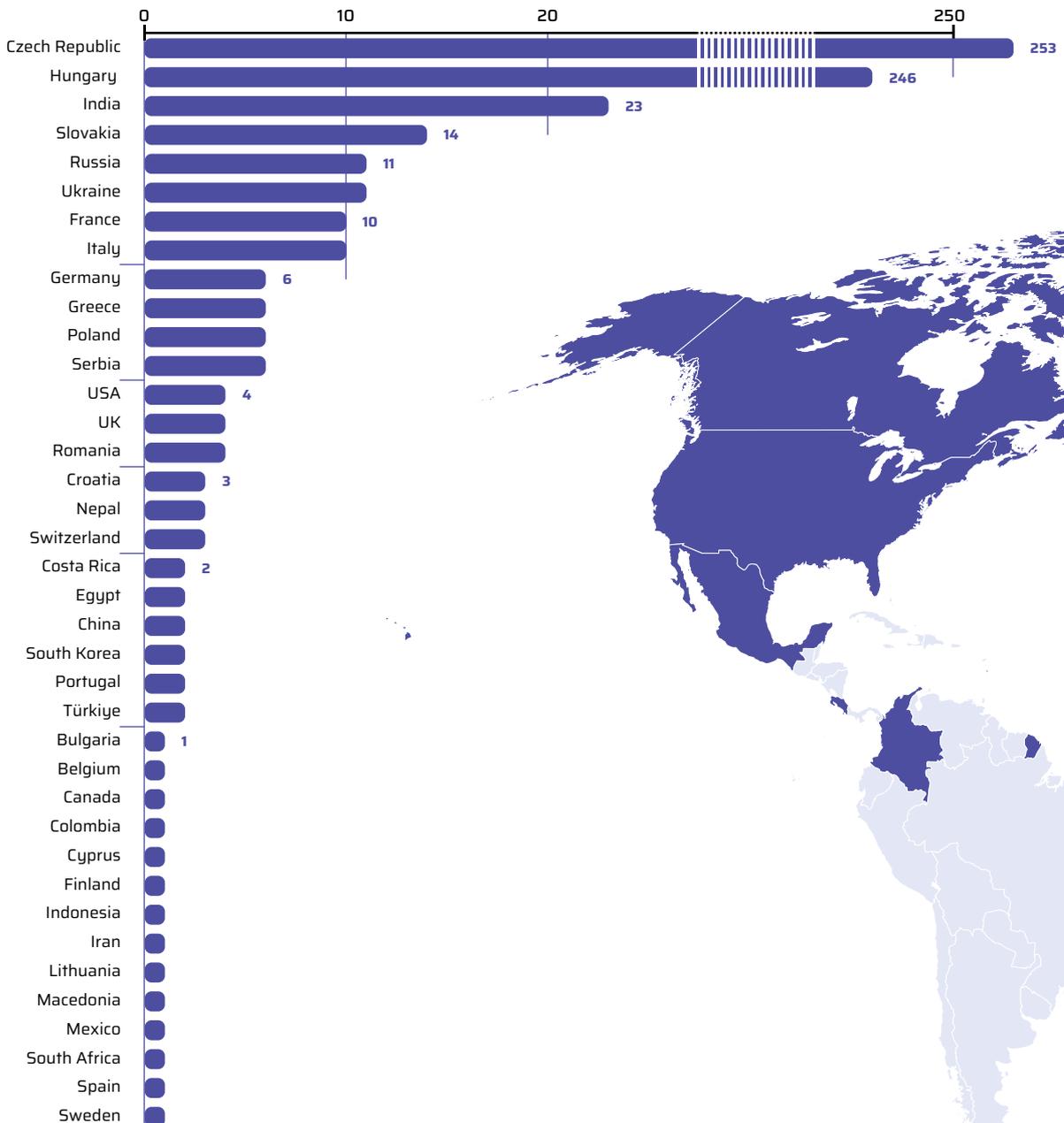
Following the decision of the ELI General Assembly Meeting in June 2023, Romania joined as a Founding Observer effective January 2024. Romania's participation marks an essential phase toward the integration of ELI Nuclear Physics Facility (ELI NP) into the unified ELI framework. Located in Măgurele, Romania, ELI NP is known for its innovative research using their powerful 10 PW lasers. Romania's contributions underscore its dedication to a unified European laser science infrastructure. Through active participation in ELI's User Programme and collaborative scientific projects, Romania is strengthening ties within the ELI community, paving the way for full membership and further enriching ELI's collective scientific capabilities.



ELI Staff

The ELI 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 administrative staff.

Staff by Country of Origin



649

STAFF MEMBERS

38

COUNTRIES

21.8 %
Administration



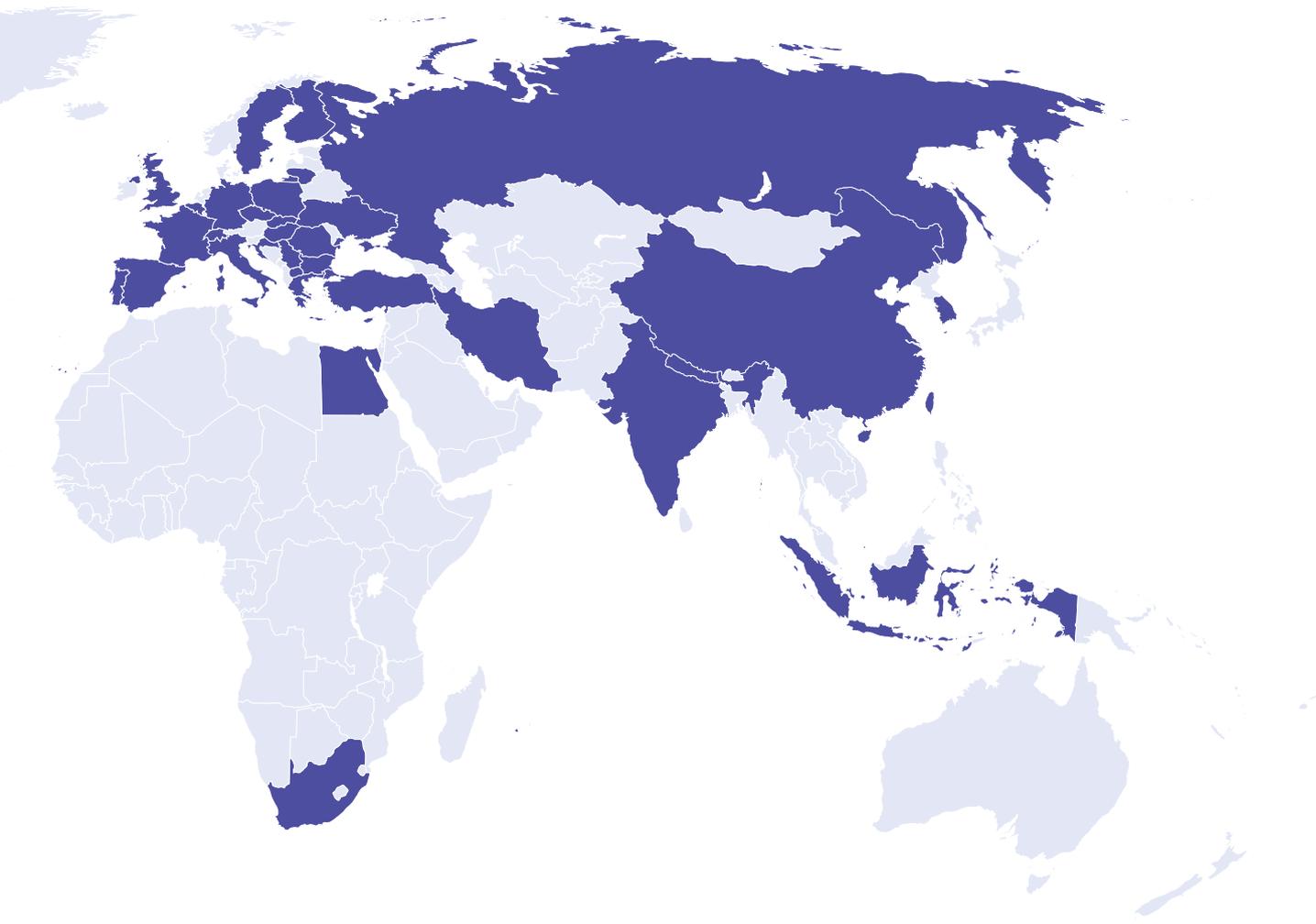
43.7 %
Researchers

34.5 %
Technicians
and Engineers

28 %
Female



72 %
Male





Science in Focus

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User Programme

The ELI User Programme realises the core mission of the organisation by offering streamlined access to ELI’s advanced laser research facilities. Managed centrally, the programme provides users with unified, competitive, and open access to ELI’s scientific capabilities.

Since its launch over three years ago, the ELI User Programme has successfully conducted 6 Calls for Users. Each Call progressively expands the range of instruments and technologies available, further empowering researchers to pursue groundbreaking discoveries. Across these 6 Calls, a total of 563 experiment proposals were submitted by Principal Investigators from 38 countries, confirming the wide international interest in ELI, including America and Asia.

The countries with the highest numbers of experimental proposals (based on the affiliations of the Principal Investigators) include the host countries of ELI (Czech Republic, Hungary and Romania) in addition to the United Kingdom, the United States, Germany, Italy and France.

»The continued growth of the ELI User Programme is evident now not only in the number of proposals, but also in the increasing quality of experiments. New instruments coming online is a big factor driving demand, and we are seeing returning users as well.«

 ELI Director General **Allen Weeks**.

»The quality of the proposals in the [5th] Call was exceptional, I’m very happy to say that we managed to push through the really highest rated projects and I’m looking forward to seeing many of them implemented.«

 **Charlotte Palmer** of Queens University Belfast and Chair of the Particle Acceleration and Applications Peer Review Panel.

Open Excellence-Based Access

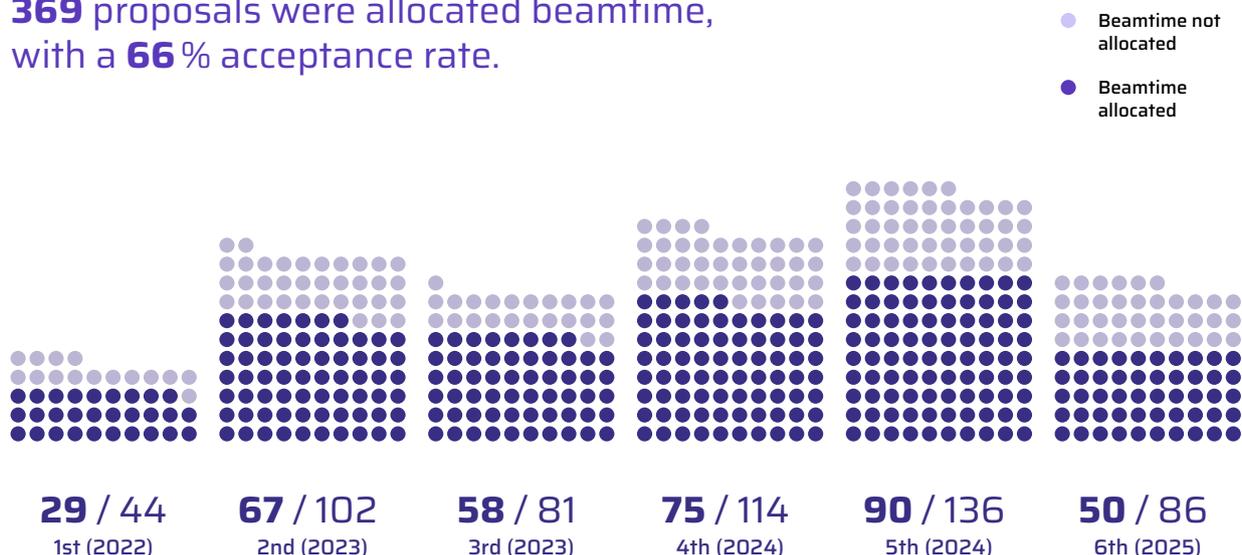
Proposals accepted / Proposals submitted

User Call (Year)	ELI ALPS	ELI Beamlines	ELI NP	All
1st (2002)	8 / 11	17 / 17	4 / 16	29 / 44
2nd (2023)	32 / 35	31 / 49	4 / 18	67 / 102
3rd (2023)	28 / 38	26 / 33	4 / 10	58 / 81
4th (2024)	43 / 56	32 / 58	0 / 0	75 / 114
5th (2024)	35 / 55	39 / 59	16 / 22	90 / 136
6th (2025)	26 / 39	24 / 47	0 / 0	50 / 86
Total	172 / 234	169 / 263	28 / 66	369 / 563
Acceptance Rate	≈ 74 %	≈ 64 %	≈ 42 %	≈ 66 %

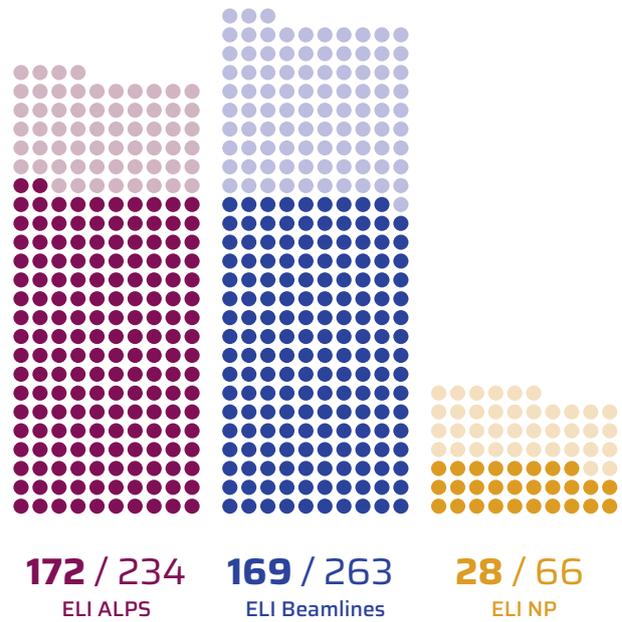
Of the 563 experimental proposals submitted a total of 369 proposals were successful and were allocated beamtime to perform the proposed experiments. Proposals are submitted via a unified User Portal and following an initial feasibility review are evaluated by an external Peer Review Panel based on scientific excellence. Feasible experiments with the highest scientific merit are allocated beamtime.

With the 5th a new record was set with 136 proposals submitted, involving over 450 scientists from 35 countries. Following the evaluation by the Peer-Review-Panel a total of 90 proposals were accepted for implementation. On average, users submitting experimental proposals have a 66% acceptance rate.

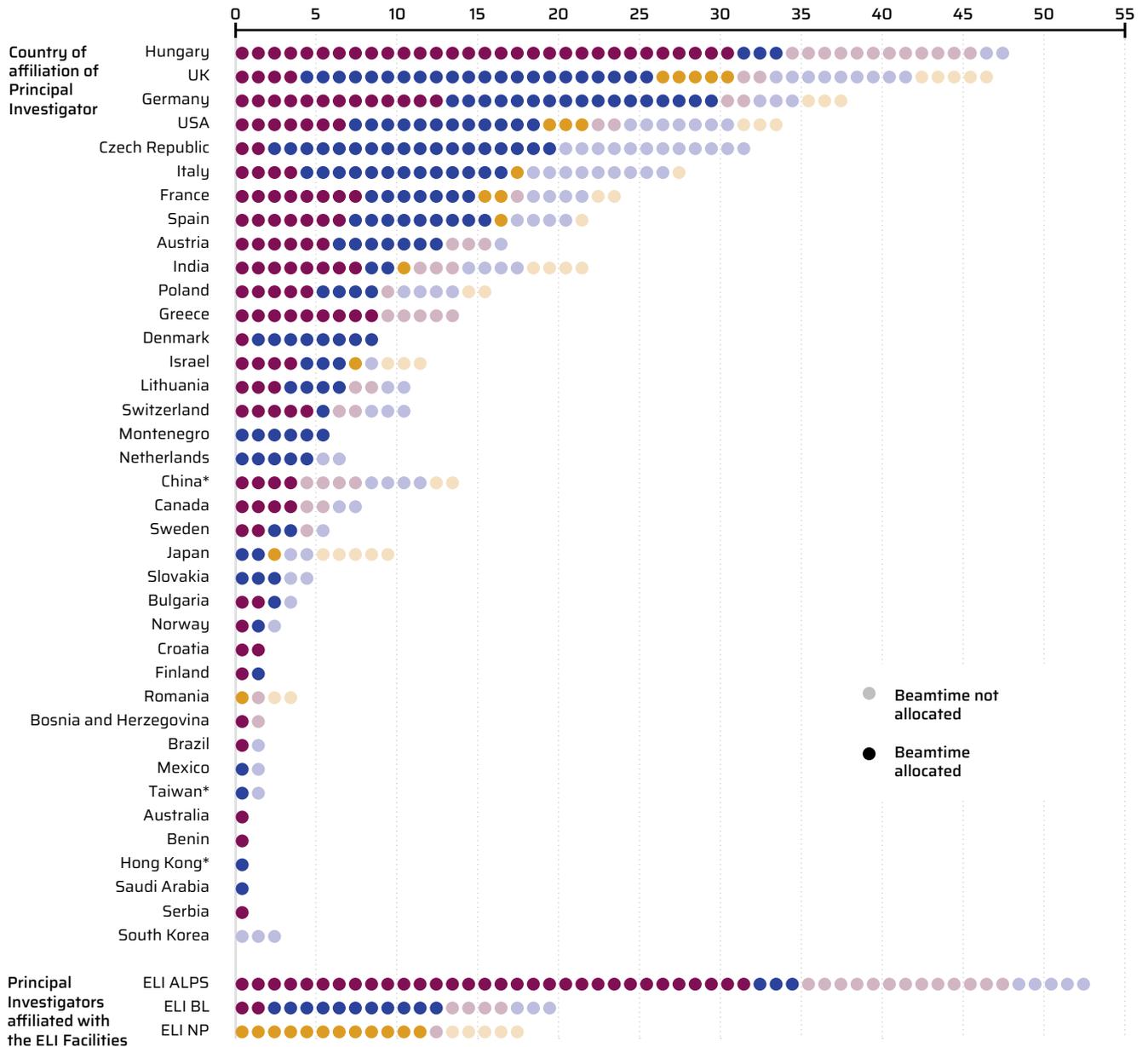
Of the **563** experimental proposals submitted **369** proposals were allocated beamtime, with a **66%** acceptance rate.



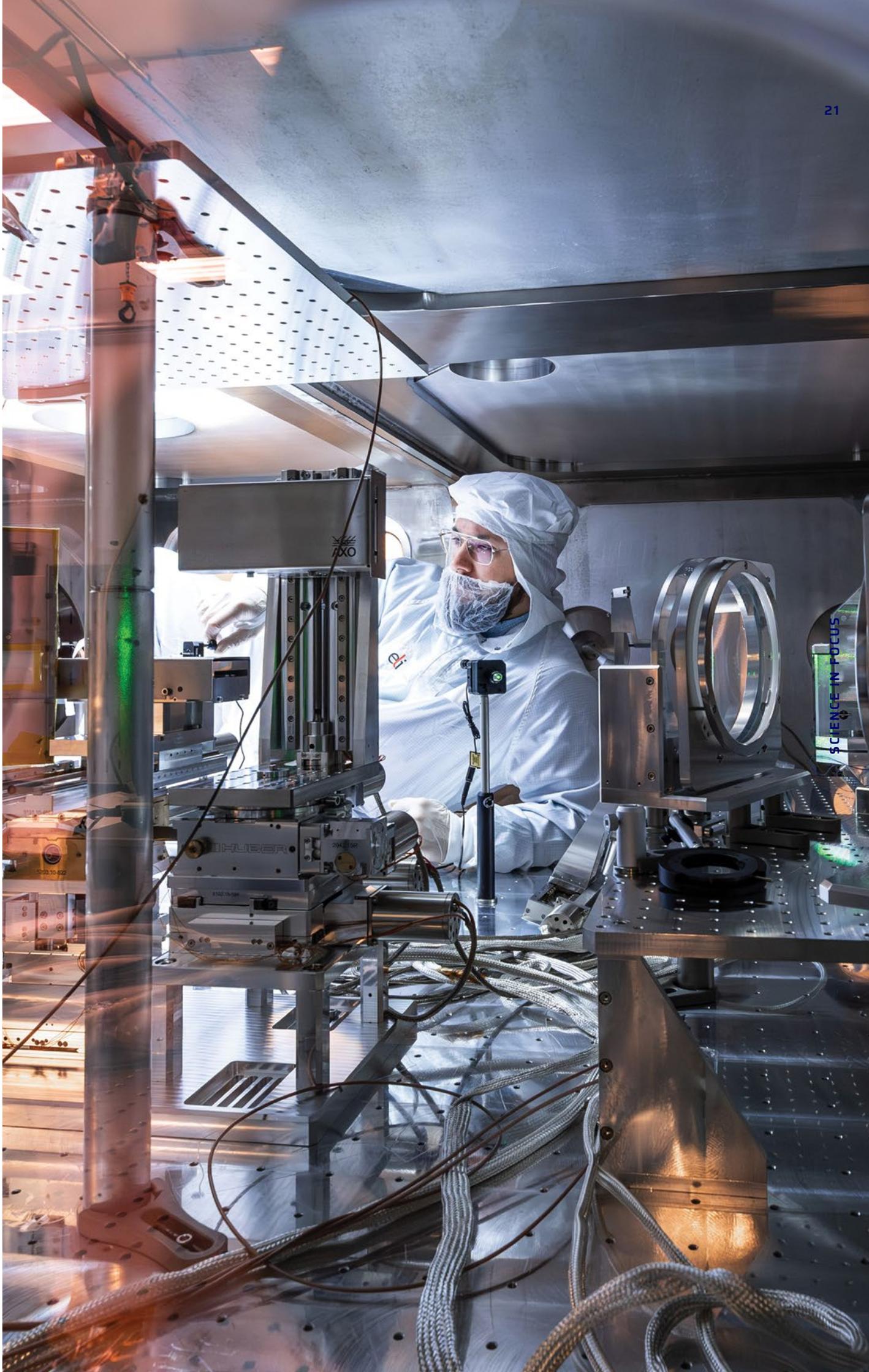
Of all the accepted proposals, **172** were submitted to ELI ALPS, **169** to ELI Beamlines and **28** to ELI NP.



Across the six calls proposals were submitted by Principle Investigators affiliated with institutes in 38 countries.



*The statistics for Mainland China, Hong Kong and Taiwan are provided separately for more granularity, but counted as one single country.



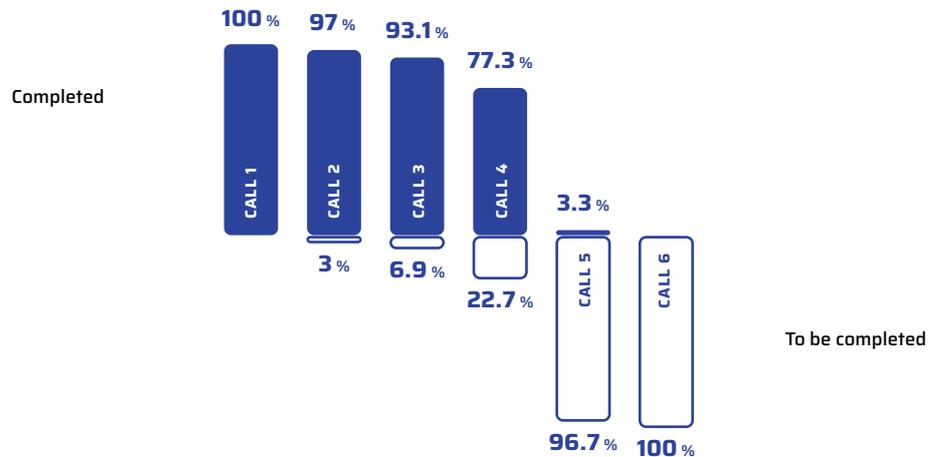
Areas of Science

ELI supports diverse, high-impact research spanning multiple scientific domains. The largest shares of user experiments focus on Atomic, Molecular, and Optical (AMO) chemistry and physics, alongside Materials and Surface Science. These areas highlight ELI's role in fundamental and applied research on the interaction of intense laser pulses with matter. Particle Acceleration and Applications constitute another significant area, emphasising ELI's contributions to advancing laser-driven accelerators. Life Sciences and Relativistic and Ultrarelativistic Interactions represent essential research fields, underlining the broad interdisciplinary nature of ELI's User Programme. Additionally, Plasma Physics, with a smaller number of experiments, remains a critical area supported by ELI's unique experimental capabilities.

Implementation Status of User Experiments (editorial deadline June 2025)

As of the end of June 2025, ELI has successfully implemented over 209 out of the 369 approved user experiment proposals across 6 User Calls. The first 2 Calls have been fully implemented while Call 3 and 4 are nearly finalised. Beamtime for the most recent Call 6 has just been allocated, and experiments will be scheduled for implementation. This steady progress demonstrates ELI's commitment to effectively managing and delivering access to its facilities. User Calls are scheduled to open twice a year in spring and in autumn.

209 experiments have been completed.



160 experiments are ongoing, scheduled or in scheduling.



Materials and Surface Science

This field investigates how intense laser fields modify the physical and chemical properties of materials. At ELI, researchers use advanced diagnostics to probe surfaces, nanostructures, and thin films, enabling insights into phase transitions, defect formation, and material responses on femtosecond timescales.



Atomic, Molecular, and Optical Physics

AMO physics explores the fundamental interactions between light and matter at the atomic and molecular level. The ELI facilities enable studies of electron dynamics, ultrafast ionisation, and high-harmonic generation with unprecedented time resolution, helping to unravel the structure and behaviour of atoms and molecules under extreme conditions.



Particle Acceleration and Applications

ELI's laser systems provide access to advanced laser-plasma acceleration schemes that generate compact, high-energy beams of electrons, protons, and ions. These sources support a wide range of applications, from medical imaging and radiobiology to high-energy-density physics and next-generation accelerator technologies.



Relativistic and Ultrarelativistic Interactions

ELI offers a platform for exploring light-matter interactions in extreme regimes, where particles approach the speed of light and quantum electrodynamics (QED) effects become significant. Experiments in this domain advance our understanding of strong-field physics, radiation reaction, and pair production.



Plasma Physics

Laser-driven plasma research at ELI focuses on the generation, characterisation, and control of plasmas under extreme temperatures, densities, and field strengths. These studies support applications in fusion science, laboratory astrophysics, and the development of novel radiation sources.



Nuclear Physics

ELI's capabilities in high-intensity laser interactions with matter enable research at the intersection of plasma physics, quantum electrodynamics (QED), nuclear photonics, astrophysics, and nuclear material science paving the way for new insights into fundamental interactions and societal applications.



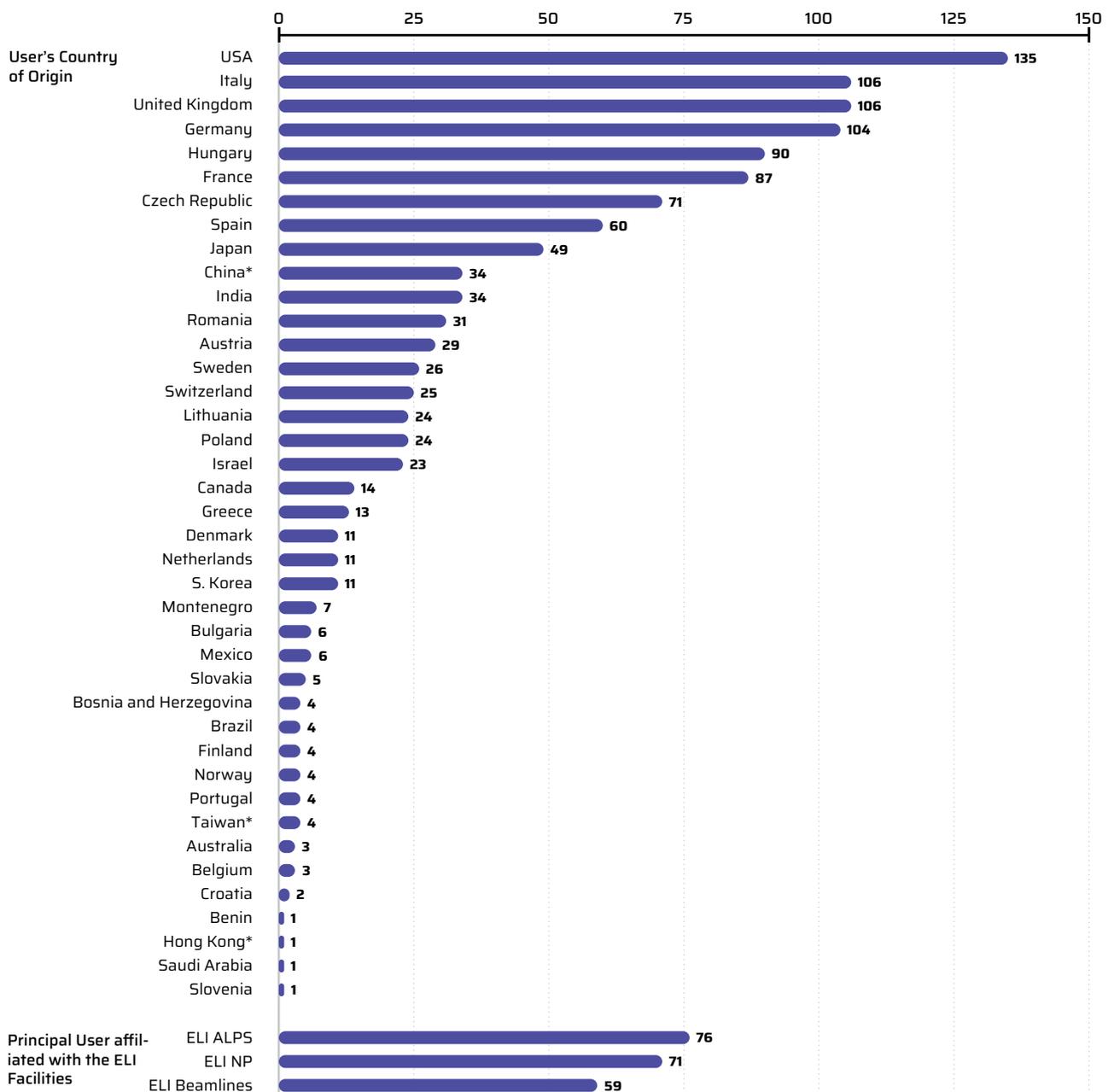
Life Sciences

Using ultrashort pulses and secondary sources such as X-rays and particle beams, ELI enables unique experiments in structural biology, imaging, and radiobiology. These capabilities allow scientists to study the dynamics of biomolecules and tissues, assess radiation effects on cells, and support medical applications in a variety of areas, such as cancer research.

User Community

ELI hosts a dynamic, international scientific user community composed of leading researchers, academics, and industry experts from diverse scientific disciplines. The User Programme also demonstrates the growing scientific user community around ELI. With over 1400 individuals from 38 countries, ELI's users represent scientific communities from all over the world. ELI ensures continuous dialogue and engagement with the user community through key events and structured feedback, strengthening global collaborations and enabling groundbreaking discoveries.

ELI user community:
 ≈ **1400** individuals from **38** countries



*The statistics for Mainland China, Hong Kong and Taiwan are provided separately for more granularity, but counted as one single country.

Launch of Mission-Based Access in Inertial Fusion Energy (IFE)

Building on the excellence-based access model, ELI introduced a mission-based access which provides researchers competitive access to ELI's experimental suite through programmes addressing specific scientific and technological challenges. Mission-based proposals must align directly with defined missions and typically involve multiple experiments and resource contributions from participants.

In December 2024, ELI launched the first mission-based call for access in Inertial Fusion Energy (IFE). This initiative is designed to accelerate breakthroughs in laser-driven fusion technology, a research and innovation area with immense potential to provide clean, sustainable energy solutions and address global energy demands.

The IFE programme supports research stakeholders from academia and industry worldwide, offering extended beamtime for rigorous experimentation. This long-term commitment enables the pursuit of comprehensive projects designed to overcome fundamental scientific and engineering challenges within the fusion energy domain. In the first stage of the application process ELI received 17 Expressions of Interest (EoI) from leading research groups all over the world. This demonstrates the strong interest from the scientific community in ELI's capabilities to drive advancements towards the realisation of IFE. As the next stage the teams will submit full proposals and only selected projects will gain multi-year access to ELI's flagship lasers to address sustainable energy and other pressing societal challenges.

Through these strategic and collaborative efforts, the IFE programme positions ELI as a leading driver of innovation, fostering significant scientific advances and contributing to solving some of the world's most pressing challenges, impacting society as a whole.

Scientific Highlights

As the ELI User Programme continues to evolve, experiments conducted at the ELI facilities are beginning to yield a growing number of scientific results. These outputs demonstrate the unique capabilities of ELI's advanced laser systems and secondary sources, and their value across a wide range of research fields.

From ultrafast dynamics in atoms and materials to particle acceleration, plasma physics, and applications in life sciences and fusion energy, the results highlighted in this section reflect the scientific momentum building across the infrastructure. They also showcase the growing impact of ELI as an open-access user facility supporting high-quality, frontier research.



Imaging the Ultrafast Electron Dynamics at Graphene/Metal Interfaces

Faster, smaller, and more efficient—these are the fundamental demands of next-generation information technologies to process increasing amounts of data in shorter timeframes. Meeting these demands requires an extensive understanding of the fundamental behaviour of electrons and their angular momentum (spin) in novel low-dimensional materials, particularly on ultrashort and femtosecond-timescales.

With this goal, researchers from the Universities of Augsburg and Kaiserslautern-Landau in Germany, in collaboration with scientists from ELI ALPS in Szeged, Hungary, have investigated the ultrafast electron dynamics of a functionalised, atomically thin carbon layer (graphene) on a magnetic surface.

“The functionalisation with heavy metal atoms gives us a unique opportunity to activate the spin degree of freedom in graphene and to induce semiconductor-like band gaps—both of which are crucial for future spintronics applications,” explains Eva Walther, a PhD student at the University of Kaiserslautern-Landau.

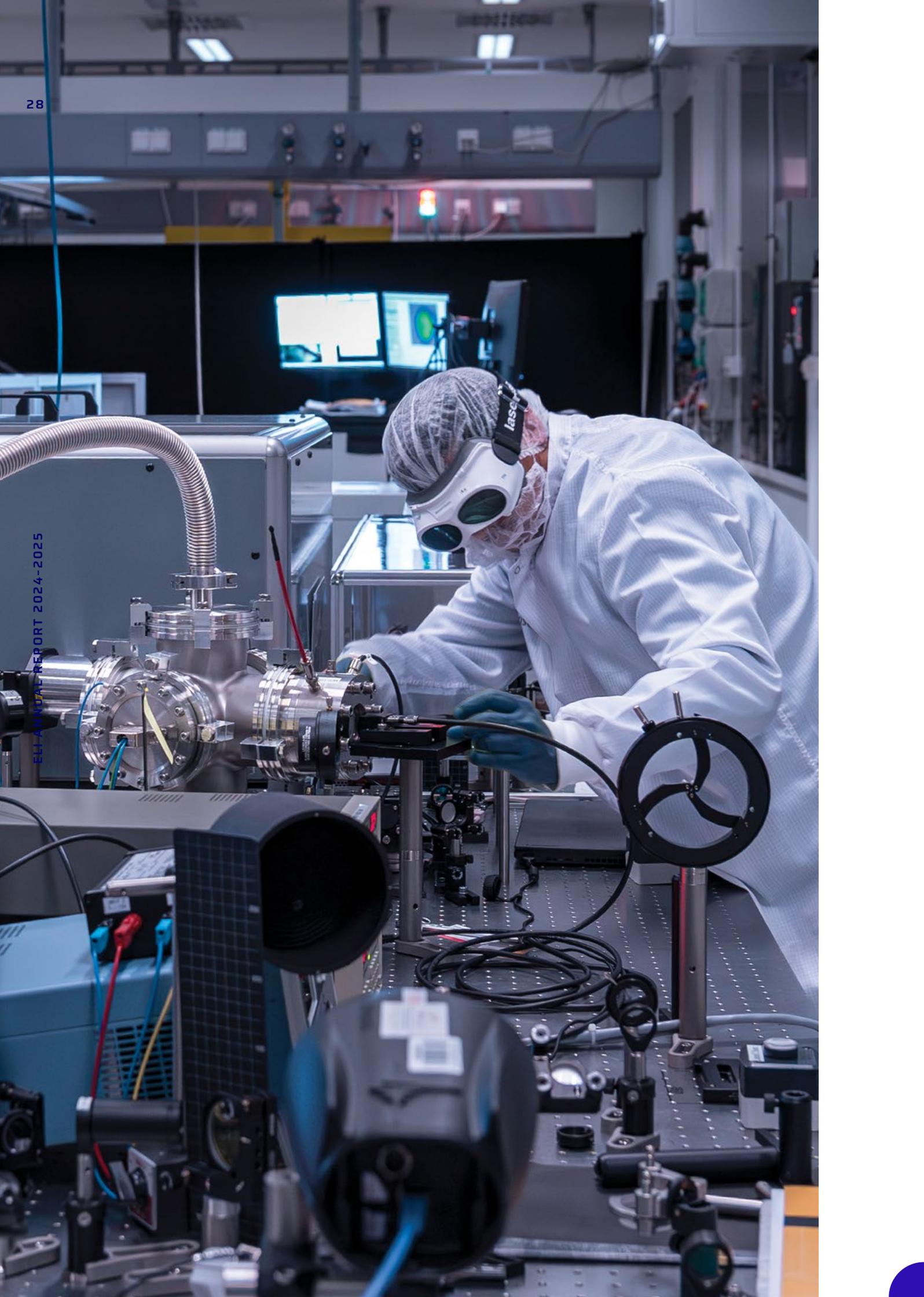
A main challenge in this study is identifying the experimental signatures of each component in the graphene/lead/nickel system. This was studied by using pump-probe photoelectron spectroscopy at the NanoESCA end station. “Ultrashort laser pulses were used to optically excite the sample and initiate the electron dynamics. A second femtosecond EUV pulse

then generates photoelectrons, which was detected across the entire Brillouin zone using the NanoESCA instrument,” says László Óvári, Head of the Surface and Chemical Dynamics Group.

»We observed a pronounced band gap in the graphene layer resulting from its interaction with lead atoms. This band gap influences the ultrafast electron dynamics, leading to charge transfer between the graphene and the underlying nickel surface, ultimately modifying the energy level alignment at the interface.«

These findings provide new insights into the ultrafast band-structure dynamics of functionalised low-dimensional materials and lay the groundwork for future exploration of their spin dynamics at ELI.





Cryogenic Technique Boosts High-Power Multicycle Terahertz Pulses

Read the full publication:



A team from the Cockcroft Institute, the University of Manchester, and the Lancaster University (UK), led by Darren Graham, demonstrated a novel approach to generating high-power, narrow-bandwidth terahertz (THz) pulses. The team achieved this by using hand-assembled stacks of periodically poled lithium niobate (PPLN) wafers which are cryogenically cooled. The experiment leveraged the powerful pump laser of the High-Energy Terahertz (HE-THz) source at ELI ALPS, which deliver pulses of 1 μm wavelength, 500 fs duration, and up to 500 mJ energy.

During the experiment the researchers constructed PPLN stacks comprising up to 48 wafers and cooled them to 97 K. The cryogenic cooling significantly reduced the THz absorption losses within the lithium niobate, and enabled the generation of multicycle pulses with a centre frequency of 0.39 THz, and pulse energies reaching as high as 0.42 mJ, with an average power output of 21 mW.

The cooling technique not only reduced THz absorption losses but also maintained the tiny micrometer-scale inter-wafer gaps which are essential for optimal pulse transmission. This resulted in more uniform waveform.

These results highlight how these large area sources can be scaled to even greater numbers of wafers to push both the energy and a narrower bandwidth beyond current capability. This opens possibilities in areas such as THz-driven particle acceleration, THz imaging, and control over material properties.



HIGHLIGHT 3

Exploring Ultrafast Charge Carrier Dynamics in 2D Semiconductors

Read the full publication:



Researchers from the Felix Bloch Institute for Solid State Physics at Leipzig University, in cooperation with scientists at ELI Beamlines, gained new insights into the ultrafast behavior of charge carriers and excitons in atomically thin materials. The focus of the experiment was monolayer molybdenum disulfide (MoS_2)—a two-dimensional semiconductor with promising applications in next-generation optoelectronic and quantum devices.

Using ultrafast pump-probe spectroscopy the team was able to track how excitons and free charge carriers behave on femtosecond timescales after being excited by a short laser pulse. These measurements provided detailed information about how photoexcited carriers relax, recombine, and interact with one another in the ultrathin material.

A key result of the experiment was the ability to directly observe how light-triggered processes unfold in monolayer MoS_2 in real time. When struck by a short laser pulse, the material generates excited states called excitons. These excitons form in just a few hundred femtoseconds and begin to evolve rapidly: some relax, others break apart, and some interact with freely moving charge carriers.

This ultrafast activity, occurring in less than a trillionth of a second, plays a major role in how efficiently the material conducts electricity or converts light into energy. By understanding how these processes compete and interact, researchers can better design high-performance, ultrathin devices such as photodetectors, transistors, and flexible solar cells.

The experiment was enabled by the state-of-the-art femtosecond laser systems at ELI Beamlines, allowing researchers to capture the incredibly fast dynamics within the material with exceptional precision. The study highlights ELI's capabilities in ultrafast spectroscopy and showcases how the facility supports a diverse range of scientific disciplines, including advanced materials research.

By revealing how energy flows and dissipates in atomically thin semiconductors, this work lays important groundwork for the development of next-generation optoelectronic technologies, from ultrafast sensors to efficient light-harvesting devices and helps bridge fundamental research and device-relevant applications.



HIGHLIGHT 4

Laser-Driven Characterisation of Cultural Heritage Materials

The characterisation of the composition of materials plays a crucial role in the knowledge, conservation, and restoration of art objects. In this context, the irradiation of materials using X-ray tubes and proton accelerators enables the emission of secondary radiation (characteristic X-rays) from the samples, that can provide useful information about their composition. These methodologies, known as X-ray Fluorescence Spectroscopy (XRF) and Particle Induced X-ray Emission (PIXE), are among the most powerful tools due to their detection capabilities and non-destructive nature.

The use of photons and protons produced through the interaction of a high-intensity laser with a solid target has been under investigation because of the potential versatility and compactness of these innovative sources. The experiment conducted by the team from Politecnico di Milano (Nanolab, Department of Energy), in collaboration with the RayLab company, Istituto di Scienze del Patrimonio Culturale (ISPC) of the Italian National Research Council, and a team at ELI Beamlines, aimed to explore the use of protons and photons generated via the L3 beamline to characterise materials relevant to cultural heritage (i.e. bronzes and ceramics).

High-energy photons and protons emitted from the interaction between the laser pulse and a thin metal foil were injected into a novel device developed by the

researchers, which allowed for the measurement of the energy of the accelerated particles. With this instrument, the radiation was propagated through air and used to irradiate the samples. The characteristic X-rays emitted by the irradiated materials were measured using a specific camera.

For the first time, the analysis of the obtained data enabled the quantitative characterisation of cultural heritage objects in air without relying on reference samples of known composition. These results lay the foundation for the development of laser-based accelerators tailored for cultural heritage studies, suggesting that, with further optimisation, this approach could achieve elemental sensitivity comparable to conventional sources while maintaining the inherent versatility of laser-driven systems.



HIGHLIGHT 5

Temporal Characterisation of Solid-state Harmonics with Broad Span over 2.6 Octaves

Read the full publication:



A recent user experiment conducted with ELI ALPS's mid-infrared (MIR) laser laboratory led by Edouard Hertz from the Université Bourgogne Europe resulted in significant findings. The experiment, focuses on comprehensive characterising of ultra-broadband fields spanning from the visible to mid-infrared (MIR) spectral region.

To achieve this, the researchers employed a recently developed method called Plasma-Induced Frequency Resolved Optical Switching (PI-FROSt). This innovative approach circumvents phase-matching constraints and damage thresholds.

The radiation produced in this experiment consists of a series of harmonic fields (odd and even) generated by a 3.2 micrometres wavelength, few-cycle driving pulse operating at 100 kHz in an a-cut zinc oxide (ZnO) crystal that is 270 micrometres thick.

The delayed pump and probe beams are focused in air by a common off-axis parabolic mirror. The pump beam, which arrives slightly earlier, creates a small region of plasma, which acts as a “divergent lens” and defocuses the probe beam. The defocused probe spectrum is then measured by spectrometers at different pump-probe delays. Finally, the recorded experimental spectrograms are reconstructed using the Levenberg-Marquardt algorithm to reveal the temporal structure of the pulses under investigation.

Using the same non-linear architecture, the team successfully reconstructed the harmonics up to the fifth order, covering a wide spectral range—from 0.59 to 3.6 micrometres. The relative phase remains out of reach due to the absence of spectral overlap.

This field reconstruction provides valuable insights into the complex dynamics behind harmonic generation mechanisms and can serve as a guideline to support numerical modeling. The findings also corroborates phenomena such as pulse splitting due to significant phase and group velocity mismatches in crystal targets.

The results help to better understanding ultrafast laser-matter interactions, paving the way for advances in precision spectroscopy, ultrafast imaging, and materials science applications.

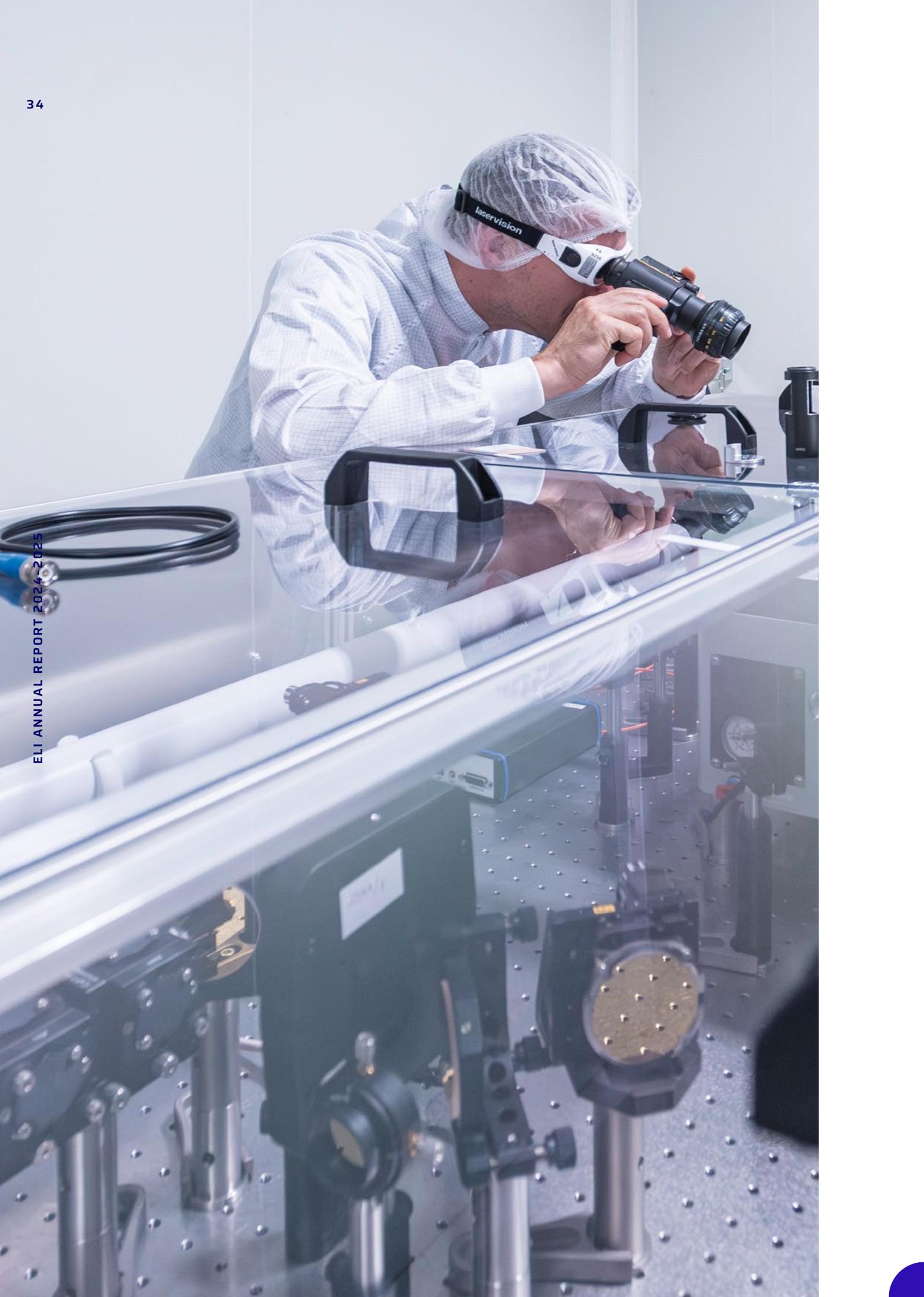
XUV Fluorescence as a Probe of Ultrafast Dynamics in Helium Nanodroplets

Helium nanodroplets are intriguing nanoscale objects with unique properties, such as ultralow temperature and superfluidity. After irradiation with XUV light, excited He^* are created, which can evolve in different ways. A possible pathway is a decay of He^* by Interatomic Coulombic decay—a process producing low-energy electrons, which cause radiation damage in biological matter. Therefore, investigation of dynamics and the fate of He^* in a nanodroplet as a model system is relevant to radiation physics and radiobiology.

In an experiment by Marcel Mudrich (Kassel University, Germany) at the MAC station at ELI Beamlines, a tunable HHG source was used to resonantly excite He nanodroplets. An XUV fluorescence probe for studying dynamics of excited He^* in a droplet was developed. In the setup a delayed NIR pulse was used to avalanche ionize the excited droplet, leading to a fluorescence signal. The measured fluorescence yield is indicative of the population of excited He^* attached to the He nanodroplets. Measuring the time-dependent fluorescence yield provides a probe of the dynamics of He^* and Interatomic Coulombic decay.

The experiments on the MAC station together with Monte Carlo simulations have revealed an important decay channel, where the excited helium atoms roam about the nanodroplet surface before Interatomic Coulombic decay takes place. This is a novel process, where the nuclear motion of He^* in the nanodroplet is important in defining the dynamics. As this decay channel involves He^* roaming, it is rather slow, evolving on a nanosecond time scale. The results are significant for radiation damage studies and radiation biology.





HIGHLIGHT 7

Harnessing Machine Learning for Advanced Laser Characterisation

Read the full publication:



In laser experiments, and especially in high harmonic generation, it is important to know the time variation of the electric field of the laser. The so-called carrier-envelope phase (CEP) describes how the oscillation of an electric field relates to the intensity shape of the pulse that envelops it. In other words, how the peaks of the pulse and the electric field are shifted relative to each other. Ultra-short laser pulses of few optical cycles can be characterised with their CEP.

However, determining the CEP is complex and requires specialised measurement instruments. A new approach by the research team at ELI ALPS employed artificial intelligence to determine the CEP.

By training a machine-learning algorithm with numerous examples of high harmonic spectra and their associated CEP values, the AI model learned to predict the CEP directly from new spectra measurements. Although training the algorithm requires significant effort and initially conventional CEP measurement for verification, its long-term use could eliminate the need for complex CEP measurement tools

This research was the first successful experimental demonstration of this AI-driven approach in practice. It introduces artificial intelligence into a new domain of laser physics—offering a smart, scalable solution for precision optics and ultrafast science.

Beyond academic interest, this advancement opens the door to developing compact, palm-sized devices capable of accurately characterising laser pulses using AI technology, which may lead to commercial applications and patented instruments.

HIGHLIGHT 8

Attosecond Metrology of VUV High-order Harmonics

Read the full publication:



Attosecond science relies on the use of attosecond pulses which are formed in the extreme-ultraviolet (XUV) spectral range. However, direct application of XUV on naturally available systems, such as atoms, molecules and other materials, leads to single photon ionization, making it impossible to study their internal dynamics without disruption.

To address this challenge, an international team of researchers from ELI ALPS, ICFO (Barcelona, Spain), Guangdong Technion-Israel Institute of Technology (Guangdong, China), Technische Universität Wien (Vienna, Austria), Université de Bordeaux-CNRS-CEA (Bordeaux, France), and the Institute of Electronic structure and Laser at Foundation for Research and Technology-Hellas (IESL-FORTH), led by Paraskevas Tzallas have developed a source delivering attosecond pulses in the vacuum ultraviolet and new methods to measure their main features (duration, intensity, etc.).

Using ELI ALPS' MIR system to conduct the experiment, the team demonstrated that semiconductors illuminated by strong mid-infrared laser light emit vacuum-ultraviolet (VUV) attosecond pulses. Crucially, the team also measured the precise duration and temporal shape of these pulses for the first time.

These results establish the basis of a new techniques to explore ultrafast changes which occur in most natural systems while preserving their bound state and without inducing their ionization. The new tools and methodology could be used for conducting studies in natural systems in all states of matter, investigating their ultrafast dynamics and even possibly using them to engineer novel quantum light states.

HIGHLIGHT 9

Ultrabroadband Hybrid Frontend Development for High-peak-power Lasers

The High Field Laser Group of ELI ALPS, in collaboration with the SYLOS Laser Group and Light Conversion developed a cutting-edge laser frontend that significantly enhances the performance of high-intensity laser systems. This innovative ultrabroadband hybrid frontend delivers ultrashort pulses with high contrast, opening new possibilities for advanced scientific and industrial applications.

At the core of this system lies an industrial-grade femtosecond optical parametric amplification (OPA) system, which provides the initial seed pulses. To effectively amplify the pulses, the researchers employed a unique approach combining of negative stretching and positive compression techniques alongside spectral shaping by an optical rotatory dispersion filter.



This enabled amplification of pulses up to an energy level of 13 mJ with an ultra-broadband spectrum corresponding to 14.5 fs in two Ti:Sa-based amplifier stages at 100 Hz repetition rate. After compression, 15 fs pulses with an extremely high contrast ratio greater than 10^{12} were achieved, already 15 ps before the main pulse. The next phase of the implementation aims to fine tune the system for high energy stability, and for even shorter output pulses.

Additionally, ongoing research in nonlinear spatio-temporal cleaning techniques is set to elevate the system's performance further, to obtain record high 10^{15} contrast ratio in combination with mJ level output energy. This new frontend is a significant step toward realising ultra-high contrast, sub-17 fs petawatt-class laser systems operating at repetition rates up to 100 Hz, promising significant impacts in fields such as material science, high-energy physics, and precision industrial processes.

HIGHLIGHT 10

First Evidence of Energy Transfer Between Retinal Chromophores

Read the full publication:



A user experiment led by John T. M. Kennis of Vrije Universiteit Amsterdam in cooperation with an international team including researchers from ELI reported the first-ever observation of energy transfer between retinal chromophores, which are light-sensitive molecules central to vision and photoreception.

The experiment was performed on the Femtosecond Stimulated Raman Spectroscopy (FSRS) at ELI Beamlines which is a cutting-edge setup for tracking ultrafast molecular processes with high temporal and spectral resolution. The results revealed a previously unknown mechanism by which biological photoreceptors can communicate, suggesting that organisms might adapt to new sensory inputs without evolving entirely new receptors.

The study focused on NeoR, a microbial rhodopsin protein that forms natural dimers, which are two identical chromophore-containing units bound together. Using ultrafast spectroscopy, the research team observed that when excited by ultraviolet (UV) light, energy is transferred from one retinal chromophore to the other within a picosecond (less than a trillionth of a second), making it an efficient molecular interaction and the first direct evidence of such a process.

The implications of this finding suggests that photoreceptor proteins may interact and share energy, allowing biological systems to perceive a broader

spectrum of light, including UV, without needing to evolve entirely new receptors. In other words, one receptor can forward information to another, effectively expanding sensory capabilities through internal communication. This introduces the possibility that visual systems may operate in more complex and cooperative ways than previously understood.

This mechanism advances our understanding of how light is processed in living organisms and opens new possibilities in both evolutionary biology and bio-engineering. It offers a potential explanation for how some organisms may gain UV vision and also inspires new strategies for designing light-sensitive materials or artificial photonic systems.

By demonstrating the potential complexity and adaptability of natural photoreception, these results open pathways for the development of biomimetic technologies and artificial photonic devices capable of mimicking these sophisticated natural systems.

Laser-Driven Ionizing Beams for Radiobiology and Cancer Therapy

Laser-driven ionizing beams, including electrons, protons, and neutrons, continue to demonstrate potential for precision radiotherapy, owing to their ultra-high dose rate per pulse and finely focused spatial resolution. Over the past year, theoretical models have further substantiated the advantages of these beams in achieving an improved therapeutic ratio—maximising tumour control while minimising toxicity to healthy tissues. Building on these models, recent experimental milestones have validated laser acceleration of ionizing particles and enabled pioneering radiobiology experiments *in vitro* and *in vivo*, confirming the feasibility of using these advanced beams in biomedical research.

A key achievement this year included significant advancements in beam stabilisation and delivery techniques across the ELI facilities. The efforts have focused on establishing a consistently operational beam setup capable of repetitive, controlled exposures which are essential for the comprehensive characterisation of biological effectiveness. In particular, improvements in alignment precision has laid the groundwork for high-repetition-rate studies with improved reliability. The continued optimisation of laser-plasma interaction parameters has also further enhanced the reproducibility of particle spectra and dose uniformity, addressing a primary challenge in laser-driven radiobiological research.

In a study conducted at the L1 ALFA beamline and at eSYLOS, an *in vivo* radiobiological experiments using ultra-relativistic, laser-driven electron beams operating at kilohertz repetition rates using Zebrafish embryo model (ZFe) was performed. Several runs in 5 experimental campaigns resulted in relevant biological effect comparison to conventional electron irradiation, confirming the suitability of the ALFA and eSylos beamlines for preclinical and biomedical applications. Furthermore, continued developments in beam homogeneity, stability, and dosimetry are expected to further refine the platforms, enabling deeper exploration of high dose rate radiobiology and paving the way toward future therapeutic implementations.



Additional experiments using complementary sources of ELI, including the Laser-Initiated Transmutation Laboratory and the ELIMAIA-ELIMED proton source enabled pioneering radiobiology experiments in both in vitro and in vivo models, which confirm the feasibility of using these advanced beams for research purposes.

The convergence of advanced laser-driven particle acceleration, precise dosimetry control, and innovative biological assays positions ELI at the forefront of radiobiology research. The encouraging in vitro and in vivo data generated provides a strong foundation for the next phase: multi-modal comparative studies, dosimetry refinement, and preclinical therapeutic investigations.

»Laser-driven particle beams are paving the way for a more targeted, high-precision cancer care. Thanks to these promising experiments, we hope that in the foreseeable future—meaning decades—laser-driven particle sources will be able to help the work of doctors.«

✍ **Prof. Dr. Katalin Hideghéty**, Head of the Biomedical Applications Group at ELI ALPS and the Radiooncology Research Group of Oncotherapy at the University of Szeged.





HIGHLIGHT 12

Opening New Frontiers in Laser-Driven Radiobiology

With the number of cancer patients increasing, the demand for radiation therapy continues to grow. Among promising treatment options is proton therapy, which offers a distinct clinical advantage over conventional radiation: the ability to deposit most of the dose directly at the tumor site while sparing surrounding healthy tissue. However, access to proton therapy remains limited due to the high cost and complexity of building and operating conventional proton accelerator facilities. To address this, researchers are turning to alternative accelerator technologies such as laser-driven particle acceleration. Laser-driven radiation sources could open the door for mechanistic studies aimed at unraveling the interplay between radiation physics, chemistry, and biology.

Read the full publication:



The ELIMAIA-ELIMED beamline at ELI is at the cutting-edge of these developments. The team of researchers completed the first radiobiology experiment using laser-accelerated protons, a critical milestone in demonstrating the viability of laser-driven sources for medical research and, eventually, clinical application.

The experiment, which was launched as part of the EU-funded IMPULSE project, used the L3 HAPLS laser to produce proton beams with energies of around 24 MeV, pulse durations of a few nanoseconds, and ultra-high peak dose rates exceeding 3.5×10^6 Gy/s—conditions that cannot be achieved with conventional accelerators. These beams were used to irradiate

normal human dermal fibroblasts (AG01522) in a controlled, multi-shot regime, with total doses ranging from 0.4 to 1.5 Gy.

After irradiation, the biological response was assessed through the formation of 53BP1 foci, which mark DNA double-strand breaks—a key indicator of radiation-induced damage. The results revealed that the effects of laser-driven proton irradiation were comparable to those induced by conventional clinical proton sources, validating the biological relevance of these compact, high-intensity beams.

These results are not only a validation of the beamline's capabilities but an endorsement of laser-plasma acceleration as a next-generation technology for radiotherapy. Beyond their practicality, the beam characteristics—such as ultra-short pulses and extremely high dose rates—may open new avenues in treatment effectiveness, to reduce damage to normal tissue.

With the ELIMAIA-ELIMED beamline now fully operational for radiobiological studies, ELI has taken a step in bridging laser physics and radiation medicine. This underscores ELI's central role in building a new foundation for laser-based cancer therapy—one that is more accessible, more precise, and more adaptable to the medical needs of the future.

HIGHLIGHT 13

Generation of Positrons at Kilohertz Rates

The eSYLOS beamline at ELI ALPS is a laser wakefield accelerator designed to generate tens of MeV electron beams at 1 kHz repetition rate, a capability making it an ideal platform for fundamental and applied research in various fields. A first user experiment conducted by a research team from Queen's University Belfast (UK) in cooperation with the ELI team, focused specifically on the generation of positrons at kilohertz rates. The experimental campaign utilised the SYLOS2 laser system, which reliably delivers ultrashort pulses at a high repetition rate (40 mJ, 14 fs, at 1 kHz) to explore the laser and plasma (gas) parameter regime and the methodology for stable and reproducible electron beam acceleration/generation and characterisation.

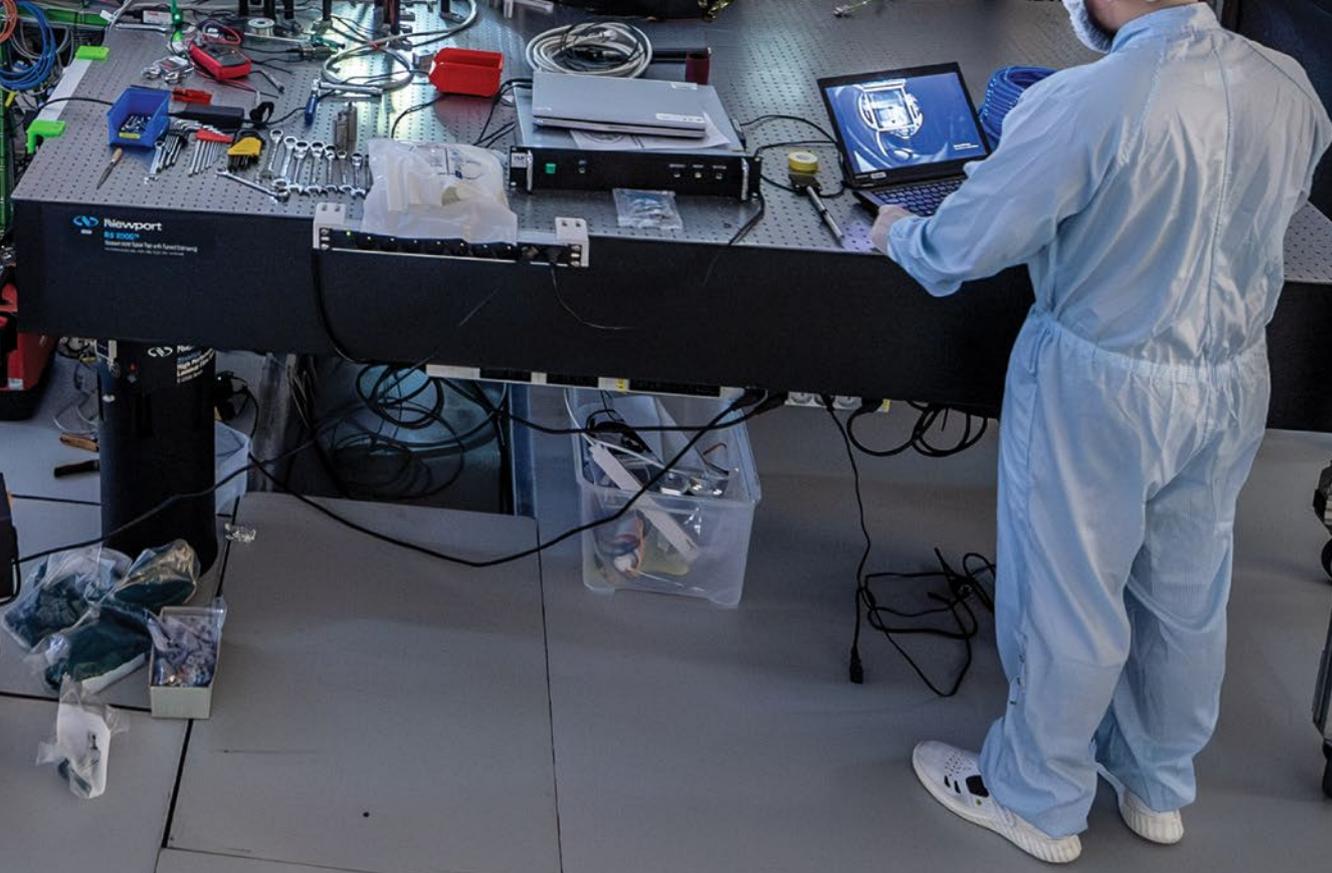
During the experimental campaign the researchers achieved continuous operation of the electron beam for 6 hours at 10 Hz and for 2 hours at the maximum repetition rate of 1000 Hz. This resulted in a remarkable total of 216'000 and 7.2 million shots, respectively, highlighting the beamline's operational reliability and stability. To ensure safety and compliance with radiation regulations, the experiments were conducted remotely from the dedicated MTA control room.

These results demonstrated the generation of measurable positron populations following the interaction of a kHz laser-wakefield accelerated electron beam from eSYLOS with a mm-scale high-Z converter target. Preliminary analysis of the data indicates that the produced positron populations are suitable for high-resolution material characterisation and defect detection. The application is of particular interest for the manufacturing industry.

The results not only underline the capabilities of the eSYLOS beamline but also pave the way for novel applications and further breakthroughs in materials science and industrial technology.



⚠️ GAS ALARM	🚫 E2 HALL STATE
⚠️ GAS WARNING	🚫 ACCESS DENIED
⚠️ RADIATION ALARM	⚠️ POST EXPERIMENT
⚠️ RADIATION WARNING	⚠️ LASER - HIGH POWER
	⚠️ LASER - LOW POWER
	🔍 SEARCH IN PROGRESS



SCIENCE IN FOCUS

Gammatron Beamline Ushers in a New Era of Ultrafast Hard X-ray Science

Read the full publication:



Conventional X-ray sources like synchrotrons and X-ray free-electron lasers (XFELs) facilities rely on kilometers of electron accelerators and complex undulator arrays to generate hard X-rays. In contrast, the newly commissioned Gammatron beamline at ELI Beamlines harnesses laser-plasma acceleration to drastically reduce the scale and infrastructure requirements, while enabling the production of femtosecond hard X-ray pulses.

Hard X-rays, which are already essential in medical imaging, materials science, and high-energy physics, become even more powerful when you add the dimension of time. When delivered in femtosecond bursts (one quadrillionth of a second), these ultrafast X-rays allow scientists to freeze motion at the atomic scale. With this capability, researchers can observe matter in motion: from ultrafast chemical reactions and structural phase transitions, to warm dense matter dynamics and high-resolution biological imaging.

The Gammatron beamline (pictured on the previous spread) is driven by the high-repetition-rate L3 HAPLS laser and delivers femtosecond hard X-ray pulses through two mechanisms: the Betatron radiation and inverse Compton scattering (ICS). The Betatron source, which is open to users, offers broadband X-rays with photon energy from 1 to 100 keV. The ICS is in development and will extend capabilities into the MeV range.

Both schemes provide low-divergence, micron-scale X-ray sources that are intrinsically synchronised with the driving laser, enabling high-precision pump-probe

experiments. Early applications include phase-contrast imaging, time-resolved X-ray absorption and emission spectroscopy, and warm dense matter studies.

“The ability to deliver micron-sized X-ray sources with femtosecond resolution opens new paths for exploring ultrafast dynamics in matter,” notes the research team behind the beamline. “A key strength of the Gammatron beamline lies in its flexibility. Designed for both Betatron and ICS operations, it serves a wide range of disciplines, from materials science, plasma physics to biomedical imaging and high-energy-density studies.” The diversity of the beamline appeals to a wide user community.

The Gammatron beamline represents a new generation of ultrafast beamlines. It demonstrates how compact, high-performance sources can democratise ultrafast science and foster new collaborations across disciplines. It also marks a turning point, transforming laser-plasma X-ray generation from a promising research topic into a practical, high-impact instrument for advancing science.

HIGHLIGHT 15

Helical Coil Innovation Sharpens Laser-Driven Ion Beams

Laser-accelerated ion beams are gaining increasing attention for their unique ability to deliver high radiation doses in ultra-short bursts. These beams have promising applications across high-energy-density physics, radiobiology, and advanced materials research, thanks to their intrinsic ultra-high dose rates and femtosecond-scale temporal precision.

A challenge, however, has persisted: laser-driven ion beams naturally exhibit significant angular divergence, limiting the dose that can be effectively delivered over realistic distances. This issue not only reduces the beam's practical impact but complicates integration with ion optics or transport systems that would condition the beam for applications.

To overcome this, a team from Queen's University Belfast, in collaboration with STFC's Central Laser Facility, ELI Beamlines, Universidad of Santiago de Compostela and the local ELI Nuclear Physics (ELI NP) team have developed a novel solution by employing a miniature helical coil section, placed at the rear of the foil from which the protons are accelerated. As protons are accelerated, a high-amplitude, ultrashort electromagnetic pulse is launched along the coil. This pulse travels in sync with a selected energy group of the emitted protons. Inside the coil, a strong radial electric field focuses the protons inward, effectively constraining them along the central axis and creating a collimated beamlet with a narrow energy spread.

This technique was implemented for the first time using a short pulse laser at full PW power at ELI NP. During the campaign, the standard configuration of the coil being directly connected to a multi-micron-thick TNSA foil, was extended with a novel target design which mounted the coil on a separate washer support, enabling the use of ultra thin foils just hundreds of nanometers thick. This new arrangement, allowed using ultra thin foils of 100s nm thickness, extends the application of the collimation technique to advanced acceleration mechanisms in relativistic transparency regimes, and, in principle, to species other than protons which are accelerated from the target bulk.

This experimental success illustrates how target design and electromagnetic field engineering can significantly improve the quality of laser-driven ion beams. It also underlines how the unique capabilities of ELI NP's petawatt system are enabling the next generation of laser-plasma acceleration science.



Direct Laser Acceleration from Hollow Targets with 1 PW Laser

This research was supported by the US National Science Foundation (NSF Grant No. PHY-2206777).

A collaborative team from the University of California, San Diego (UCSD) and ELI NP has conducted an experiment that marks a step forward in the field of direct laser acceleration (DLA). Using the 1 petawatt (PW) laser at ELI NP, the team explored a new method for producing high-energy electron beams with improved directionality.

In conventional DLA, electrons are typically accelerated by interacting with the transverse electric field of the laser pulse while oscillating sideways through the plasma. This results in substantial beam divergence, which has been widely considered an inherent limitation of the method.

To overcome this, the team investigated a different approach by leveraging the laser's longitudinal electric field. This was achieved using a structured target with a hollow cylindrical channel designed to guide the laser pulse and extend the acceleration length well beyond the Rayleigh range.

Electrons were first injected into the channel by the laser's transverse field, and accelerated forward by the longitudinal field. In this geometry, the electric and magnetic forces generated by the moving electron population effectively cancel each other out, preventing strong restoring forces that normally cause beam spreading. As a result, the electrons were accelerated in a more stable, collimated beam.

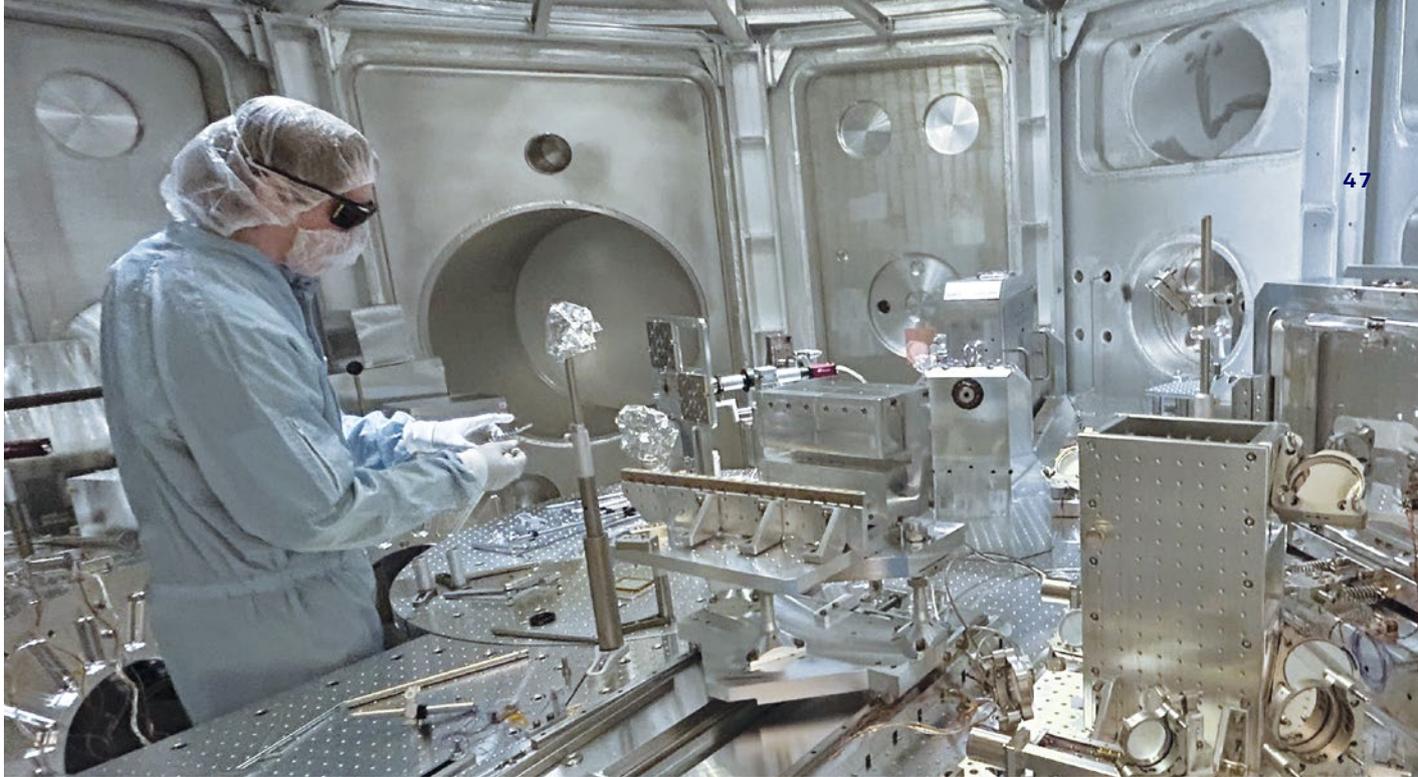
Measurements taken during the experiment, supported by 3D particle-in-cell simulations, confirmed that this setup successfully produced a low-divergence, high-energy electron beam. Most of the energy transfer occurred through the

laser's longitudinal field, enabling the generation of super-ponderomotive energies without compromising beam collimation.

A key technical achievement that made this experiment possible was the exceptional temporal contrast of the 1 PW laser. A single plasma mirror was used to suppress pre-pulse energy, reaching contrast levels of approximately 10^{-11} at 30 picoseconds before the main pulse. This ensured that the hollow channel remained empty, rather than being pre-filled with plasma until the precise moment of interaction.

The laser was tightly focused to a 4 μm diameter (FWHM) and reached peak intensities of around 2.5×10^{21} W/cm². It was directed into cylindrical targets with diameters ranging from 9 to 15 μm and lengths up to 200 μm . The interaction produced electron bunches with cutoff energies around 300 MeV and total charges on the order of a few nanocoulombs (nC).

This experiment demonstrates how structuring the target and optimising the use of laser fields can significantly improve beam control in DLA. It highlights the unique capabilities of ELI-NP's high-power laser infrastructure and opens new avenues for compact, high-performance electron sources.



HIGHLIGHT 17

Investigation of the Equation of State of Boron Nitride under Extreme Conditions via Direct-Laser Drive

An experiment led by Dr. Katarzyna Batani from the Institute of Plasma Physics and Laser Microfusion in Warsaw has provided new insights into the behaviour of hexagonal boron nitride (h-BN) under extreme conditions, specifically within the regime of warm dense matter (WDM). These conditions correspond to temperatures on the order of a few electron volts, densities greater than the solid density ($\rho > \rho_{\text{solid}}$), and pressures exceeding 1 Mbar. Understanding the complex behaviors of matter in WDM states is essential for numerous fields, including inertial confinement fusion, laboratory astrophysics, and materials science.

This experiment is the result of an international collaboration, including researchers from ELI Beamlines. The research was conducted at the Plasma Physics Platform (P3), where the L4n laser was used to generate a shock wave that propagated simultaneously through both the h-BN sample and a reference material (either aluminum or quartz). Shock propagation was monitored using Streaked Optical Pyrometry (SOP) and Velocity Interferometry (VISAR) diagnostics, as shown in the figure.

The unique capabilities of the L4n laser system enabled the collection of a comprehensive dataset, allowing for robust statistical analysis. During the experiment, the L4n laser delivered up to ~200 J of energy at 2ω ($\lambda = 525.5$ nm) with a temporally square

pulse duration of ~1.9 ns. On average we could shoot with a high repetition rate of 1 shot every ~5 minutes, taking into account the time needed for target alignment.

The results have provided valuable data for the exploration of the Hugoniot curve of h-BN, spanning the pressure range from 1 to 9 Mbar, corresponding to compressions of 2 to 3 times the density of solid h-BN (2.05 g/cm³ in our samples).



Strategic Initiatives and International Collaborations

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Building Global Partnerships

Collaboration lies at the heart of scientific progress. In today's complex research landscape, addressing major challenges requires coordinated efforts across disciplines, institutions, and borders. ELI is committed to fostering a dynamic and inclusive environment that brings together researchers, institutions, governments, and industry to share expertise, combine resources, and accelerate discovery. Working together not only strengthens scientific capabilities but also expands access to ELI's world-class research infrastructure.

Strategic initiatives and collaboration with partner countries and institutional entities enhances scientific diversity, unlocks new funding opportunities, reinforcing ELI's position as a leading international research infrastructure. ELI uses a diverse array of engagement activities to supporting the formation of consortia, coordinating bilateral partner days, facilitating stakeholder visits, and concluding agreements or Memoranda of Understanding. These efforts focus on building lasting partnerships and fostering science diplomacy in support of ELI's mission.

As a recognised Landmark on the ESFRI Roadmap, ELI actively contributes to the competitiveness of Europe and in particular the European Research Area (ERA) maintaining regular engagement with EU-level institutions. ELI is also a key stakeholder in strategic coordination platforms and projects on a European level and related Horizon Europe initiatives aimed at fostering integration, interoperability, and sustainability across the European research infrastructure landscape.

»ELI is a unique example of scientific collaboration in the world which is already having a significant impact. ELI can be a platform to promote science and technical capacities which is an added value on a local, regional and national level.«

 **José Luis Martínez Peña**, European Strategy Forum on Research Infrastructures (ESFRI) Chair.



Driving Scientific Impact

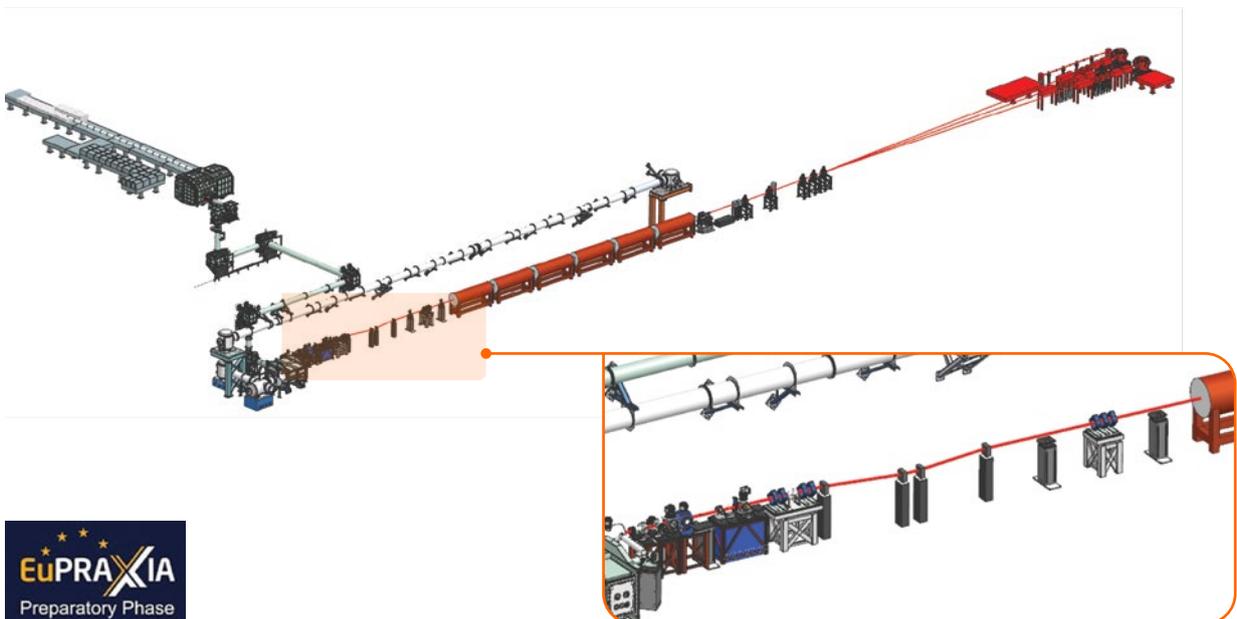
ELI Selected as 2nd EuPRAXIA Site for Laser-Driven Plasma Acceleration

The EuPRAXIA Consortium selected ELI, specifically the ELI Beamlines Facility, as the site for its laser-driven plasma accelerator pillar. This decision follows an extensive evaluation process involving expert assessments of infrastructure readiness and technical capabilities.

EuPRAXIA, included in the 2021 Roadmap of the European Strategy Forum on Research Infrastructures (ESFRI), aims to pioneer compact, high-performance electron accelerators using advanced laser- and beam-driven plasma wakefield acceleration technology. The second site at the ELI Beamlines Facility will complement the beam-driven facility being established at INFN Frascati, Italy, forming a pan-European distributed research infrastructure dedicated to transformative research and innovation in accelerator science.

»This decision adopted by the EuPRAXIA Consortium is a great achievement. The choice of the second site is one of the most relevant milestones of the EuPRAXIA Preparatory Phase and a crucial step toward the implementation.«

Dr. Pierluigi Campana, EuPRAXIA's Coordinator.



The ELI Beamlines Facility was selected for its infrastructure readiness, state-of-the-art laser systems, and comprehensive technical expertise. With its advanced high-power, high-repetition-rate laser systems, including the newly developed L2 DUHA laser, and versatile experimental setups, ELI is ideally equipped to implement and operate the Laser-Plasma-Accelerator-based 1-GeV Free-Electron Laser (FEL) envisioned by EuPRAXIA. Leveraging existing infrastructure to reduce the need for further investments, ensuring a cost-effective deployment is ELI's effective integration strategy. The alignment of the EuPRAXIA facility with ELI's established research priorities in FEL and plasma acceleration technologies positions the infrastructure to lead globally competitive science and technology developments.

Hosting the EuPRAXIA site at ELI unlocks substantial scientific, technological, and economic benefits, strengthening Europe's competitiveness in laser-plasma research. The initiative is expected to boost collaborations between academia and industry, attract additional investments, while fostering innovation and growth in the broader Central European region.

The next steps involve the preparation of a Technical Design Report (TDR) that outlines the relevant technologies and stages of implementation. The TDR will serve as a foundation for the realisation of the second site, with operations expected to begin in 2031

COLLABORATION HIGHLIGHTS

Strengthening Global Partnerships

ELI Deepens Strategic Cooperation with Canada

ELI and Canada's Institut National de la Recherche Scientifique (INRS) reinforced their longstanding collaboration with an Memorandum of Understanding (MoU). The agreement formalises joint efforts in cutting-edge laser science, with a focus on advancing both fundamental and applied research in areas such as attosecond physics, radiation damage studies, and high-precision diagnostics.

This partnership builds on over a decade of strong scientific engagement between Canadian institutions and the ELI facilities. Canadian researchers, particularly from INRS and the Advanced Laser Light Source (ALLS), have been at the forefront of ultrafast laser science, contributing substantially to developments in attosecond pulse generation, ultrafast molecular dynamics, and plasma physics.



To support the implementation of the renewed partnership, several workshops and visits served to both celebrate past collaboration and lay the groundwork for new joint activities. Topics covered ranged from target development and dosimetry to radiation damage studies and beamline access for joint experiments. The exchange also included discussion of future mobility schemes, personnel exchanges, and cooperative efforts to expand the international laser science community.

This agreement not only underlines the value of Canadian-European cooperation in large-scale research infrastructures, but also strengthens ELI's global network. As ELI continues to grow its international partnerships, this collaboration will serve as a model for scientific diplomacy, joint research excellence, and shared commitment to peaceful scientific advancement.

Swiss Contributions Drives Innovation and Cooperation at ELI

The Swiss Contribution is a part of Switzerland's commitment to reducing economic and social disparities within the European Union and provides targeted funding to strengthen research and innovation capacities across selected EU Member States. As Europe's first pan-European laser-based research infrastructure, ELI is uniquely positioned to benefit from this programme through new strategic partnerships that reinforce its scientific mission and long-term sustainability.

Two dedicated projects were initiated under the Swiss-Hungarian and Swiss-Czech Cooperation Programmes supporting ELI. These projects aim to enhance cross-border collaboration, develop advanced technologies, and increase Swiss researcher participation in ELI's User Programme.

Swiss-Hungarian Cooperation Programme

At ELI ALPS in Szeged, Hungary, a four-year project was launched focused on building strong, lasting partnerships between Swiss and Hungarian researchers,

facilitating knowledge transfer and promoting shared access to ELI's state-of-the-art infrastructure. The programme supports visiting Swiss researchers and collaborative projects, leading to the development of upgraded instrumentation. Other key outputs include joint scientific publications, researcher training through study visits, and increased representation of Swiss-affiliated scientists in experiments and development activities at ELI.

Swiss-Czech Cooperation Programme

At ELI Beamlines in the Czech Republic, the proposed SWISSELITE project (Swiss Contributions to Technological Advancements at ELI Beamlines) focuses on three main areas: co-development of next-generation diagnostics and detector technologies (in partnership with PSI and CHUV), expanding ELI's user base through Swiss participation in the User Programme, and building an innovation ecosystem via training, researcher exchanges, and pathways for commercialising scientific outputs.

Both initiatives reflect Switzerland's recognition of ELI's potential as a unique European research infrastructure that bridges cutting-edge laser science with impactful scientific and societal applications. They align with ELI's strategic priorities of strengthening international cooperation, enabling shared access to infrastructure, and translating advanced technologies into scientific excellence.





ELI's Strategic Partnership with Poland Advancing Research, Innovation and Training Together

Poland has played a central role in the development of ELI since the Preparatory Phase (2007–2010), and its engagement has steadily increased through ongoing scientific collaborations, institutional partnerships, and coordinated national efforts under the ELI-Polska Consortium.

The Polish scientific community has contributed significantly to ELI's evolution by actively engaging in joint experiments, the co-development of unique instruments, and student training and exchanges. Notable collaborations include a long-term project on X-ray spectroscopy between the ELI Beamlines Facility and the Polish research centre SOLARIS. These efforts have resulted in multiple joint publications and experimental campaigns in fields such as laser-plasma diagnostics, magnetic field studies, and Proton-Boron fusion.

The ELI Beamlines Facility also maintains an active collaboration with the Institute of Plasma Physics and Laser Microfusion (IPPLM) in Warsaw, focusing on laser-accelerated high-energy electron beams. This work has involved the use of various focal lengths to optimise secondary source generation and has contributed to advancing key techniques in high-energy laser research.

Coordinated activities under the ELI-Polska Consortium, led by the Military University of Technology in Warsaw, have strengthened national-level engagement. In cooperation with ELI, the consortium hosted Partner Days, participated in scientific conferences, and organised an ELI Industry Day to promote collaboration with industrial stakeholders.

There is also strong cooperation on education and training efforts including online training course attended by over 140 students from across Poland. This initiative was co-organised by the Candela Foundation, a student-led organisation, and

supported by Wrocław University of Science and Technology, reinforcing the shared commitment to nurturing the next generation of laser scientists and engineers.

Through these joint efforts, Poland and ELI are building a future-oriented partnership that supports scientific excellence, technological development, and the growth of a strong, cross-border research community.

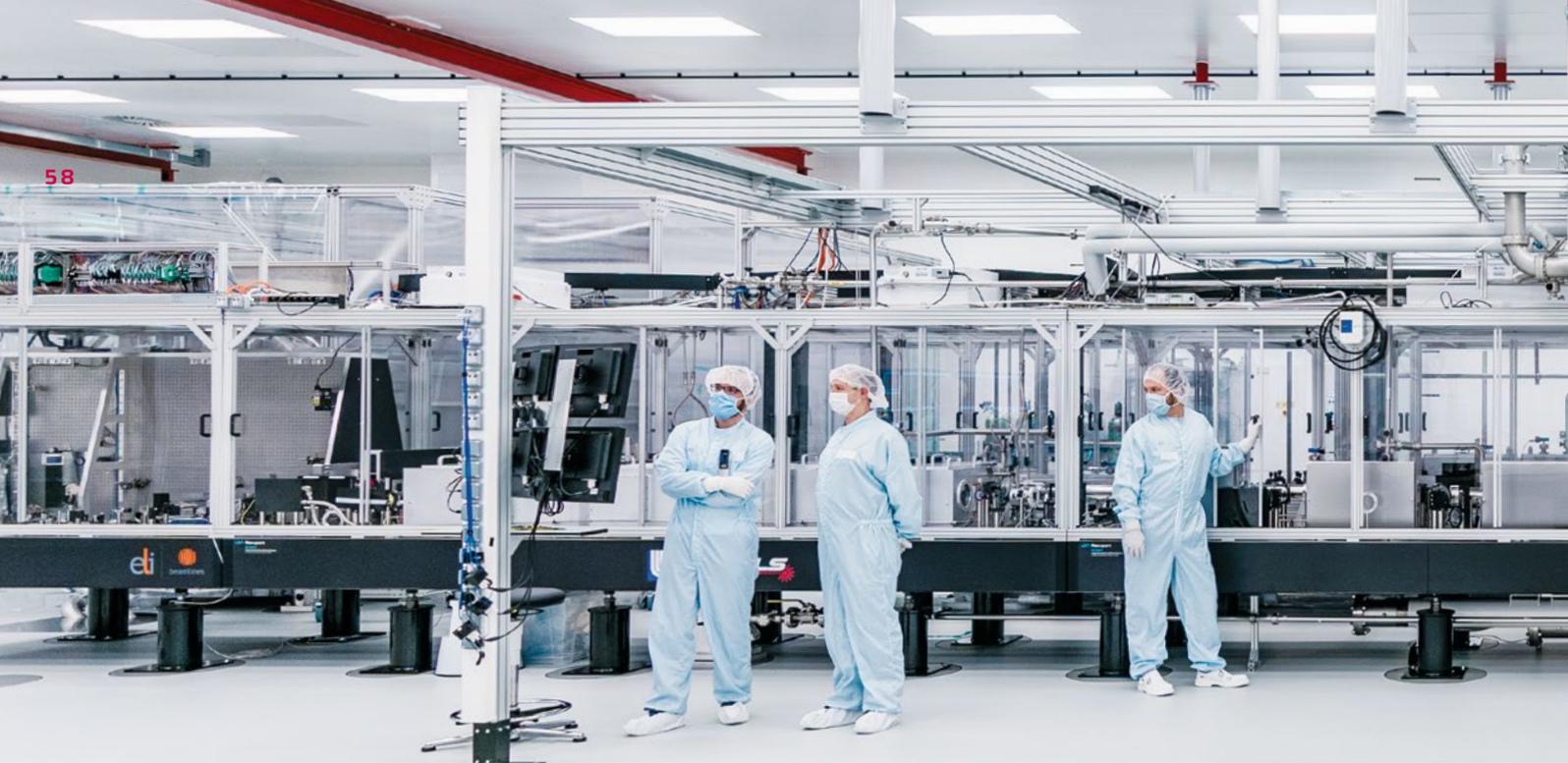
Low-Energy Ion Acceleration and Neutron Generation

The Low-Energy Ion Acceleration and Neutron Generation beamline, LEIA-n, represents an advancement of laser-driven neutron source technology and exemplifies the value of long-term scientific cooperation. Developed and operated by the University of Szeged at the ELI ALPS Facility the LEIA-n beamline has achieved cutting-edge results. Led by Károly Osvay, the team of researchers accomplished the demonstration of continuous, high repetition rate pulsed neutron source with the use of low-energy, high average power lasers and the attainment of record-breaking laser-neutron conversion efficiency.

Commissioned with the SEA laser of the ELI ALPS Facility, which delivers 21 mJ, 12 fs pulses at 10 Hz, the system reliably accelerates deuterons to over 1 MeV with a stability better than 10%. Fast neutrons are generated through DD fusion, achieving an output of 2×10^5 neutrons per second with a shot-to-shot stability of 7%. The performance has been enhanced using the SYLOS 3 laser system, producing 100 mJ, sub-10 fs pulses, achieving the current state-of-the-art of short pulse laser-based neutron sources. That sustained an average output of 10^7 neutrons per second over two hours and demonstrated peak neutron fluences of 2×10^8 neutrons/cm²/s at the sample position.

In a joint study with the ELI ALPS Biomedical Applications group, Oslo University Hospital, and Vilnius University, the LEIA-n neutron source was used to irradiate in-vivo biological samples (see Scientific Highlights)—including zebrafish embryos and human cells—delivering a dose of 1.6 Gy. The potential impact of this technology is far-reaching, with promising applications in fields such as radiobiology, oncology, materials research, medical isotope production, fundamental research, as well as in nuclear industry including green energy.

Looking ahead, the collaboration aims to further develop the source to achieve quasi-continuous neutron generation at 1 kHz. The LEIA-n beamline is a prime example of the benefits of integrating university-driven innovation with the technical capabilities of a large-scale international user facility. The collaboration not only strengthens ELI's leadership in laser-based neutron research but also contributes to broader scientific and societal application.



Expanding Cooperation between ELI and US Partners in Laser Science and Technology

ELI continued to strengthen its strategic ties with leading research institutions in the United States, fostering collaborative projects that span high-power laser development, laser-plasma physics, advanced diagnostics, and fundamental materials research. These partnerships demonstrate the shared commitment of both sides to advancing breakthrough technologies and high-impact applications.

The longstanding cooperation between ELI and Lawrence Livermore National Laboratory (LLNL) was strengthened with a new Memorandum of Understanding (MoU). LLNL has played a foundational role in ELI's development, having designed and delivered the L3 HAPLS laser, a petawatt-class, the high-repetition-rate laser. The new MoU aims to expand joint research in laser-driven fusion, diagnostics, and high-repetition-rate target systems.

ELI also signed an MoU with Colorado State University (CSU) focused on facility design consulting, radiation protection, and staff exchanges to support the development of CSU's Advanced Beam Laboratory. Similarly, ELI is progressing toward a formal collaboration with the University of Rochester's Laboratory for Laser Energetics (LLE), with planned joint development of actively cooled disk amplifiers and next-generation diagnostics, and shared expertise in facility design, safety, and experimental methodology.

Additionally, ELI collaborates with US Partners via the X-Lites initiative, part of the AccelNet programme funded by the U.S. National Science Foundation, and with the Department of Energy supported LasernetUS both form scientific networks around extreme light facilities.



ELI also engages with the IFE*STAR initiative (Inertial Fusion Energy Science and Technology Accelerated Research), which brings together international research institutions, national laboratories, and universities to accelerate progress in laser-driven fusion energy. The initiative aims to develop a coordinated scientific roadmap and foster collaborative R&D on next-generation fusion technologies for clean, sustainable energy

These partnerships demonstrate ELI growing role as a trusted international platform for high-intensity laser science and innovation. U.S.-based researchers now represent the third-largest international group accessing ELI's facilities, underlining the importance of ELI-U.S. cooperation in advancing research, technology development, and training.

»We are looking forward to expanding our existing collaborations with ELI on areas such as ultrabright high-repetition-rate sources for enhanced radiography, fusion and plasma physics research. ELI has also already acted as a great proving ground for our machine learning and optimisation technologies, and the MoU should help us expand this as well in future.«

James McCarrick, LLNL Program Director for High Energy Density and Photon Systems.

Advancing Development at ELI with External Funding

ELI participates in a range of European and nationally funded projects that support strategic development, scientific mission, and innovation agenda. These projects enable investment in infrastructure, technology development, and international collaboration. The following section provides an overview of key initiatives that contribute to ELI's growth and long-term sustainability.



IMPRESS

Interoperable electron Microscopy Platform for advanced REsearch and Services

Start: 02/01/2023
End: 31/01/2027

Duration: 48 months



THRILL

Technology for High-Repetition-rate Intense Laser Laboratories

Start: 01/01/2023
End: 31/12/2026

Duration: 48 months



RADNEXT

RADIation facility Network for the EXploration of effects for indusTry and research

Start: 06/01/2021
End: 31/05/2026

Duration: 60 months



EuPRAXIA

EuPRAXIA Preparatory Phase Project

Start: 11/01/2022
End: 31/10/2026

Duration: 48 months



EuPRAXIA-DN

EuPRAXIA Doctoral Network

Start: 01/01/2023
End: 31/12/2026

Duration: 48 months

STEFF

Strong-field electrodynamics in Flying Focus pulses

Start: 05/01/2023
End: 30/04/2025

Duration: 24 months



Probono

PROton BORon Nuclear fusion:
from energy production to medical
applicatiOns

Start: 24/10/2022

End: 30/10/2026

Duration: 48 months



EURIZON (former Kremlin Plus)

European network for
developing new horizons
for RIs

Start: 02/01/2020

End: 30/04/2025

Duration: 48 months



ERIC FORUM 2

Second implementation
project for the ERIC Forum

Start: 09/01/2023

End: 31/08/2027

Duration: 48 months



FlexRICAN

Flexibility in RIs for global CARbon
Neutrality

Start: 03/01/2024

End: 28/02/2027

Duration: 36 months



Lasers4EU

European Laser Research
Infrastructure Serving Science
and Industry

Start: 10/01/2024

End: 30/09/2028

Duration: 48 months



LaserFusion

Innovative Education & Training
in Laser Inertial Fusion Energy

Start: 08/09/2024

End: 07/09/2027

Duration: 36 months



PACRI

Plasma Accelerator systems for
Compact Research Infrastructures

Start: 03/01/2025

End: 28/02/2029

Duration: 48 months



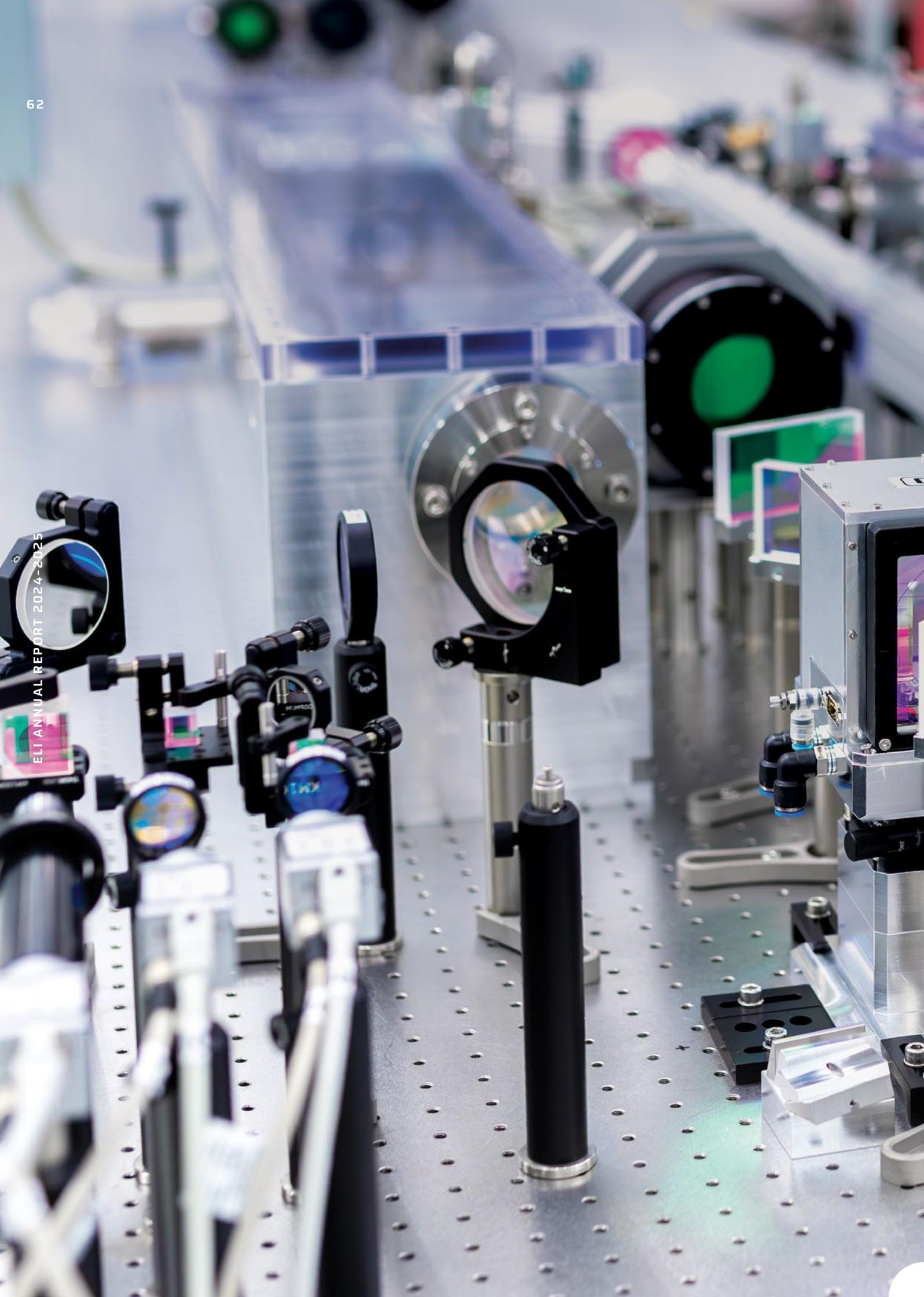
LASER-PRO

LASER-PRO - Excellent Laser
Technologies for the Sustainable
Prosperity of Europe

Start: 01/01/2025

End: 31/12/2028

Duration: 48 months



Innovation, Industry and Technology Development

Driving Innovation Through Technology and Partnerships64

Next-Generation Coatings Laboratory for High-Power66

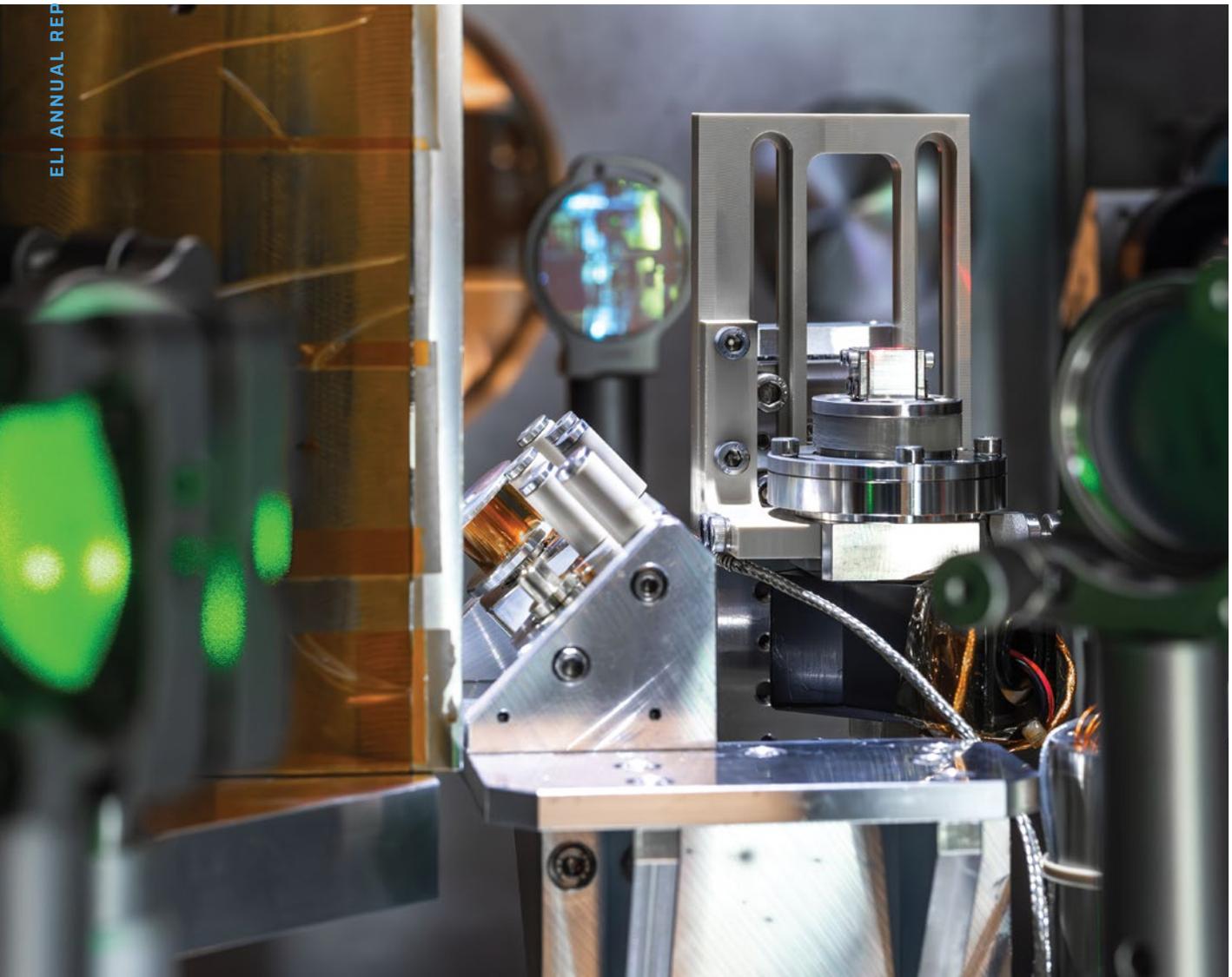
High-repetition Rate Attosecond Beamlines68



Driving Innovation Through Technology and Partnerships

ELI continues to strengthen its innovation ecosystem through new initiatives, strategic collaborations, and industry partnerships, while advancing internal structures that support knowledge transfer, technology development, and sustainability.

To foster innovation across its facilities, ELI advanced its internal processes for innovation management, including harmonised IP handling procedures, alignment of research outputs with market needs, and clearer innovation pathways from concept to application. ELI also continues to expand its Innovation Liaison Officer (ILO) network across its member countries, providing direct points of contact between scientific teams and industry stakeholders.



The TA ČR Sigma project, granted by the Technology Agency of the Czech Republic, enabled the launch of a four-year initiative supporting internal proof-of-concept (PoC) projects aimed at exploring the commercial and societal potential of early-stage technologies generated at ELI. PoC projects are essential for de-risking innovation, supporting spin-out potential, and enabling closer collaboration with industry.

ELI maintained a portfolio of 54 active intellectual property (IP) assets. In parallel, ELI's applied research capabilities are attractive for new industry clients and public-private collaborations. ELI participated in several contract research projects with industrial and institutional partners, some of which are listed below:



Rigaku Corporation • Japan

ELI supported the development of a laser-induced X-ray source using a liquid gas microjet as a target. A functional prototype was demonstrated under laboratory conditions, with further customisation of the target system planned.



Industrial Technology Research Institute • Taiwan

ELI conducted a feasibility study on 3D coherent diffraction imaging techniques for nanostructure inspection in semiconductor materials. The collaboration supports the development of novel wafer imaging solutions using laser-driven X-ray sources.



Marvel Fusion • Germany

Laser-Induced Damage Threshold (LIDT) testing was carried out at ELI Beamlines on ten optical components intended for high-power fusion experiments. The results contribute to Marvel Fusion's efforts to advance a sustainable, laser-driven approach to clean energy generation.



HB11 Energy • Australia

ELI signed a collaboration agreement with HB11 Energy, a startup pioneering laser-driven hydrogen-boron fusion. The partnership focuses on the co-development and manufacturing of micro-structured laser targets to support fusion experiments at ELI facilities. This cooperation leverages ELI's advanced laser infrastructure to accelerate HB11's novel approach to clean fusion energy.

Next-Generation Coatings Laboratory for High-Power

The ELIAS coating laboratory was constructed and inaugurated at the ELI Beamlines Facility. ELIAS is among the largest optical coating systems in the world, and designed for the deposition of thin-film multilayers on large-scale optics.



The facility was established to address the increasing need for high-durability, precision-coated optics capable of withstanding the extreme conditions of multi-petawatt-class laser systems. Using electron beam evaporation assisted by ion plasma, the system can coat optics as large as 1.2 meters in diameter and weighing up to 250 kg, which is a critical capability for fabricating components such as transport mirrors, focusing optics, diffraction gratings, and anti-reflective layers with high damage thresholds.

Beyond its scale, ELIAS is also modular. It supports the development of advanced nanostructured layers, including GLAD (Glancing Angle Deposition) coatings. These nanolayers are tailored for high-performance laser applications requiring precise control over optical properties, such as laser beam shaping and resistance to femtosecond-scale laser pulses. Optics of up to 500 mm in diameter can be processed with these specialised coatings.

Initial test depositions successfully demonstrated ELIAS's capabilities. In one case, gold nanolayers were created as prototype mirrors for the 10 PW L4 ATON laser beamline, and were validated for laser immunity across the entire 1.2-meter aperture using 110 femtosecond pulses.

The facility is not only a cornerstone for advancing science within the ELI ecosystem, but also a catalyst for industry engagement and technology transfer. ELIAS enables the development of advanced optical materials for both scientific and commercial use, with applications in energy, telecommunications, and semiconductor sectors.

»ELIAS allows us to further develop collaborations on the design of special dielectric layers with research centres in Europe, the USA, Japan, and Korea—as well as with industrial partners developing next-generation laser systems.«

 **Daniel Kramer**, Group Leader of Optical Materials Development.

The establishment of ELIAS was supported by the IMPULSE and THRILL projects under Horizon Europe. Its development involved the ELI Beamlines Optics group and technical collaboration with companies such as Vacuum Innovations, LLE, Streicher s.r.o., CCR GmbH, and Coherent Technologies, with key input from the ELI Beamlines technical teams.

High-repetition Rate Attosecond Beamlines

The rapid advancement of ultrafast femtosecond laser technology has revolutionised the study of extreme laser-matter interactions, enabled by two key developments: ultra-high peak power lasers exceeding the petawatt scale in single-shot or low-repetition modes, and few-cycle laser systems operating at high repetition rates (≥ 1 kHz) with high average power, ideal for experiments requiring statistical precision. These complementary approaches converge at the ELI ALPS Facility. Among their most impactful applications is high-harmonic generation (HHG), a process that converts low-frequency photons into soft x-rays. HHG has fundamentally transformed atomic, molecular, and optical physics, laying the groundwork for attosecond science and driving innovations in ultrafast optoelectronics which was recognised by the 2023 Nobel Prize in Physics.

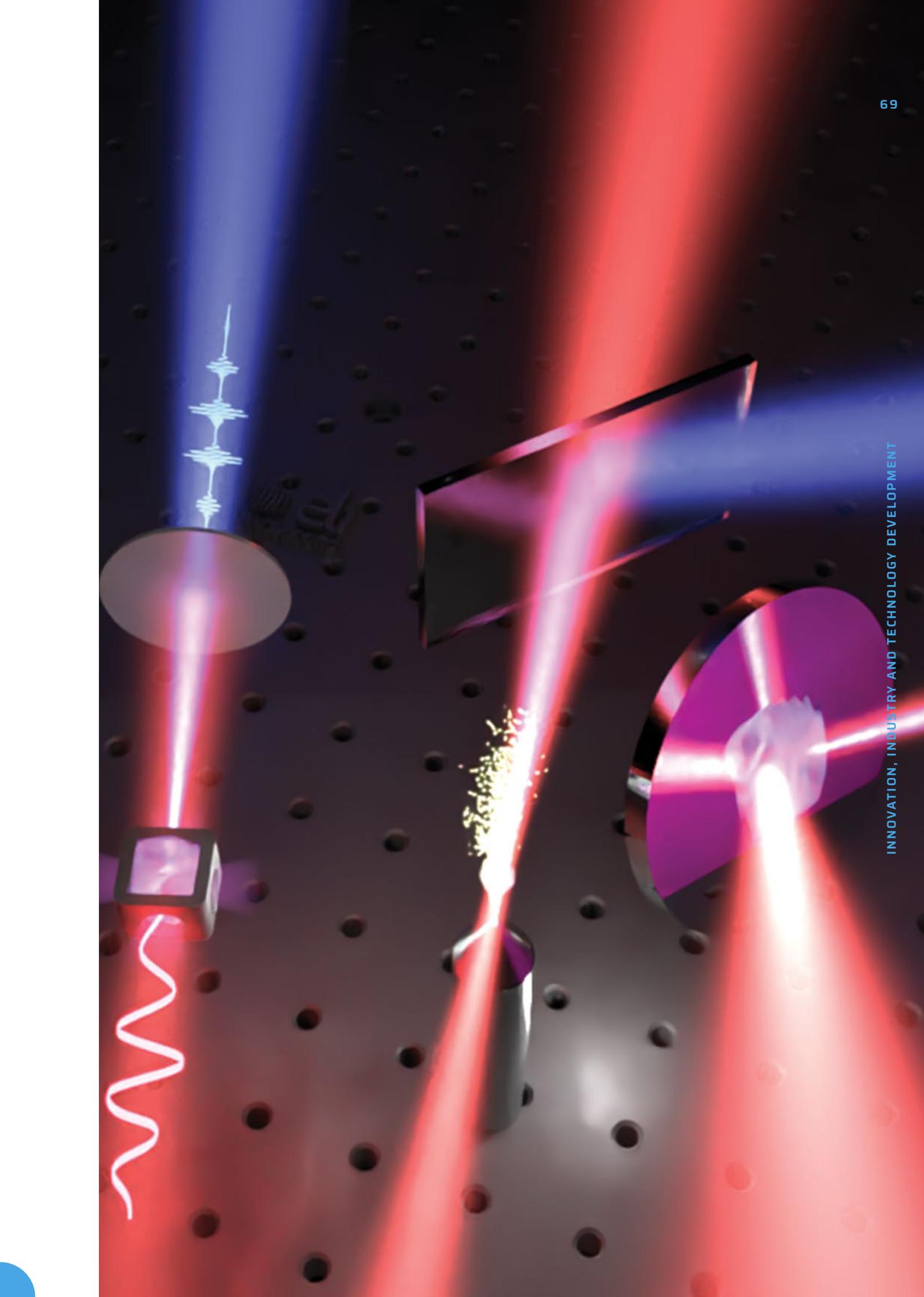
Read the full publication:



The ELI ALPS Facility plays a leading role in advancing the scientific frontier in this field, with its suite of advanced beamlines that generate attosecond extreme ultraviolet (XUV) pulses at high repetition rates ranging from 1 kHz to 100 kHz, utilising both plasma- and gas-based sources.

As part of an international collaboration, the research group of Nobel Laureate Anne L'Huillier (Lund University), alongside scientists from ELI ALPS and the Foundation for Research and Technology (Greece), showcase the design, capabilities, and scientific potential of these beamlines while outlining a strategic vision for their impact across diverse research fields in a recent publication .

The ELI ALPS Facility offers five state-of-the-art beamlines to users worldwide through the ELI User Programme. These systems support a broad spectrum of experiments, from fundamental studies of electron dynamics to applied research in nanotechnology, plasma optics, and ultrafast spectroscopy. Their high-repetition-rate operation significantly improves data quality, supports simultaneous diagnostics, and enables advanced data-driven methodologies, including machine learning-based predictive modelling, unlocking new possibilities for cutting-edge scientific discovery.





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SCIENTIFIC OUTREACH AND ENGAGEMENT

Scientific Engagement

Building the ELI User Community

The annual ELI User Meeting, held on 26–28 June 2024, at the ELI Beamlines Facility in the Czech Republic, is a cornerstone event for ELI’s diverse and growing scientific community. This event, attended by 150 participants from 20 countries, provides a platform to showcase the latest developments of the ELI facilities, highlight key research results, and discuss developing the evolving User Programme. A Workshop on Advanced Technologies complemented the programme focused on discussions around instrumentation advancements and to foster collaborations among the partners.

Representatives from all three ELI facilities shared updates on capabilities, notable experiments, and new instrumentation, including advancements in high-repetition-rate laser systems. Researchers presented cutting-edge studies across multiple scientific disciplines, such as particle acceleration, plasma physics, and ultrafast



laser interactions. A core goal for the event is to provide a platform for vibrant discussions, which provided invaluable feedback from participants, enriching the ELI user community's scientific endeavours.

Engagement with the Global Research Community

Disseminating ELI's scientific results and advancements is a key priority to engage with the global research community. ELI scientists actively participate in a wide range of international scientific conferences and events, disseminating research findings and advancements about ELI's state-of-the-art instrumentation. Participation in these events not only highlights ELI's cutting-edge research but also reinforces the cooperative ties with the global scientific community. ELI is also engaging strategically in key community conferences and event with exhibition booths and through sponsorships. This focused participation enhances ELI's visibility, supports user recruitment efforts, and ensures alignment with its core scientific and outreach objectives to establish ELI as a hub for groundbreaking international research and innovation.



EDUCATION AND TRAINING

Fostering Scientific Talent

ELI Summer School: A Growing Tradition of Learning

The 9th edition of the ELI Summer School (ELISS 2024) brought together over 125 students from 24 countries for an immersive five-day experience in the science related to ELI at the ELI ALPS Facility in Szeged, Hungary. The annual event is a cornerstone educational event designed to engage and inspire students. ELISS supports young scientists in exploring ELI research topics and envisioning future careers in the field.

ELISS2024, held from 2-6 September 2024, featured expert lectures on attophysics, plasma generation, ultrafast X-rays, and high-energy lasers, as well as hands-on activities and lab tours. Participants had the opportunity to engage with state-of-the-art technology, gaining first-hand experience with ELI's cutting-edge research



infrastructure. A highlight of the school was the poster session, during which 41 young researchers presented their scientific work. Beyond professional discussions, ELISS fostered networking and collaboration, allowing students to connect with peers and leading experts.

High School Students Explore Quantum Dots at Talent Academy

As part of the 2024 Talent Academy, 12 exceptional high school students had the unique opportunity to synthesise and study quantum dots—tiny crystals with remarkable optical properties that could revolutionise future display technologies. Over an intensive 30-hour challenge at the ELI Beamlines Facility and HiLASE laser centre, students created carbon quantum dots of varying sizes and used them to design a pixel following the RGB colour model. With guidance from staff scientists, the participants engaged in hands-on chemistry, optical setup, and programming, gaining insight into interdisciplinary research. The programme also emphasised teamwork and communication, leading up to a final conference where students presented their findings. The most outstanding participants were awarded summer internships at the laser institutes, paving the way for future careers in cutting-edge science.

The Next Generation of Scientists at the ELI ALPS Summer Camp

The ELI ALPS Facility hosted its Summer Camp, welcoming 21 high school students from across Hungary and Serbia for an intensive week of hands-on activities in physics in June 2024. The students engaged with lectures by researchers from ELI ALPS and the University of Szeged for interactive learning and discussion as well as for lab visits. The programme offered an opportunity for participants to dive into topics beyond the standard curriculum, with highlights including Nobel Prize-winning research, quantum physics, and optical measurement exercises. The camp also introduced students to broader scientific disciplines, including ecology and environmental science, during an excursion to the Tisza riverside. The success of the camp was evident not only in the students' enthusiasm but also in their active participation, thoughtful discussions, and eagerness to pursue further studies in physics.







ENGAGING THE GENERAL PUBLIC

Bringing Laser Science to Life for All Ages

ELI actively engages with the broader public through diverse outreach activities, events, and educational programmes. From open days and interactive science fairs and exhibitions, to public lectures and workshops, ELI fosters curiosity and promotes an appreciation of laser science and technology among people of all ages. Through these initiatives, ELI helps bridge the gap between complex scientific research and everyday understanding, highlighting the societal impacts and potential of laser-driven innovations. By making science accessible and exciting, ELI strengthens its connections with local communities, inspires future scientists, and reinforces public support for groundbreaking research.

Twice a year, the ELI facilities open their doors to the public, offering a unique opportunity to explore cutting-edge laser science first hand. In May the International Day of Light and Researchers' Night in September, feature facility tours, engaging lectures, live experimental demonstrations, and other entertaining, yet educational activities designed to showcase the wonders of optics and laser science. Importantly, these events play a crucial role in inspiring future generations, particularly young students, to explore the fascinating world of physics and lasers. By sparking curiosity and excitement through hands-on experiences, the public events at ELI encourage audiences of all ages to engage with the exciting world of science.

Outreach in a
Nutshell:

9077

TOTAL VISITORS

5050

3382

645

GENERAL PUBLIC
VISITORS

EDUCATIONAL
VISITORS

OTHER
VISITORS



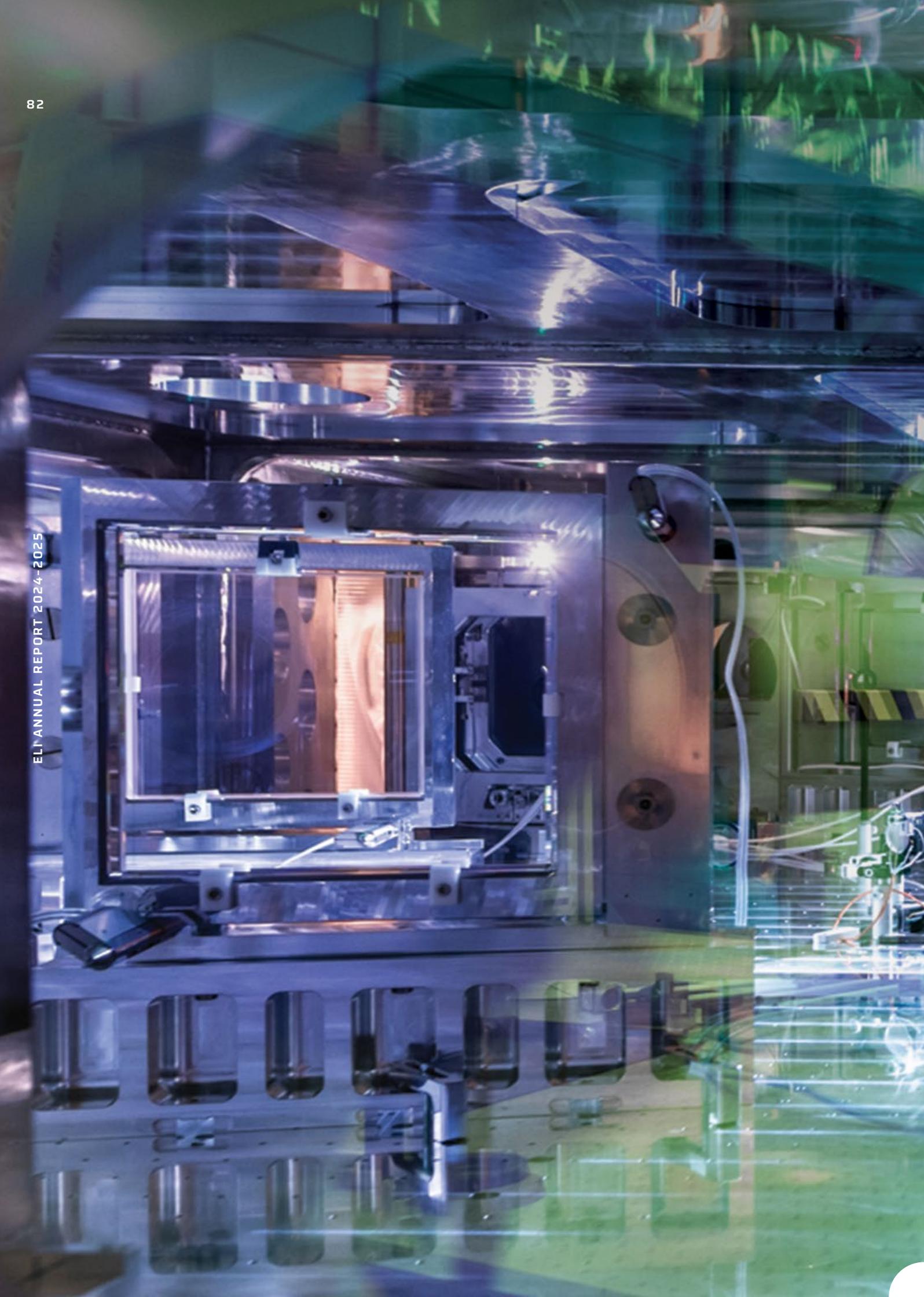
High-Profile Guests

Highlights included visits from Nobel Laureates Gérard Mourou, Donna Strickland, Anne L'Huillier, and Ferenc Krausz, whose groundbreaking work forms the foundation of attosecond and high-intensity laser science at ELI. ELI hosted the President of the Czech Republic, Petr Pavel, and Her Majesty Queen Máxima of the Netherlands, as well as Ambassadors and Ministers from various countries, and representatives from international organisations including the ESFRI Forum Meeting in Szeged, affirming ELI's role within Europe's strategic research landscape.

The increasing number of visitors showcases ELI's growing relevance in science, innovation, and scientific diplomacy worldwide.







ELI Governance

New Leadership84

ELI Governance86



GOVERNANCE

New Leadership

In 2024, ELI saw a shift in its governing bodies. Prof. Caterina Petrillo (above left), who served as ELI General Assembly Chair from the establishment of ELI as a European Research Infrastructure Consortium, stepped down at the end of 2024. Petrillo played a crucial role in guiding ELI through an important phase of its growth and helped advance ELI's scientific and organisational development. Her leadership strengthened ELI's positioning as an international user facility and a driver of innovation. The entire ELI team thanks her for her invaluable contributions.

Petrillo is succeeded by Jan Hrušák (above middle), who was appointed as the new Chair of the General Assembly. Hrušák brings extensive expertise in European research policy and strategic research infrastructures, particularly through his long-standing involvement with ESFRI (European Strategy Forum on Research Infrastructures), where he served as Chair from 2019 to 2021. His leadership is expected to further ELI's integration into the European research landscape and support its long-term sustainability.

ELI also extends a heartfelt thanks to Sandro De Silvestri (above right) who is stepping down as Italian Delegate to ELI having served many years and contributing to the evolution of the European laser research landscape. As a leading figure in the early scientific development of ELI and a valued member of its governance bodies, his insights and commitment have been instrumental in shaping the scientific vision of the infrastructure. His contributions will and already have a lasting impact, and the ELI community is grateful for his leadership and longstanding support.



The International Scientific and Technical Advisory Committee (ISTAC) also saw a change with new members appointed. Members of the ISTAC represent a variety of recognised experts from scientific and technical fields relevant to ELI and are elected for three-year terms. Roger Falcone (University of California, Berkeley) (above left), and Thomas Tschentscher (European XFEL) (above right), were elected as Chair and Vice-Chair respectively in November 2024. Their expertise will be instrumental in advising on the scientific direction and technical progress of ELI. ELI is grateful to the previous group of ISTAC Members, and in particular to John Collier (Central Laser Facility) (above middle) who served as ISTAC Chair up until the end of 2024.

ELI extends its sincere gratitude to all members of its governance bodies for their time, dedication, and invaluable expertise. Their guidance and commitment have been instrumental in shaping ELI's success and advancing its mission as a world-leading research infrastructure.

»ELI's unique suite of cutting-edge instruments provides unparalleled opportunities for scientific discovery. I'm delighted to serve as the ELI ISTAC Chair and help guide the organisation towards continued excellence while contributing to the progress in laser science and high-intensity research.«

***R* Roger Falcone**

ELI Governance

According to the European Commission Implementing Decision (EU) 2021/960 of 30 April 2021 setting up the Extreme Light Infrastructure European Research Infrastructure Consortium (ELI) with Host countries and Founding Members Czech Republic and Hungary; Founding Members Italy and Lithuania; Full Member Bulgaria; Founding Observers Germany and Romania with the Czech Republic acting as the statutory seat of ELI. ELI is governed by the ELI General Assembly according to the Statutes of the European Research Infrastructure Consortium.



General Assembly

The General Assembly (GA) is made of representatives from the member countries. It appoints the Director General (DG) and Chair, and approves the budget and technical scope of the research facility. The GA and DG are supported by independent advisory bodies, the Administrative and Finance Committee (AFC) and International Scientific and Technical Advisory Committee (ISTAC).

ELI GA Chair:

Jan Hrušák
J. Heyrovský Institute of Physical Chemistry of the
Czech Academy of Sciences; Czechia

Hosts:

Czech Republic

Marek Vyšinka • Delegate
Ministry of Education, Youth and Sports (MEYS)

Jan Řídký • Delegate
Czech Academy of Sciences (CAS)

Michael Prouza • Expert Advisor
Institute of Physics of the Czech Academy of
Sciences (IoP)

Hungary

Ferenc Nagy-Rébék • Delegate
Head of Department, Ministry of Culture and
Innovation (KIM)

István Szabó • Delegate
Deputy CEO for Strategy and Innovation, HUN-REN
Hungarian Research Network

Members:

Italy

Sandro De Silvestri • Delegate
National Research Council (CNR)

Michele Crisafi • Delegate
Ministry of University and Research (MUR)

Eugenio Nappi • Expert advisor
National Institute for Nuclear Physics (INFN)

Giorgio Rossi • Expert advisor
University of Milan "Statale"

Lithuania

Gediminas Račiukaitis • Delegate
Center for Physical Sciences and Technology

Aidas Matijošius • Delegate
Laser Research Center, Vilnius University (VU)

Tadas Juknevičius • Expert advisor
Ministry of Education, Science and Sport (SMMIN)

Dalia Kaškelytė • Delegate
Laser Research Center, Vilnius University (VU)

Bulgaria

Milena Damyanova • Delegate
Ministry of Education and Science (MON)

Lubomir Kovachev • Delegate
Bulgarian Academy of Sciences (BAS)

Ekaterina Iordanova • Expert advisor
Director of Institute of Solid State Physics, Bulgarian
Academy of Sciences (BAS)

Observer & Host:

Romania

Mihnea Cosmin Costoiu • Delegate
National University of Science and Technology

Observer:

Germany

Eckart Lilienthal • Delegate
Federal Ministry of Research, Technology and
Space (BMFTR)

Sebastian Schmidt • Delegate
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Bernadette Klose • Expert advisor
DLR Project Management Agency

Barbara Schramm • Expert advisor
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

Administrative and Finance Committee (AFC)

The AFC advises the General Assembly (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 among other aspects and gives advice and recommendations for decisions to the GA. The Chair of the Committee is appointed by the GA.

ELI AFC Chair:

László Bódis
Ministry of Culture and Innovation (KIM); Hungary

Members:

Czech Republic

Jan Buriánek • Vice-Chair, Delegate
Ministry of Education, Youth and sports (MEYS)

Petr Lukáš • Delegate
Nuclear Physics Institute (CAS)

Hungary

László Lengyel • Delegate
National Research, Development and Innovation Office (NRDI)

Italy

Veronica Buccheri • Delegate
Istituto Nazionale di Fisica Nucleare (INFN)

Antonella Tajani • Delegate
National Research Council (CNR)

Lithuania

Artūras Malysis • Delegate
Ministry of Education, Science and Sport (SMMIN)

Bulgaria

Zornitsa Georgieva • Delegate
Ministry of Education and Science (MON)

Observers:

Romania

Andreea Crupa • Delegate
Ministry of Research, Innovation and Digitalization

Germany

Bernadette Klose • Delegate
DLR Project Management Agency

Barbara Schramm • Delegate
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)



International Scientific and Technical Advisory Committee (ISTAC)

The ISTAC is made up of expert scientists not engaged by or otherwise immediately connected with ELI, and advises the GA on scientific matters. The members of the ISTAC and its Chair are appointed by the GA. The ISTAC independently assesses the scientific goals and advises on the scientific objectives of ELI. The 14 leading experts in the field of laser science offer independent advice on all strategic issues, scientific and technical activities to the ELI management and GA, including making recommendations on the User Programme of the ELI facilities.

ELI ISTAC Chair:

Roger Falcone • Chair
University of California, Berkeley

Félicie Albert
Lawrence Livermore National Laboratory (LLNL)

Andrius Baltuška
Photonics Institute TU Wien

Angela Bracco
Università degli Studi di Milano

John Collier
Central Laser Facility, STFC

Per Eng-Johnsson
Lund University

Leonida A. Gizzi
National Research Committee (CNR)

Ekaterina Iordanova
G. Nadjakov Institute, Bulgarian Academy of Sciences

Katalin Kamaras
Institute for Solid State Physics and Optics, Wigner
Research Centre for Physics

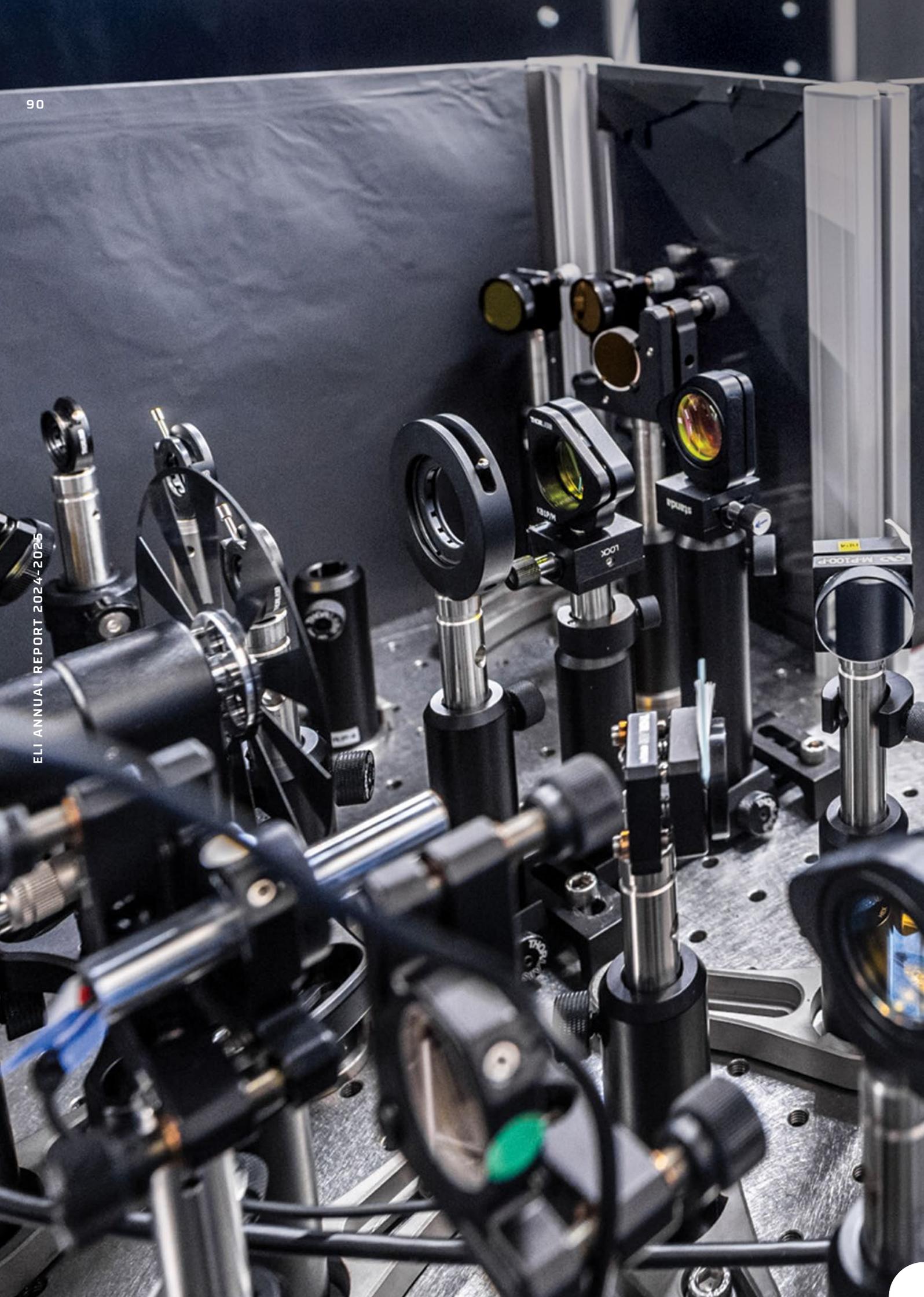
Katia Parodi
Ludwig-Maximilians University Muenchen (LMU)

Tomáš Polívka
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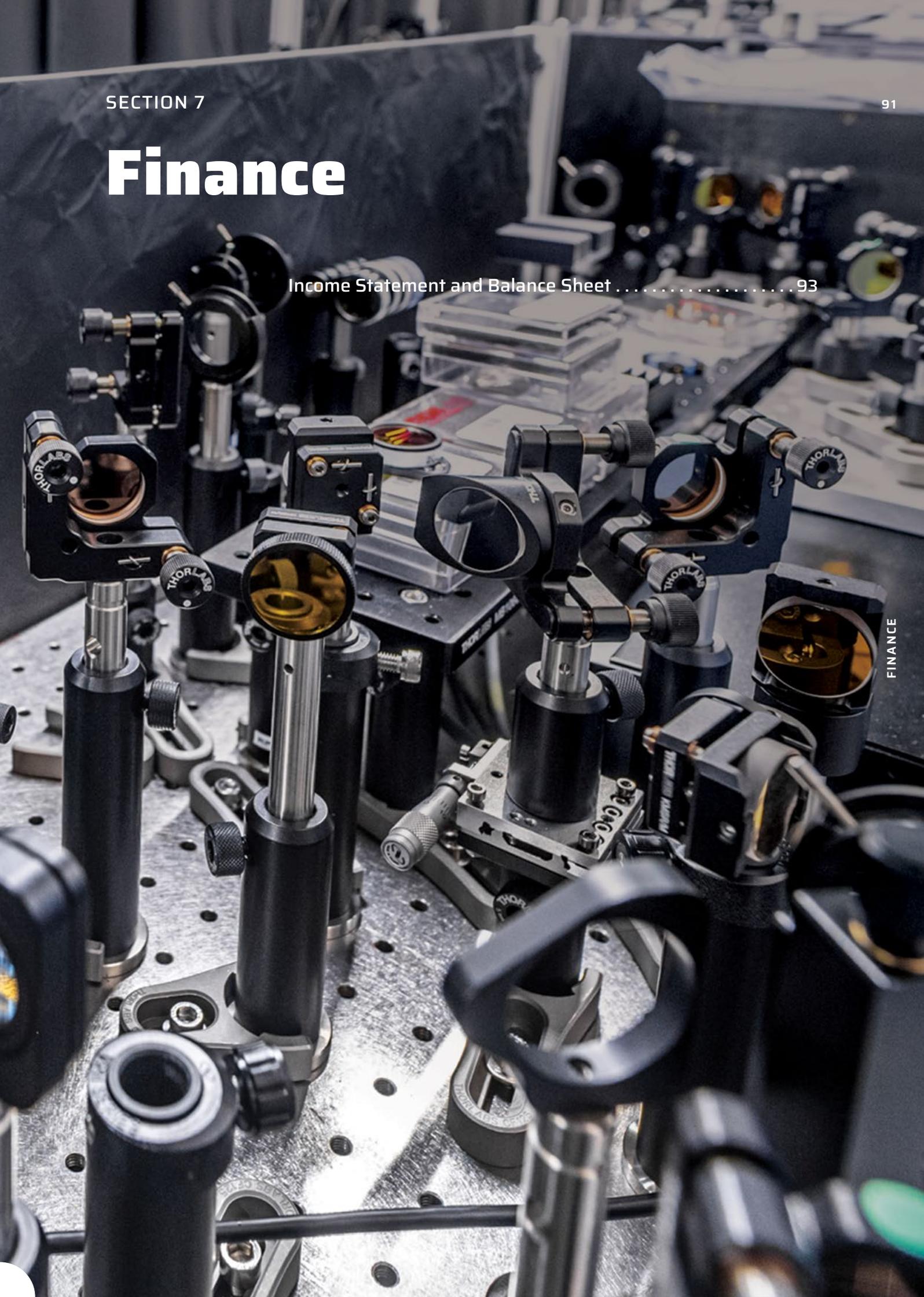
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Finance

Income Statement and Balance Sheet 93





Income Statement and Balance Sheet

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

The Extreme Light Infrastructure (hereinafter referred to as 'ELI'), 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 ELI General Assembly.

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

ELI 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.

When keeping the books and preparing the financial statements, ELI 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.

The ELI General Assembly at their 9th Meeting on 9-10 October 2023 in Prague, Czech Republic authorised the ELI Director General according to the Decision GA09/01 to complete the purchase of the Municipality of Szeged's shares in ELI-HU Non-profit Ltd and to further capitalise the ELI-HU Non-profit Ltd to the extent necessary to acquire a controlling share. During the 10th ELI GA Meeting held online on 5 December 2023 the acquisition of controlling shares in ELI-HU non-profit Ltd has been approved, as stated in decision GA10/01, with effect as of 01 January 2024 and entry into force of the amendment Articles of Association of the ELI-HU Non-profit Ltd to fulfill the ELI statutory requirements to operate the facility ELI ALPS as an integral part of ELI. The 75% controlling share of ELI in ELI-HU Non-profit Ltd is reported in long term financial assets in balance sheet.

The Income Statement and Balance Sheets for ELI and ELI-HU Non-profit Ltd are presented on the following pages.

The accounting period is the calendar year 2024.

Income Statement for ELI

Revenues	k€
Operational subsidies	3 345
Membership fees	47 860
Interest income	1 442
Foreign exchange gains	265
Revenues from funds related to grants	617
Other Revenues - (depreciation from subsidies, rental income, others)	15 333
Revenues from sales of own services	366
Total Revenues	69 228
Expenses	k€
Purchase and Services Consumption	13 288
ELI-ALPS operating costs	22 413
Change in inventory of own products and capitalization	-109
Personnel expenses	16 849
Taxes and fees	17
Other expenses (foreign exchange expenses, other operating expenses)	1 504
Depreciation and provisions	15 250
Income tax	16
Total Expenses	69 228
Net income	0

Balance Sheet for ELI

Assets	k€
Tangible and intangible assets	350 873
Accumulated depreciations - Tangible and intangible assets	-114 765
ELI-HU non-profit nominal value of the majority share	146
VAT receivables	1 851
Other receivables	555
Bank accounts	25 371
Prepaid expenses	5 014
Accrued revenues	193
Total Assets	269 238
Liabilities	k€
Own equity	226 942
Funds	37 828
Trade suppliers	915
Wages payable	821
Payables to social security institutions and public health insurance companies	442
Other direct tax payables	120
Other payables	32
Provisions and reserves	10
Estimated accrued expenses	406
Deferred expenses	1 722
Deferred revenues	0
Total Liabilities	269 238

Income Statement for ELI-HU Non-profit Ltd

Revenues	k€
Operational subsidies	25 957
Interest income	489
Foreign exchange gains	158
Other Revenues - (depreciation from subsidies, rental income, others)	79 540
Income from ELI and services	21 713
Total Revenues	127 857
Expenses	k€
Purchase and Services Consumption	12 263
Change in inventory of own products and capitalisation	-256
Personnel expenses	10 064
Taxes and fees	301
Other expenses (foreign exchange expenses, other operating expenses)	264
Depreciation and provisions	103 521
Income tax	31
Total Expenses	126 189
Net income	1 669

Balance Sheet for ELI-HU Non-profit Ltd

Assets	k€
Tangible and intangible assets	207 575
Accumulated depreciations - Tangible and intangible assets	-53 946
ELI-HU non-profit nominal value of the majority share	0
Inventory	309
VAT receivables	-832
Other receivables	2 276
Bank accounts	16 612
Prepaid expenses	182
Accrued revenues	1 759
Total Assets	173 936
Liabilities	k€
Own equity	2 493
Funds	0
Profit & loss account	1 669
Long term liabilities	71 670
Trade suppliers	3 764
Wages payable	504
Payables to social security institutions and public health insurance companies	214
Other direct tax payables	115
Other payables	8 073
Provisions and reserves	1 072
Estimated accrued expenses	0
Deferred expenses	1
Deferred revenues	84 361
Total Liabilities	173 936

Publisher Information

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 www.eli-laser.eu

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