The Extreme Light Infrastructure ERIC

ANNUAL REPORT
2023–2024

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Letter from the Director General

Dear Colleagues,

This past year has been a period of significant milestones and transformative achievements for ELI. Since 1 January 2024, ELI ERIC is operating the ELI ALPS and ELI Beamlines Facilities together with a single governance and management structure, realising the vision for ELI.

One of the key benefits of this integration is the establishment of a single User Office. This office spearheads the core mission of ELI and aligns the User Programme across all ELI Facilities. The aim is to ensure a cohesive and high-quality experience for our users. There is still much work to be done, but in the first two years since its establishment, we have launched four Joint User Calls, and the interest in ELI is growing rapidly. The message is clear: our doors are open and we welcome scientists from around the world.

The 4th Call resulted in a record number submitted proposals, with 114 from an ever-growing number of scientists. In total 341 proposals have been submitted from 31 countries by over a 1,100 individual researchers. The ELI Facilities are fast becoming hubs for interdisciplinary collaborations, enabling the exploration of new scientific frontiers, expanding and enriching our user community. The advanced systems offer high potential for data collection and productivity, fundamentally shifting how experiments can be conducted in some fields.

In line with our commitment to advancing scientific frontiers, ELI is actively pursuing groundbreaking projects. Among these, initiatives on Laser-Induced Fusion and projects such as EuPRAXIA for laser driven acceleration, and a Muon Imaging project stand out. These innovative projects demonstrate concrete ways to harness high-power laser technology for fundamental research and practical applications. These efforts are supported by collaborative endeavours with leading research institutions and industry partners, ensuring ELI's place among leaders in the field.

The unification of ELI's Facilities offers organisational advantages as well, allowing us to operate more efficiently and effectively, optimising resources and standardising practices. As we look to the future, we will leverage our integrated structure not only to maximise the research impact, but also to develop ELI's unique innovation potential and translate that into socio-economic benefits.

The achievements outlined in this report showcase the dedication and hard work of all the exceptional staff of ELI ERIC, more than 600 people. Their continued support and dedication to the mission of ELI is fundamental to our success. Together, we will continue to push the boundaries of what is possible, making significant contributions to science and society.

Allen Weeks
ELI ERIC Director General

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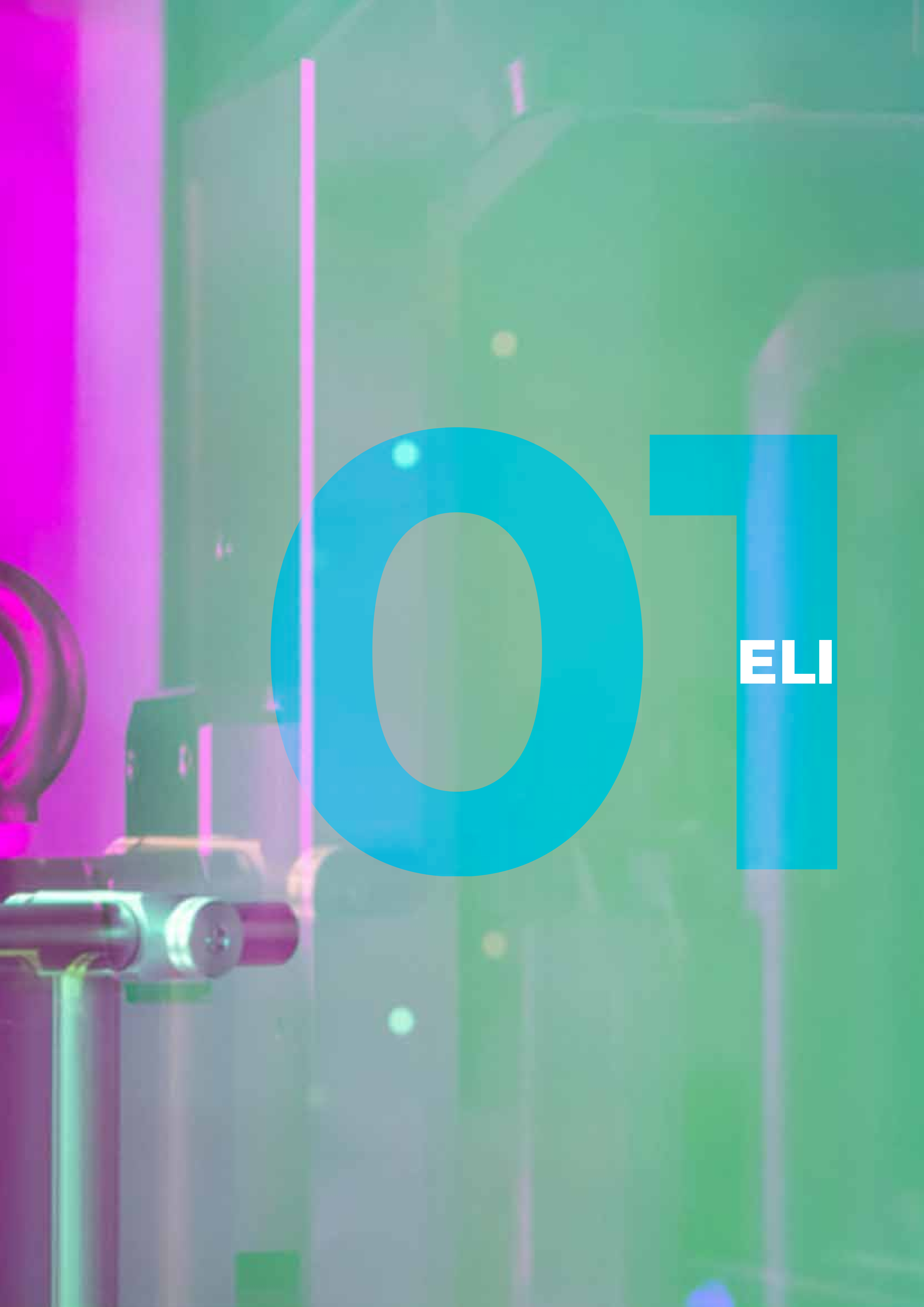


01 ELI

ELI Integrates into a Unified Organisation

The Extreme Light Infrastructure (ELI ERIC) has made great strides in the past year both as an organisation and in terms of scientific progress and outputs. As of 1 January 2024, ELI ERIC operates both the ELI Beamlines and ELI ALPS Facility as a unified organisation. The integration achieves the original vision for ELI, as laid out in the ELI White Book published 12 years ago.

The strategic alignment marks a critical milestone set in the ELI ERIC Statutes, promising a smooth transition and commencement of joint operations. This landmark integration solidifies ELI ERIC's position at the forefront of cutting-edge science, set to realise groundbreaking discoveries and foster international scientific cooperation.

Recognised as a Landmark ESFRI project and the first large-scale Research Infrastructure (RI) in Central Europe ELI provides access to world-class high-power, high-repetition-rate laser systems and enables cutting-edge research in physical, chemical, materials, and medical sciences, as well as breakthrough technological innovations.

From 1 January 2024, Romania joined ELI ERIC as a Founding Observer. That is a necessary step towards Romania's goal of becoming a Host Member and integrating the ELI NP Facility.

> **"This integration realises the core mission of bringing the ELI ERIC Facilities together as an integrated organisation. Together ELI ERIC will host the world's largest and most advanced collection of high-power lasers"**
>
> *Allen Weeks, ELI ERIC Director General*

ELI ALPS, Hungary

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

ELI Beamlines, Czech Republic

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

ELI at the Forefront of Laser Science

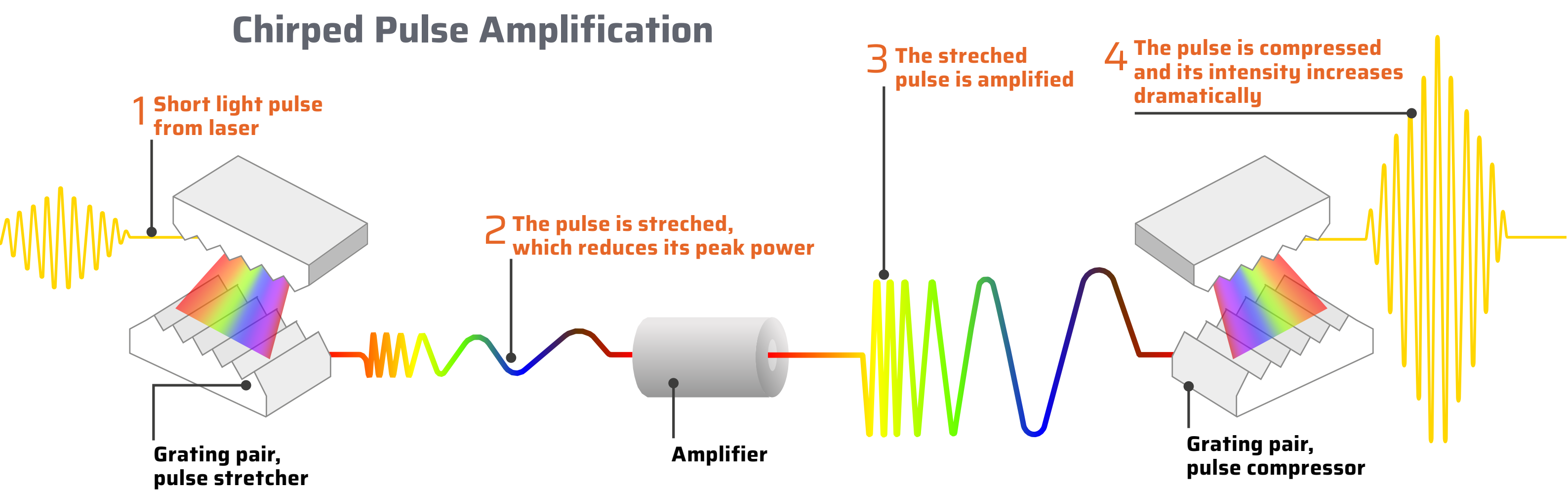
ELI stands at the cutting edge of laser science and technology, a position underscored by the Nobel Prize recognition of groundbreaking technologies like Chirped Pulse Amplification (CPA) in 2018 and attosecond physics in 2023. These advancements are fundamental to ELI's mission and capabilities. ELI is poised to lead the next generation of discoveries in laser science and beyond.

Chirped Pulse Amplification a Key Technology Driving ELI

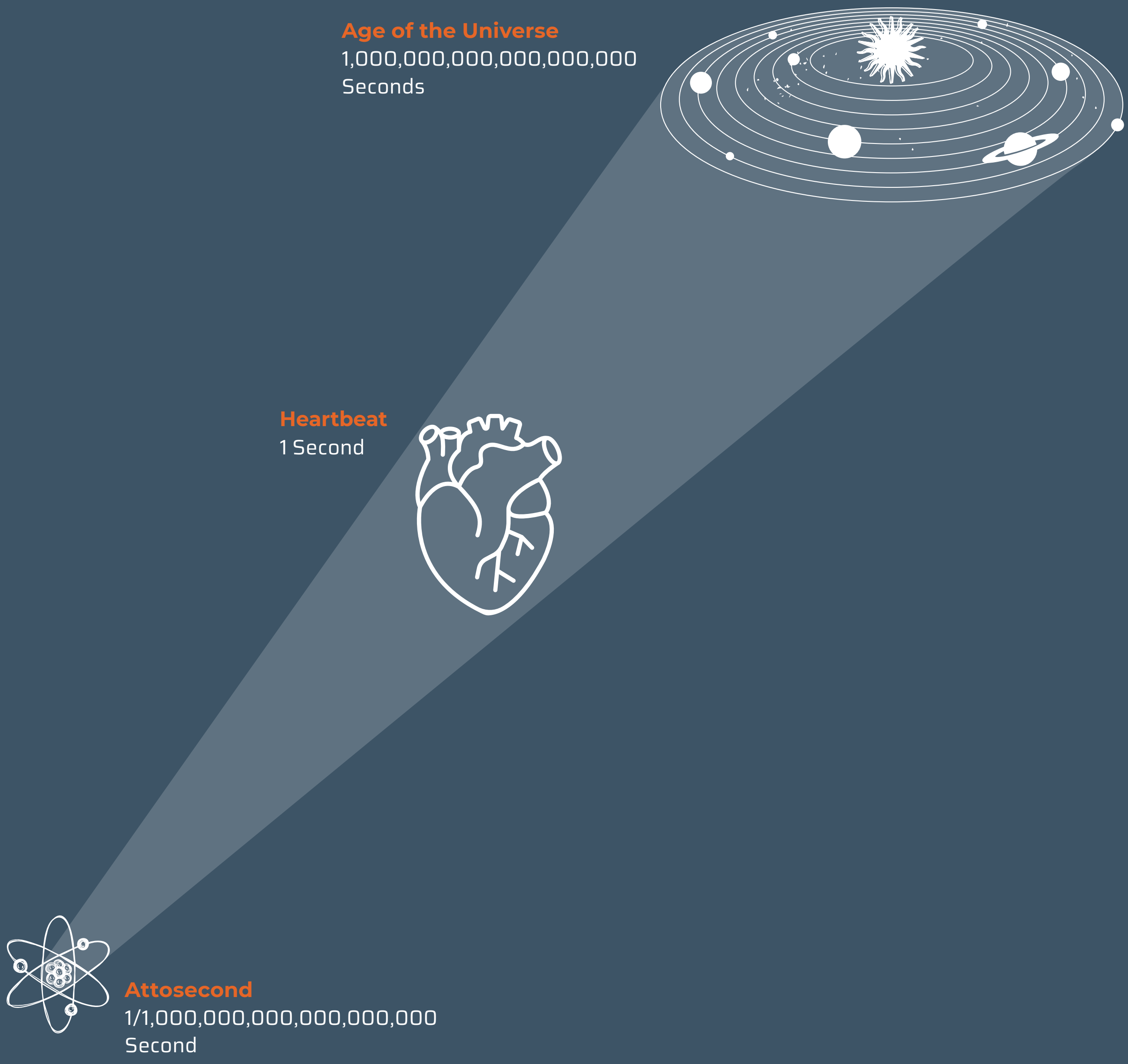
Mourou and Strickland developed a technique called 'Chirped Pulse Amplification', or CPA, in 1985 as Strickland's PhD work and first published paper.

That technique takes low-intensity light, stretches and amplifies it, then compresses it back into incredibly short, ultrafast pulses with greater power than all the power stations in the world - for a billionth of a billionth of a second. That's a key technology driving ELI. The CPA technique has revolutionised the generation of ultrafast, high-intensity laser pulses, which are crucial for applications ranging from corrective eye surgery to fundamental scientific research.

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



Creating and Characterising Attosecond Light Pulses



The 2023 Nobel Prize in Physics recognises the pivotal contributions of Pierre Agostini, Ferenc Krausz, and Anne L'Huillier in attosecond science. Their work in creating and characterising attosecond light pulses offers a view into the ultrafast processes that dictate matter's behaviour.

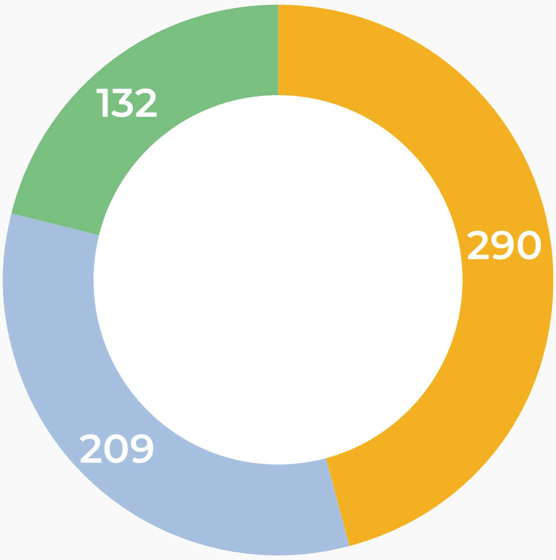
That research was instrumental in the vision to build ELI. One key mission of the ELI ALPS Facility is the generation and applications of attosecond light pulses. It is the largest and most advanced laboratory in the field.

Agostini, Krausz and L'Hullier's work carved a path for studying ultrafast electron processes. As attosecond light sources become brighter, shorter and more reliable, the potential for breakthroughs in fields like physics, chemistry, materials science or biology grows. Their efforts peeled back layers of the quantum realm, offering unprecedented insights into the processes that define the behaviour of matter.

Both L'Huillier and Krausz played vital roles in shaping ELI ALPS. Krausz proposed ELI ALPS in 2005, he is coauthor of the White Book from 2011 and ELI ALPS Science and Technology Report from 2011 more than a decade ago.

L'Huillier's leadership led to the design and realisation of the SYLOS LONG gas harmonic generation beamline. As one of the longest harmonic generation beamlines in the world, its high flexibility, and built-in pump-probe interferometer, and optional future developments make it a versatile tool for conducting a wide range of studies in the ultrashort timescale. Its adaptability and planned enhancements for a broader range of pump-probe wavelengths make it a key instrument for ultrashort timescale research.

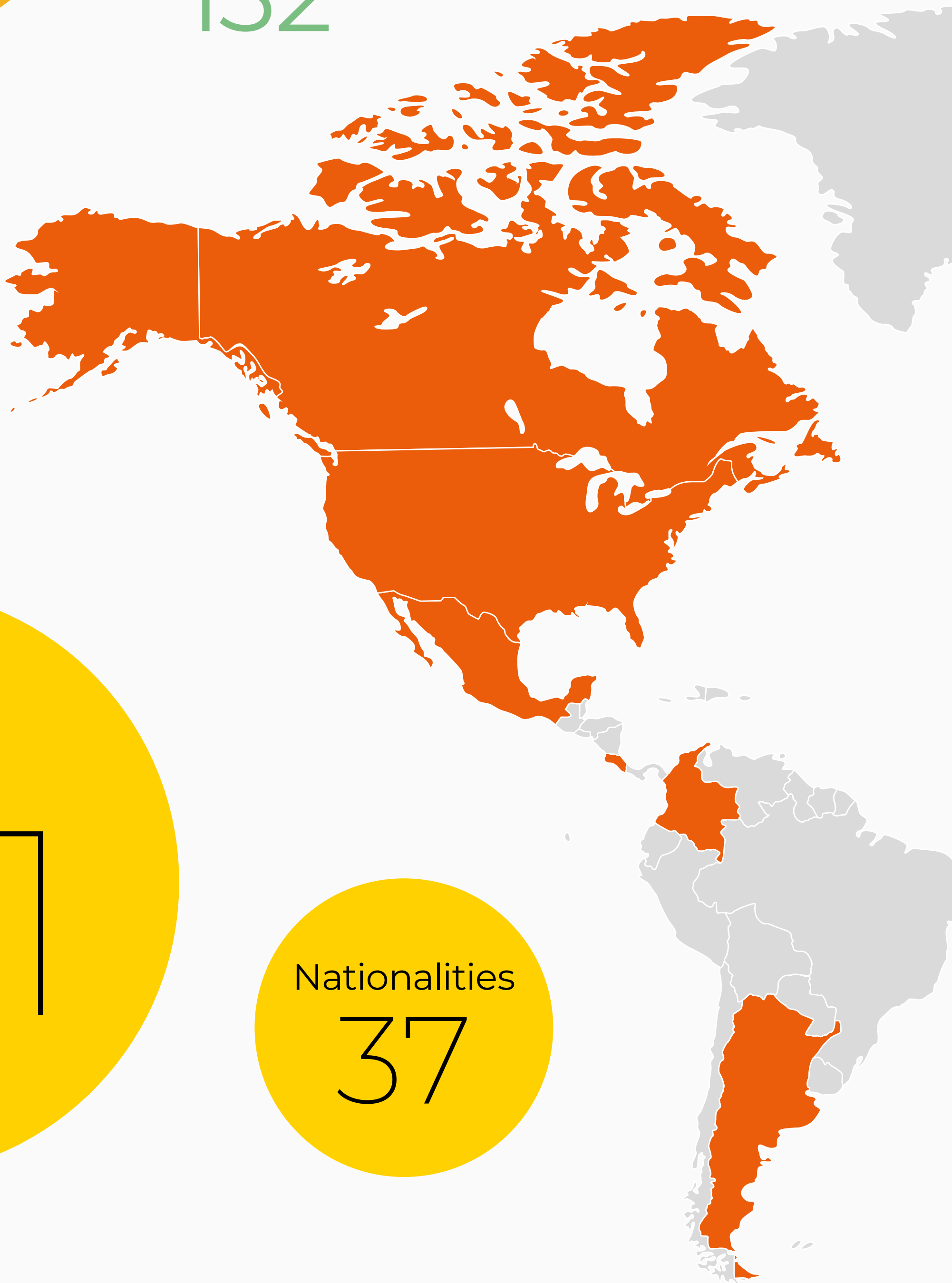
ELI ERIC Staff



Researchers
290

Technicians/Engineer
209

Admin
132

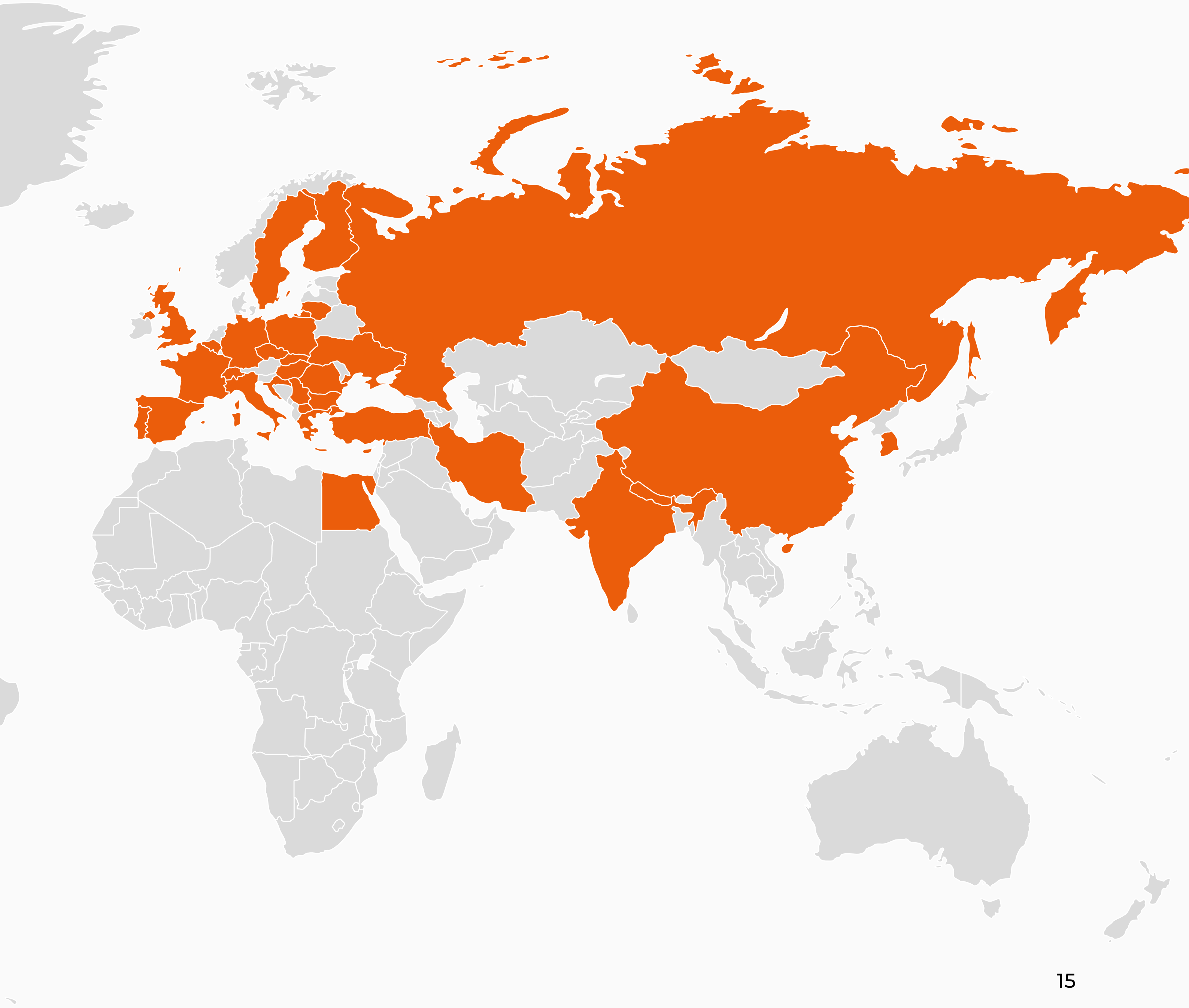


Total
631

Nationalities
37

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

Argentina	1	Egypt	2	Mexico	1	Spain	2
Belgium	1	Finland	1	Nepal	3	Sweden	2
Bulgaria	1	France	11	North Macedonia	1	Switzerland	3
Canada	1	Germany	1	Poland	6	Turkey	2
China	1	Greece	4	Portugal	2	Ukraine	10
Columbia	1	Hungary	241	Romania	3	United Kingdom	6
Costa Rica	1	India	20	Russia	11	United States	6
Croatia	3	Iran	1	Serbia	7		
Cyprus	2	Italy	10	Slovakia	12		
Czech Republic	247	Lithuania	2	South Korea	2		



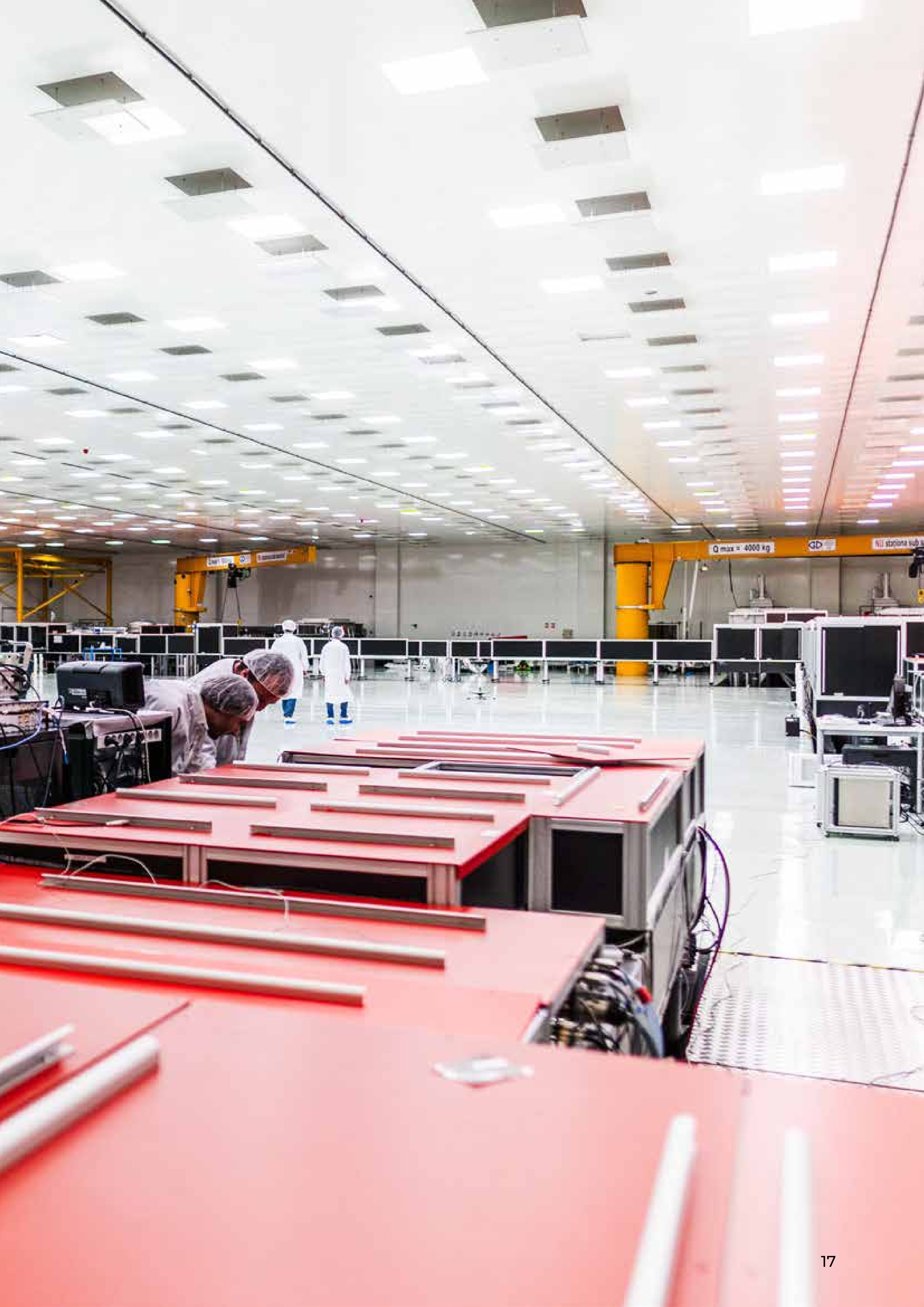
New Founding Observer - Romania

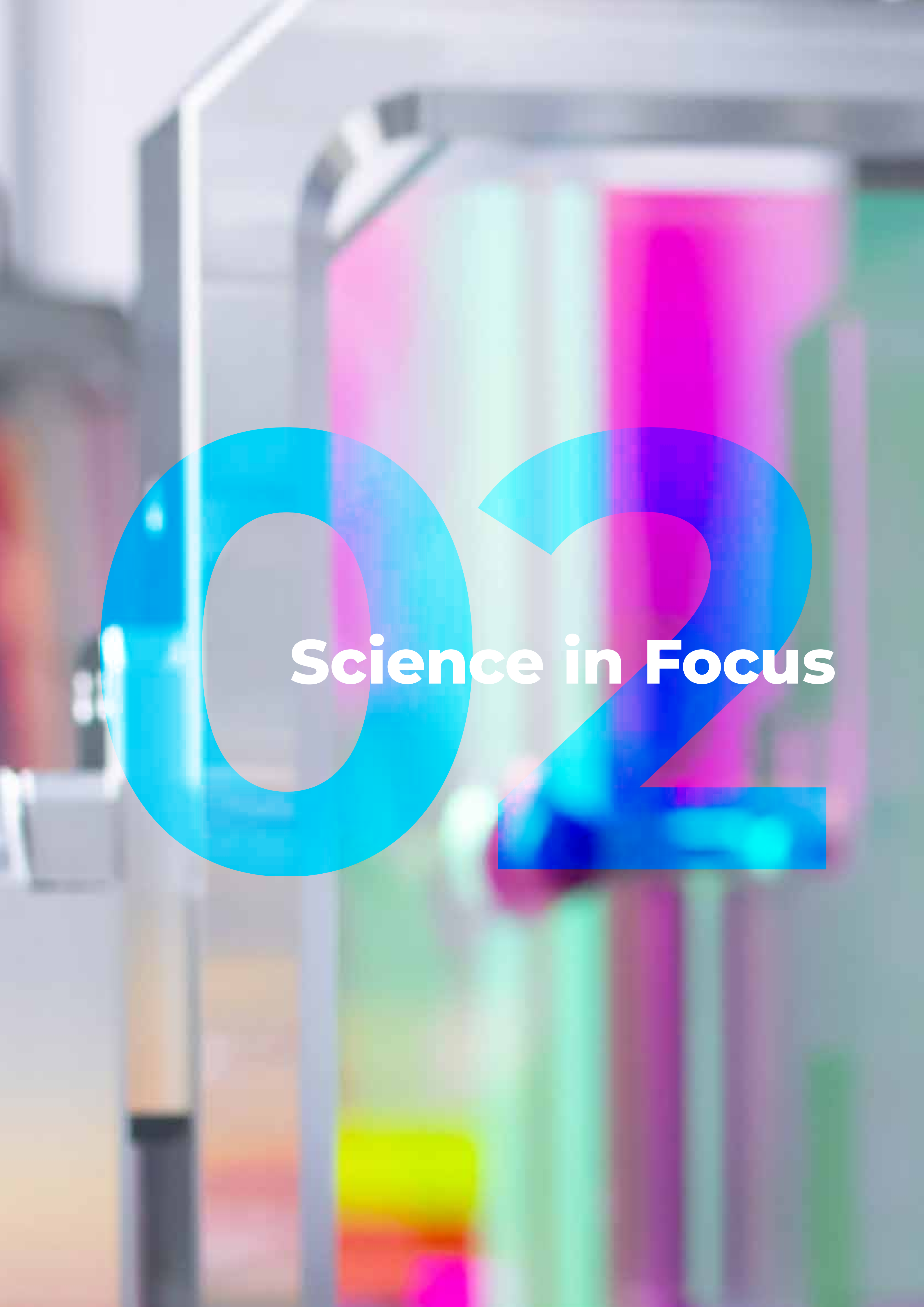
ELI Nuclear Physics

Cooperation with ELI Nuclear Physics (ELI NP) has been enabled by the IMPULSE Project and ELI NP is actively participating in the Joint ELI User Calls and User Meetings. Following a decision of the ELI ERIC General Assembly in June 2023, Romania participates in the ELI ERIC governance as a Founding Observer. This is an important step in the relationship between ELI ERIC and the ELI NP Facility which Romania hosts. This decision opens a new chapter in the alliance, laying the groundwork the ELI NP Facility to integrate into the ELI ERIC organisation in the future.

Located in Magurele, Romania, ELI NP is focused on laser-based nuclear physics. It will host two machines, a very high-intensity laser, where beams from two 10 PW lasers are coherently added to get intensities of the order of 10^{23}–10^{24} W/cm^2, and a very intense, brilliant gamma beam obtained by incoherent Compton back scattering of a laser light off a brilliant electron beam from a conventional linear accelerator. , and a very intense, brilliant gamma beam obtained by incoherent Compton back scattering of a laser light off a brilliant electron beam from a conventional linear accelerator. Applications include frontier fundamental physics, new nuclear physics, astrophysics, nuclear materials and radioactive waste management.

ELI NP has made significant progress with the 10 PW lasers, demonstrating short pulses at full energy and recently focusing those pulses to a high intensity on solid targets.


Q max = 4000 kg



02 Science in Focus

Joint User Programme

The Joint ELI User Programme continues to play a pivotal role in providing researchers with centralised access to ELI ERIC's state-of-the-art scientific equipment. This programme is a significant milestone for ELI, unifying its three facilities and demonstrating their readiness to support groundbreaking scientific research.

Managed by ELI ERIC, the Joint User Programme offers a single access point to all capabilities at the ELI Facilities. Access is competitive, international, free of charge and based on scientific excellence. ELI also offers proprietary access opportunities to the industry. This alignment with the European Union Charter for Access to Research Infrastructures ensures scientific excellence.

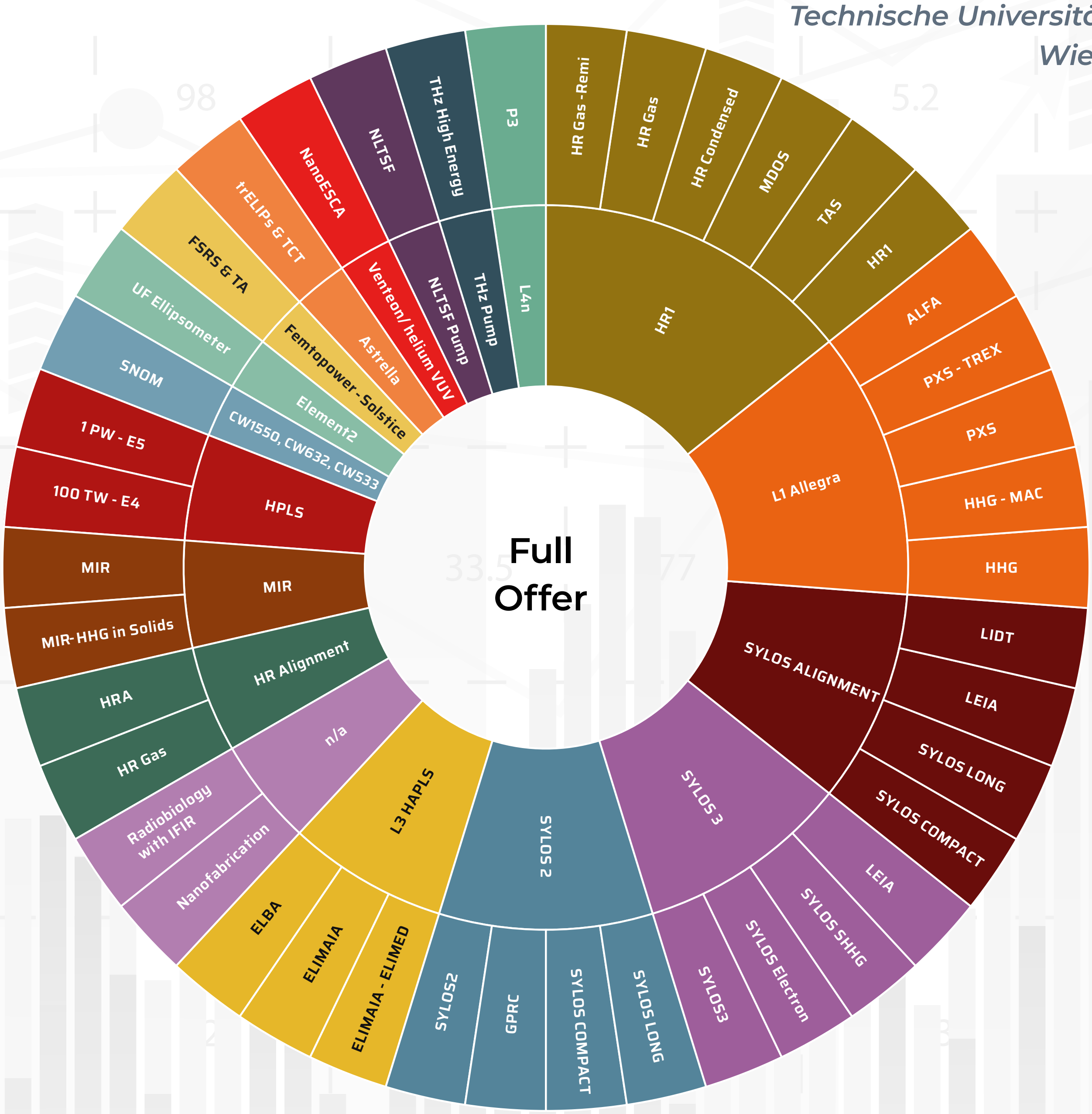
Since launching the Joint ELI User Programme nearly two years ago, ELI has opened 4 Calls. With each Call increasingly more instruments and equipment are made available to the external user community for research. The graph demonstrates the evolution of equipment coming online during the two years of User operation from a combination of 10 primary and secondary sources to 42 combinations of secondary sources, experimental and end-stations driven by 17 primary sources.

7 Primary Sources

10 combinations of secondary sources, experimental and end-stations

"ELI is the cutting edge. More and more physicists are asking questions that could be answered by attosecond physics. Universities do not generally have the resources to build their own attosecond laser sources and this is where ELI can lend a helping hand."

Alessandra Bellissimo
Technische Universität Wien



17 Primary Sources

42 combinations of secondary sources, experimental and end-stations

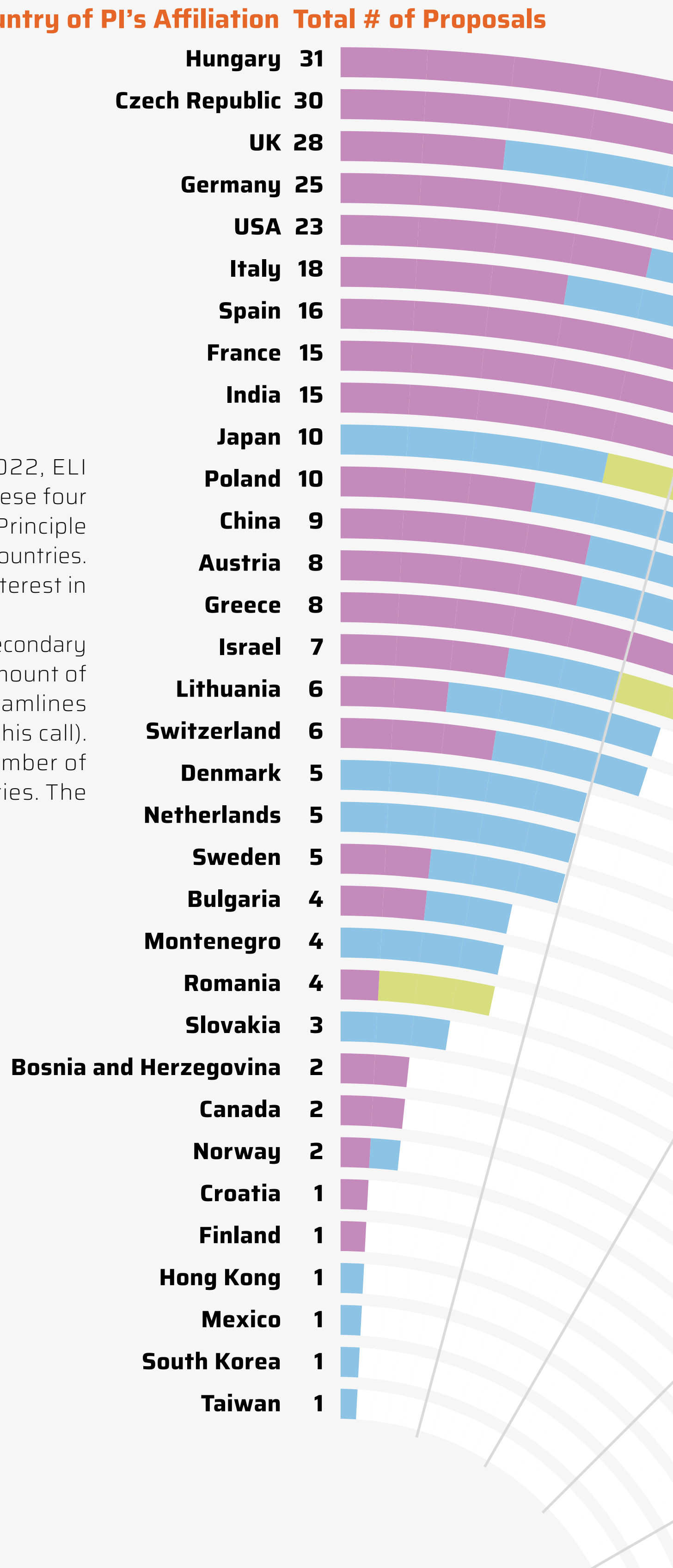
A Global Interest in ELI

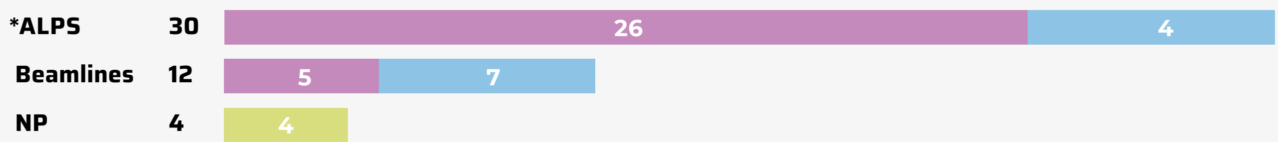
Since the inauguration of its Joint User Programme in 2022, ELI ERIC has successfully launched four Calls for Users. Across these four Calls a total of 341 experiment proposals were submitted by Principle Investigators (PI) affiliated with research organisations from 31 countries. The analysis of the countries of affiliation indicates a global interest in ELI, spanning across Europe, America and Asia.

The 4th ELI Call for Users provided open access to a range of secondary sources, experimental and end-stations and an increasing amount of primary sources (i.e., laser systems) at ELI ALPS and ELI Beamlines (instrumentation offerings from ELI NP were not included in this call). The data from the 4th Call for Users resulted in a record number of experiment proposals submitted. In total 114 from 26 countries. The increased interest is attributed to the expanded offerings.

341 **Proposals**

31 **Countries**

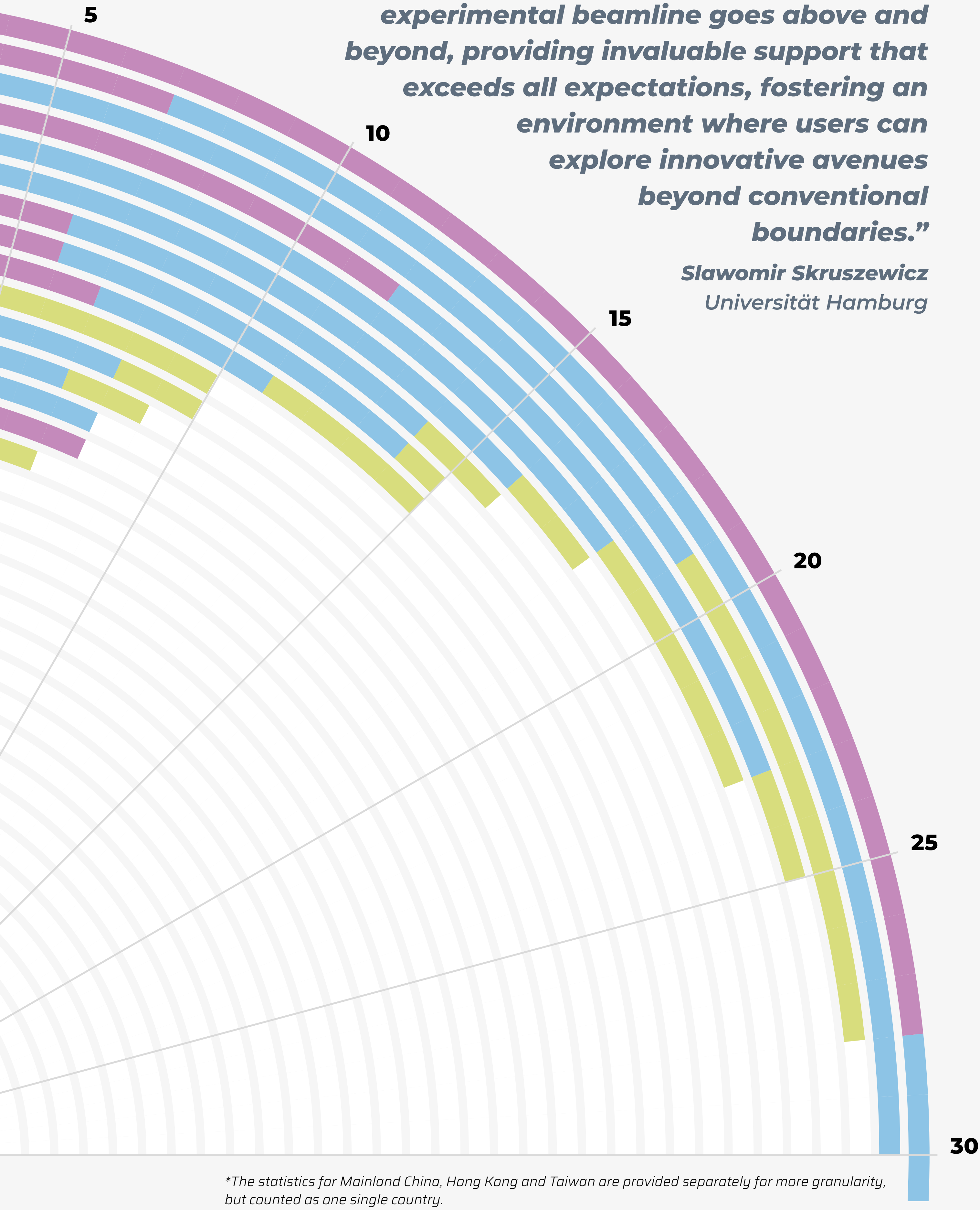




**Applications from the ELI Facilities are listed separately to not influence the national statistics of HU, CZ and RO*

"The work of the ELI colleagues at the experimental beamline goes above and beyond, providing invaluable support that exceeds all expectations, fostering an environment where users can explore innovative avenues beyond conventional boundaries."

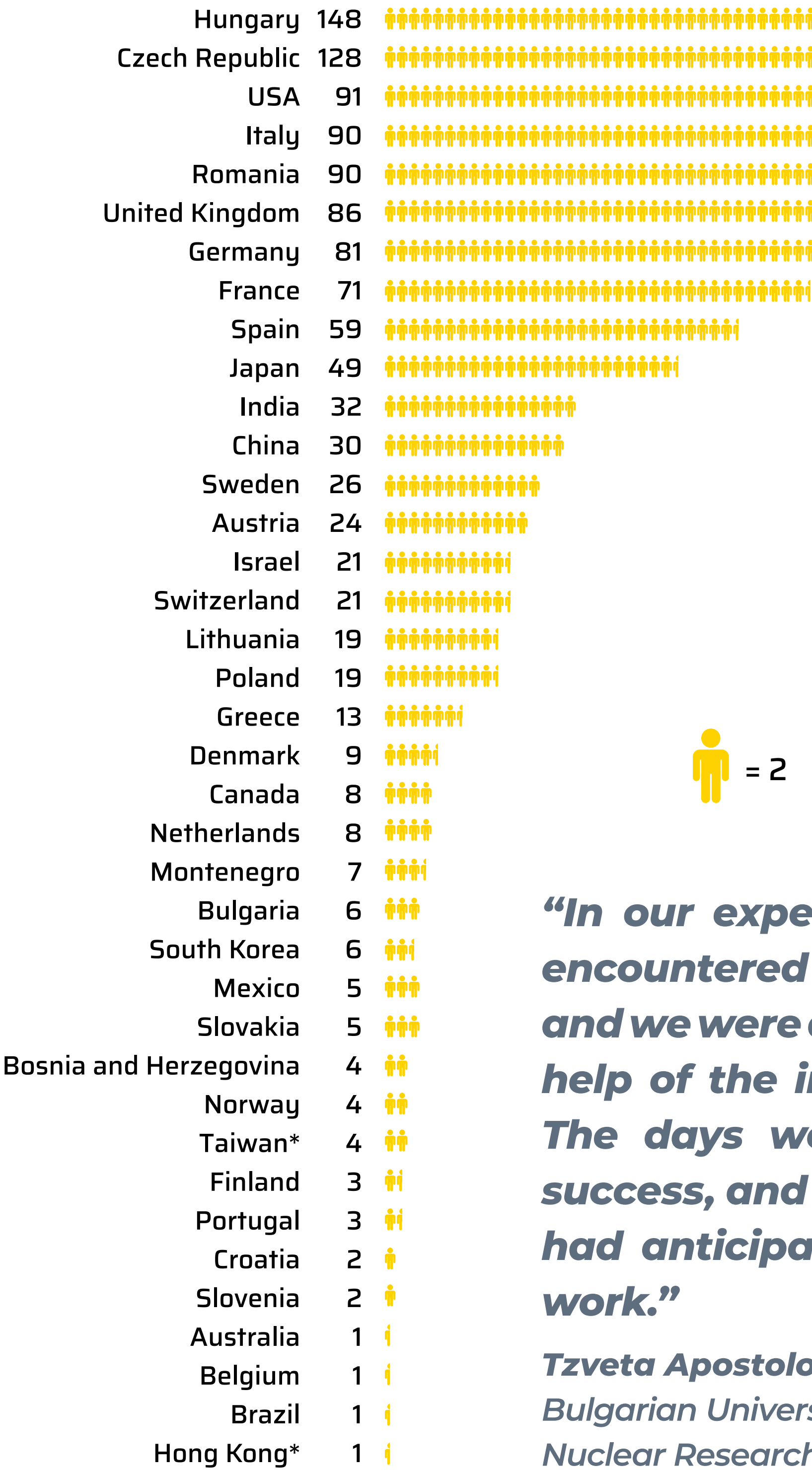
Slawomir Skruszewicz
Universität Hamburg



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

ELI's User Community

The teams submitting proposals to ELI are made up of individual scientists from all over the world. Since launching the User Programme a total of 1178 scientists have participated in submitting proposals. The infographic illustrates the origin, based on the country of their professional affiliation.



"In our experiment campaign, we encountered unexpected problems, and we were able to solve them with help of the institute's researchers. The days we spent here were a success, and we saw the results we had anticipated in our theoretical work."

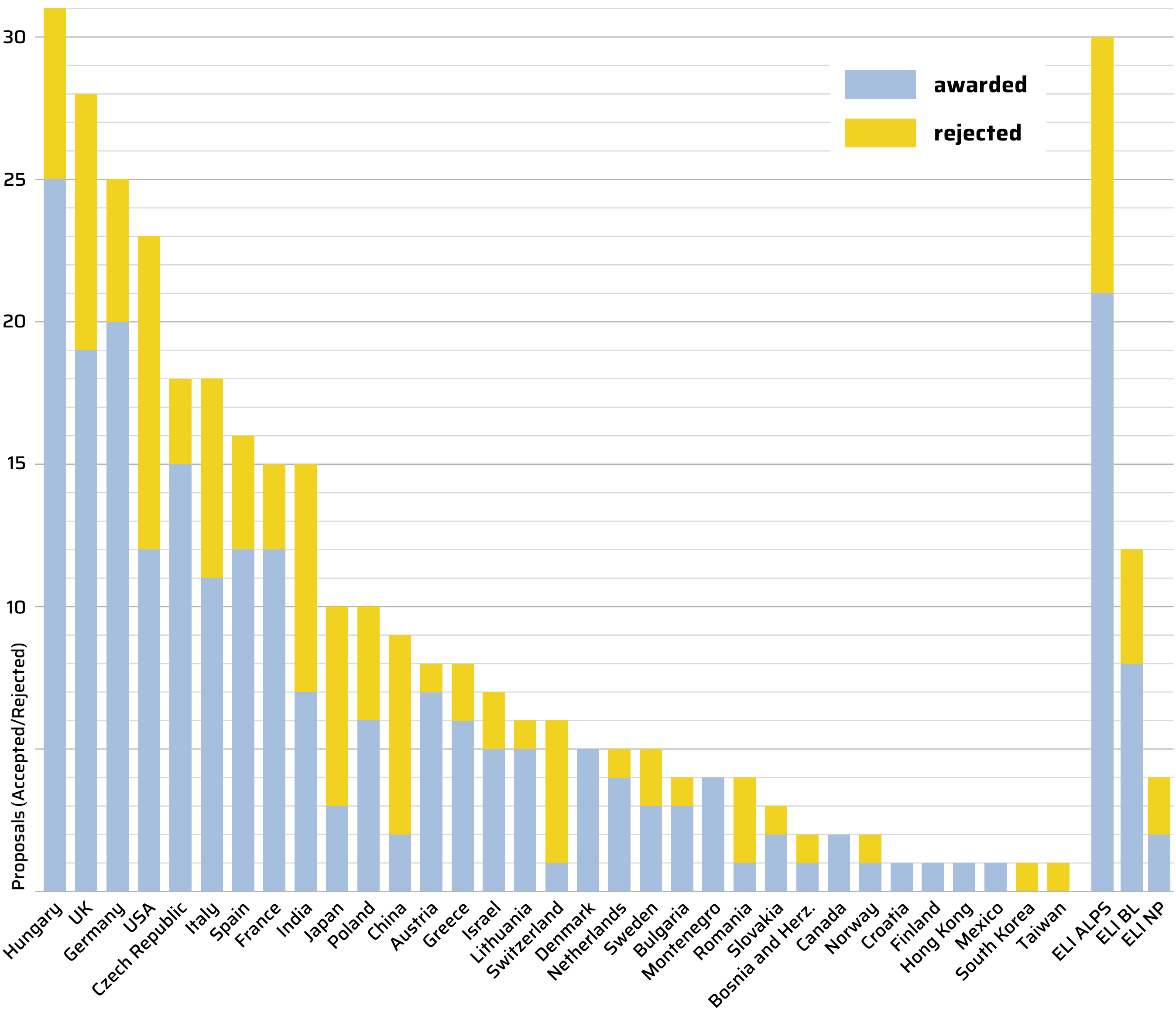
Tzveta Apostolova
Bulgarian University and the Institute for Nuclear Research and Nuclear Energy in Sofia

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

Successful Proposal

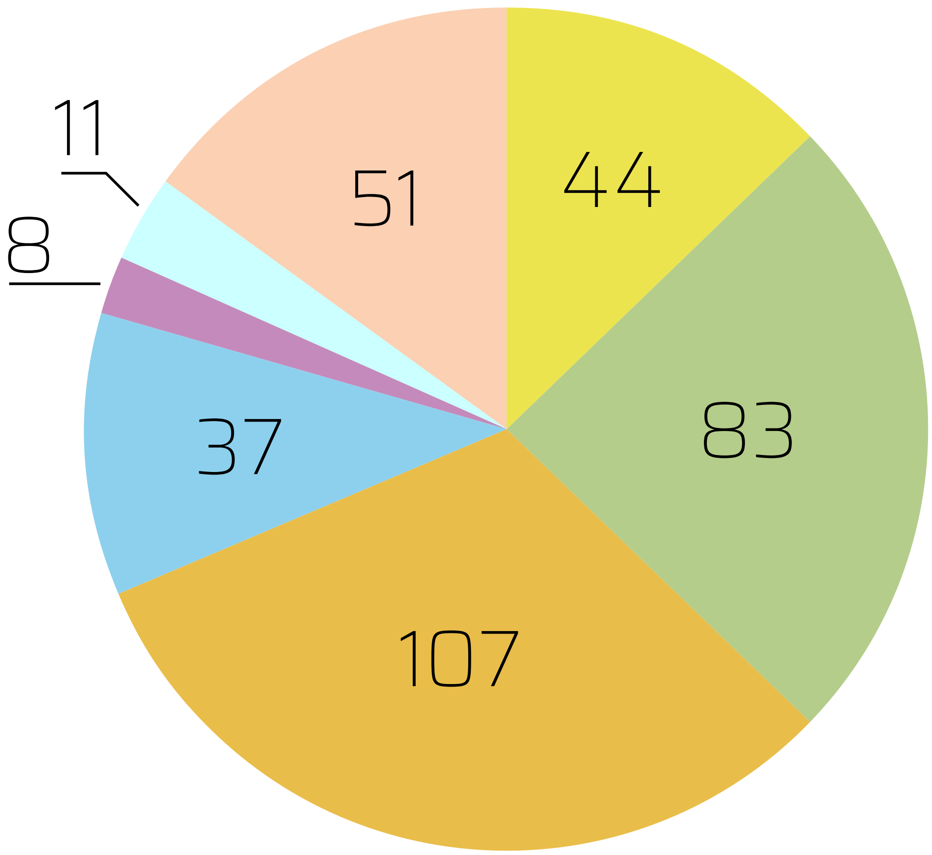
In total ELI has received a total of 341 experiment proposals of which 229 were granted beamtime.
The table above showcases the detailed statistics according to each Call and the Facility distribution of the submitted and beamtime granted.
The graph shows the distribution by country of PI's institute affiliation.

ELI ERIC USER Programme Open Excellence-Based Access						
Year	User Call	ELI Facilities Combined		ELI Facilities Individually		
		Proposals Submitted	Beamtime Granted	Proposals Submitted / Beamtime Granted		
				ELI ALPS	ELI Beamlines	ELI NP
2022	1st	44	29	11/8	17/17	16/4
2023	2nd	102	67	35/32	49/31	18/4
2023	3rd	81	58	38/28	33/26	10/4
2024	4th	114	75	56/43	58/32	0/0
Total	**4**	**341**	**229**	**140/111**	**157/106**	**44/12**



Areas of Science

The ELI ERIC User Calls have demonstrated a dynamic evolution of interest across various scientific areas. Initially, Call 1 saw a balanced distribution of proposals across AMO Chemistry and Physics in Gas and Liquid Phases, Material and Surface Science, and Life Sciences. By Call 2 there was a significant increase in the number of proposals, particularly in Life Sciences and Material and Surface Science, reflecting growing interest in these fields. This trend continued with Call 3, in which Life Sciences and AMO Chemistry and Physics maintained high levels of engagement. In Call 4 there was a substantial rise in Life Sciences proposals. Additionally, there was a notable increase in proposals for Particle Acceleration, attributed to the availability of advanced L3 HAPLS-driven instruments at Beamlines and SYLOS Electron. This progression highlights ELI ERIC's expanding offer and the scientific community's increasing recognition of its advanced research capabilities, catering to a wide array of scientific inquiries and fostering groundbreaking research across diverse fields.

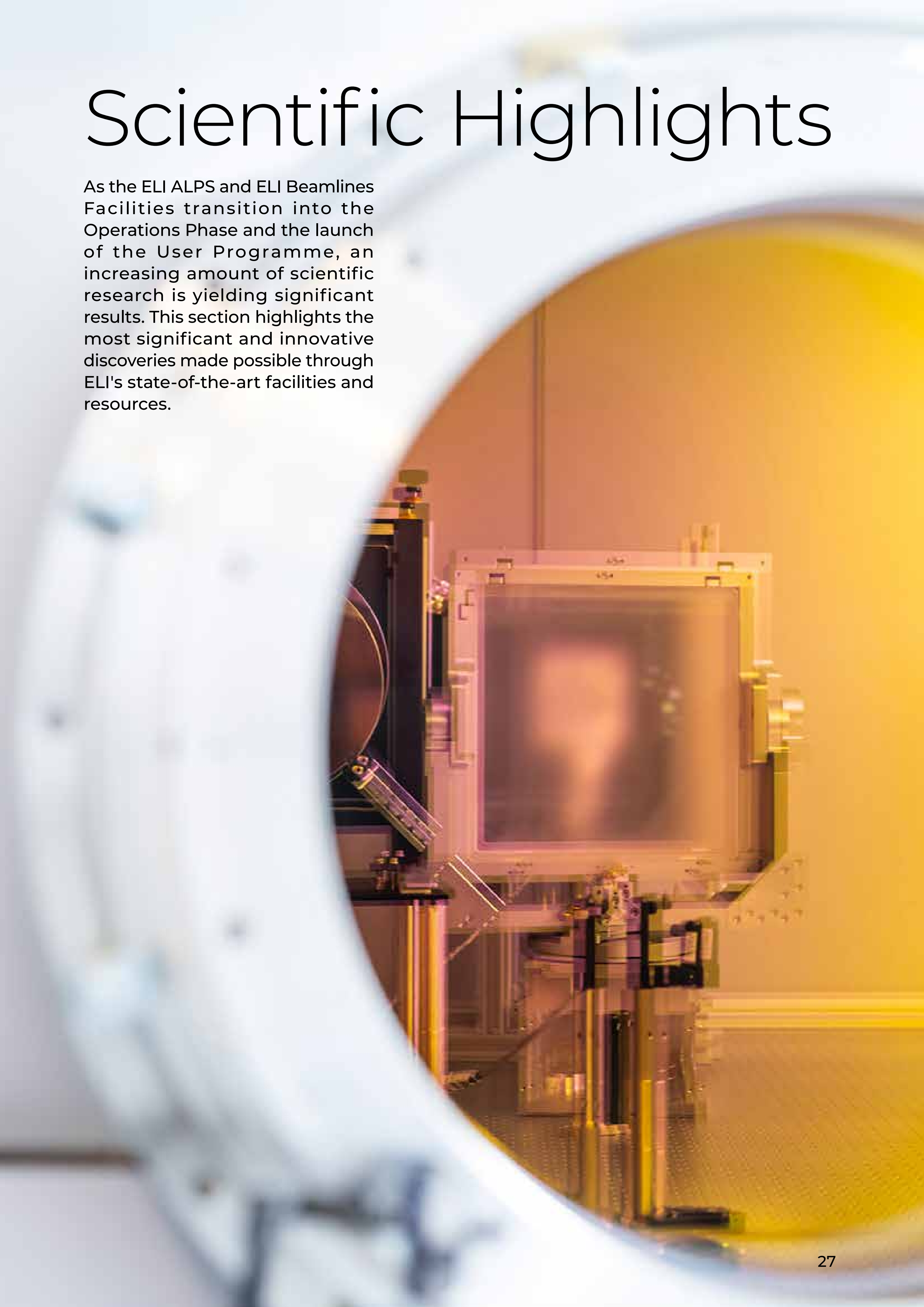


Total distribution by scientific area or facility	Call1	Call2	Call3	Call4	total
AMO chemistry and physics in gas and liquid phases	16	27	16	24	83
Material and surface science	12	32	27	36	107
Life science (medical, biological and environmental)		2	12	23	37
Plasma physics		4	2	2	8
Relativistic and ultrarelativistic Interactions		5	1	5	11
Particle acceleration and applications		14	13	24	51
NP*	16	18	10		44
Total	**44**	**102**	**81**	**114**	**341**

* Proposal approval process for ELI NP is done seperately and the classifications into areas of science is different.

Scientific Highlights

As the ELI ALPS and ELI Beamlines Facilities transition into the Operations Phase and the launch of the User Programme, an increasing amount of scientific research is yielding significant results. This section highlights the most significant and innovative discoveries made possible through ELI's state-of-the-art facilities and resources.



Few-cycle Laser Pulse Characterisation On-Target Using High-Harmonic Generation from Nano-Scale Solids

A team from the Institute of Optics and Quantum Electronics of the Friedrich Schiller University lead by Matthias Kübel have successfully developed a characterisation method for few-cycle laser pulses via high order harmonics generation (HHG) from nano-scale solid targets. The research utilised ELI ALPS' MIR laser and leverages a novel approach combining the powerful TIPTOE technique with HHG to prove that the generated harmonics spectrum modulation (of each individual one) can be used to accurately characterise the input femtosecond laser pulse. The working principle relies on perturbing HHG in solids with a weak replica of the driver pulse (HHG-TOE). The research published in Optics Express employs a method which provides a straightforward approach to accurately characterise femtosecond laser pulses used for HHG experiments right at the point of interaction.

The 45fs pulses centered at 3200nm were characterised on 50nm ZnO film by HHG-TOE using harmonics up to the 9th order. Spectral modulation versus delay was recorded then post-processed by Fourier transformation to retrieve the spectral power and phase of the probe pulse, which then compared to conventional TIPTOE measurements showing very good agreement.

The results demonstrate that HHG from solids is suitable to accurately characterise ultrashort laser pulses. The scheme appears particularly useful to measure the electric field evolution of laser pulses used for HHG experiments, as the laser pulse is characterised at the very point of interaction. HHG-TOE has the potential to become a standard tool for pulse characterisation in solid-state HHG experiments, because it is simple to implement and there are few limitations on the type of material used for the experiment.

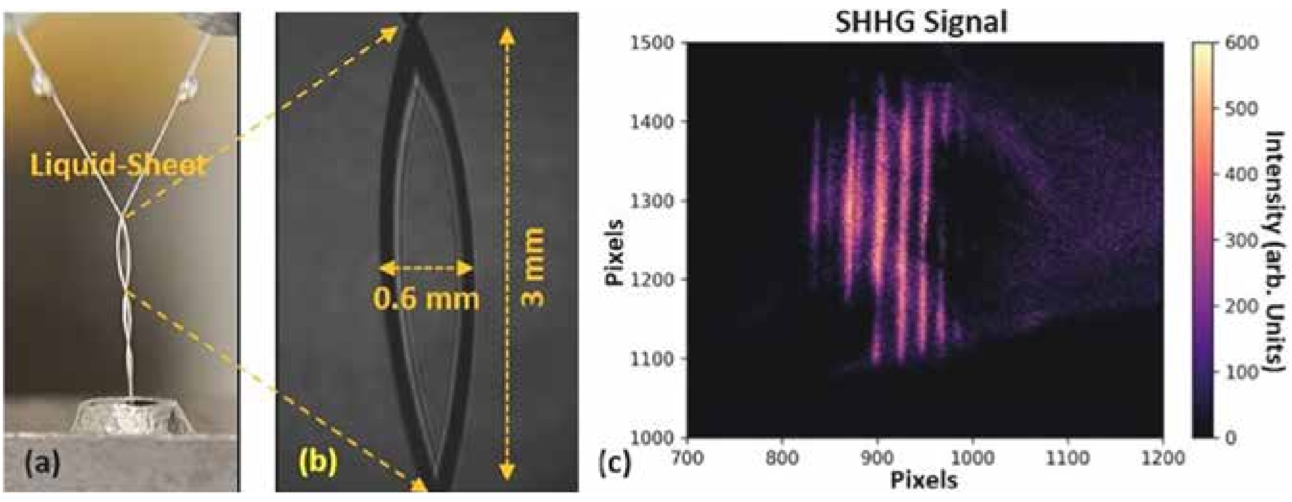
SYLOS driven Surface Plasma Interaction Platform

The SYLOS SHHG beamline at ELI ALPS is a unique and versatile platform for studying interaction of relativistically intense laser pulses with near-solid density surface-plasma. The beamline is a complex collaborative development between researchers of ELI ALPs and Laboratoire d'Optique Appliquée (LOA), with engineering and fabrication support by ARDOP. The platform consists of multiple vacuum chambers housing several sub-systems to engineer driver-laser parameters and perform relativistic experiments at high-repetition rates up to 1 kHz

Free-flowing liquid sheet of sub-micron scale thickness, generated by the collision of liquid-jets have recently emerged as promising alternative to solid targets, due to their potential for continuous unhindered operation.

In a recent commissioning experiment, surface high-harmonics were generated at the SYLOS SHHG platform with liquid sheet plasma mirror. The joint effort produced the first harmonics profile generated at 10 Hz using the SYLOS Experimental Alignment (SEA) laser of ELI ALPS. Experiments continue to obtain well calibrated high-harmonic data.

The ability to generate high-harmonic signals using liquid plasma mirrors opens new possibilities in the field of ultrafast optics and photonics. This advancement is particularly relevant for applications requiring precise control and high-frequency repetition, such as advanced imaging techniques, attosecond science, and the development of compact, high-brightness X-ray sources.



(a) Photograph of liquid sheet target in operation. (b) Magnified view of the liquid sheet. (c) Surface high harmonics signal obtained in the SYLOS SHHG beamline from liquid target.

XUV Tuning for High-Harmonic Generation: A Leap in Ultrafast Spectroscopy

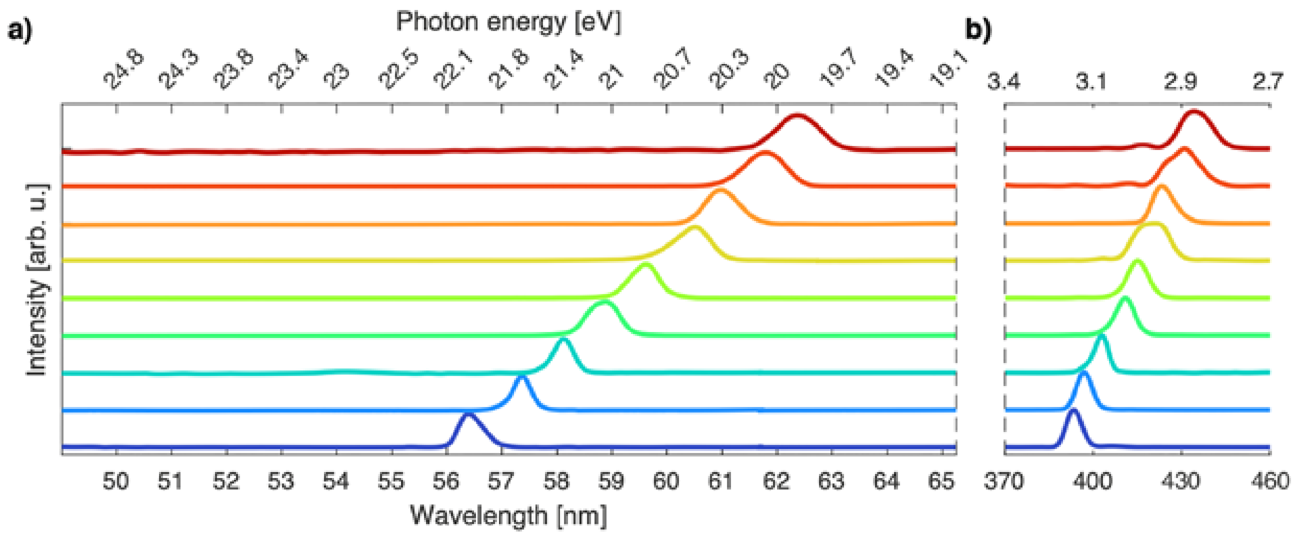
A pioneering experiment led by Marcel Mudrich, Aarhus University in cooperation with a team from ELI Beamlines studied the inherent limitations in tuning the exact peak frequency or wavelength of HHG sources, crucial for ultrashort spectroscopic applications. Awarded as part of the excellence-based access, the project is also a Flagship experiment supported by the IMPULSE project.

High-harmonic generation, a process that generates a series of spectral peaks at odd multiples of the initial laser frequency, typically lacks tunability. This limits its application in ultrashort spectroscopy where specific wavelengths are needed. The XUV tuning experiment overcame this limitation by tuning the driving laser's wavelength. Utilising the L1 Allegra laser system at ELI Beamlines (13 fs, 20 mJ, 1 kHz) based on optical parametric chirped-pulse amplification (OPCPA), achieved natural tunability.

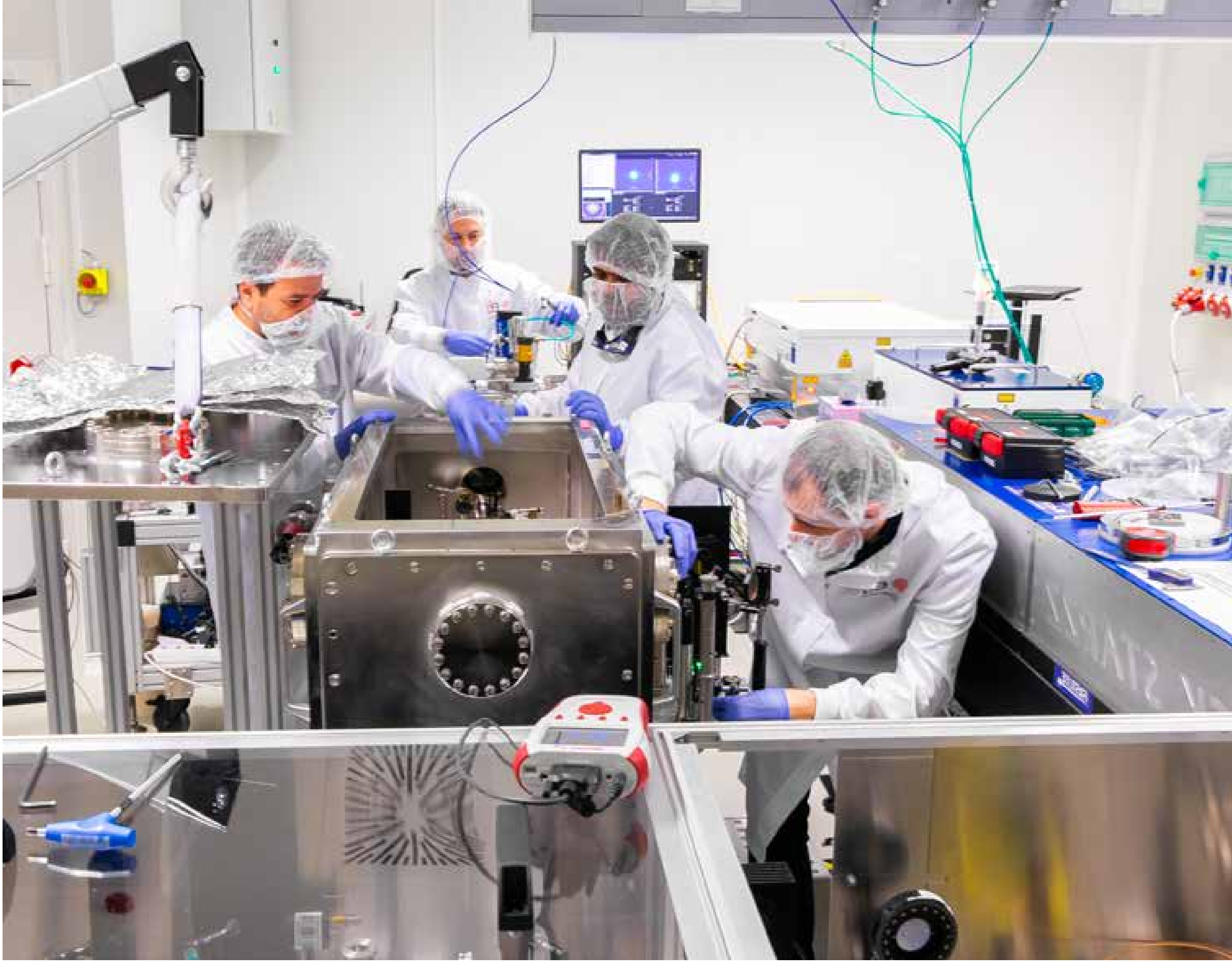
By employing the second harmonic of the L1 Allegra laser system (400 nm), the team demonstrated tunability of the 7th harmonic by adjusting the laser wavelength from approximately 395 nm to 435 nm. This resulted in a 7th harmonic wavelength range of 56.5 nm to 62.5 nm (22 eV to 19.9 eV) showcasing the ability to spectrally tune the XUV output robustly.

The success of the XUV tuning experiment has significant implications for various fields, including resonant coherent diffractive imaging, monitoring correlated electron dynamics, and studying transient states of matter. The tunable XUV source, is a significant advancement in ultrafast spectroscopy, allowing detailed studies of dynamic processes with unprecedented precision. Furthermore, the experiment illustrates the potential for further explorations, including targeting different spectral regions using other gases or harmonic numbers. The ongoing developments promise to extend the capabilities of HHG sources, making them indispensable tools in high-energy density science and beyond.

The integration of tunable XUV sources in HHG experiments provides researchers with versatile and powerful tools to explore ultrafast phenomena. This collaborative effort sets a new standard for precision and adaptability in high-energy laser research.



Jurkovičová, L., Ben Ltaief, L., Hult Roos, A. et al. Bright continuously tunable vacuum ultraviolet source for ultrafast spectroscopy. Commun Phys 7, 26 (2024). https://doi.org/10.1038/s42005-023-01513-5



Attosecond Light Source Based on Strongly Laser Driven Semiconductors

In the last decade, the process of high harmonic generation induced by the interaction of semiconductor crystals with intense laser fields has gained significant attention. This is because it offers substantial advantages for studying many-body physics and ultrafast optoelectronics. However, its potential to be utilised as an attosecond light source for applications in attosecond science has remained largely unexploited.

An international team of researchers from ELI ALPS, Technion, ICFO, TU Wien, University of Bordeaux and FORTH developed a novel scheme enabling the generation and the temporal characterisation of attosecond pulses emitted by laser-driven semiconductors, along with their application in attosecond science at ELI ALPS.

The development relies on high harmonics generated by the interaction of few-cycle CEP-stable mid-infrared laser pulses with semiconductor crystals. In addition to the conventional equipment required for generating and measuring the harmonic spectrum, the beamline features an interferometer for cross-correlation experiments (using mid-infrared and harmonic pulses) with attosecond resolution. Additionally, the endstation is equipped with UV-XUV focusing elements, a time-of-flight ion/electron spectrometer, gas valves/jets, and an effusion cell combined with a cold trap for conducting pump-probe experiments in alkali metals.

The experiment measured a harmonic spectrum with photon energies extending into the extreme-ultraviolet (XUV) spectral region. Utilising a portion of the harmonic spectrum in the UV–VUV region and taking advantage of the high polarisability of alkali metals, enabled the development of a novel attosecond spectroscopy scheme. This scheme can measure the attosecond synchronisation of the emitted harmonics and the duration of attosecond pulses formed by their superposition.

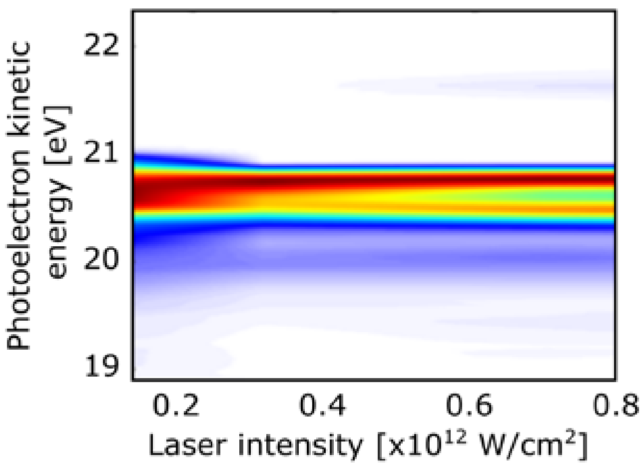
This introduces laser-driven semiconductors into attosecond science, paving the way for investigating the ultrafast dynamics of systems with low ionisation energy such as neutral atoms, molecules, solids etc. The results also underscore the importance of the laser-driven semiconductor as a source for generating non-classical, massively entangled light states in the visible-VUV spectral region.

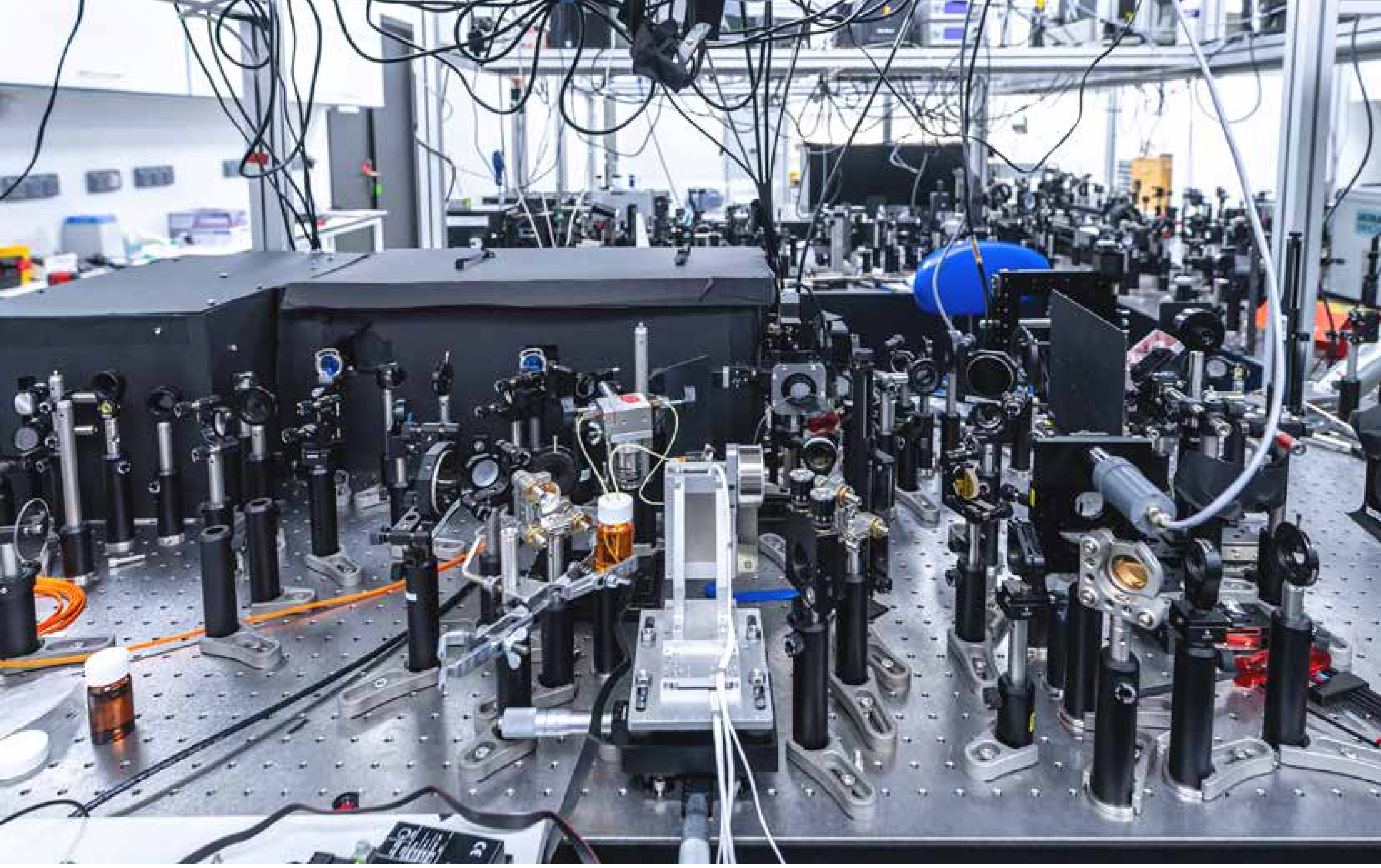
A Double-Slit Experiment in Time

The classical double-slit experiment illustrates that light (and matter) can satisfy the seemingly incompatible definitions of waves and particles (at the same time). In 1801 Thomas Young in illuminated two slits on an opaque screen, and an interference pattern appeared as a result on the screen behind it. This was the first demonstration of wave behavior of visible light. Similar measurements were performed with electrons, which manifested the principle of wave-particle duality, laying the foundations of modern physics.

In an experiment performed on the HR Condensed beamline of the ELI ALPS Facility, a scientific team led by Federico Vismarra (Politecnico di Milano/ETH Zürich) demonstrated a similar phenomenon with a little twist: instead of separating the two slits in space, they were created in different instants of time. Bound state electrons in noble gas atoms were promoted towards the continuum by an extreme ultraviolet (XUV) pulse, and an intense infrared field (IR) shifted up and down in energy the quasi-continuum trajectories. Electrons with the same kinetic energy could originate from two different time instants and could result in the appearance of an interference pattern, similarly to the classical experiment. This is called dynamical interference, which manifests as an interference pattern of the final photoelectron energy distribution (see Figure). The unique capabilities of the HR Condensed beamline enabled the successful observation of Laser-Assisted Dynamical Interference (LADI). This is the first experimental demonstration of this unique light-matter interaction regime in a two-color scheme.

The implications of this research will contribute to gaining a deeper understanding of this unexplored light-matter interaction regime. These first measurements will set the basis for future experiments in the field exploring for example dynamical interference in more complex targets, such as molecules or different quantum phases of matter.





Capturing Molecular Dynamics with Femtosecond Stimulated Raman Spectroscopy

When trying to understand the molecular mechanisms of life, techniques like electron microscopy and X-ray crystallography have enabled the visualisation of nucleic acids and proteins at the atomic level. However, these methods lack the ability to capture the dynamic processes of molecules. Femtosecond stimulated Raman spectroscopy is among the few techniques that can capture fingerprints of molecular dynamics at the timescale when actual chemical changes happen. Photoactive proteins, in particular, can be studied in great detail thanks to their property of being naturally photo-triggerable.

A recent experiment conducted at the ELI Beamlines Facility, explores the complex dynamics of rhodopsin proteins using FSRS. Rhodopsins are light-activated proteins that function as ion channels in cell membranes, making them crucial for neurological studies. The experiment revealed unexpected complexity in the early phase of the bestrhodopsin photoreaction.

The study reveals that when bestrhodopsin absorbs light, the retinal molecule inside undergoes multiple rapid transformations rather than a single change. The initial product, known as P682, forms within a trillionth of a second and consists of a mixture of two different shapes of the retinal molecule. These shapes continue to shift through a series of intermediate steps before stabilizing into a final form. Using femtosecond stimulated Raman spectroscopy, scientists were able to capture these incredibly fast changes, providing a detailed view of the molecular dynamics involved in the light-triggered process. This discovery highlights the intricate complexity of the protein's behavior and opens new avenues for understanding similar light-sensitive mechanisms in biology.

Understanding the intricate dynamics of rhodopsin proteins can advance the knowledge of vision processes and the development of optogenetic tools, which use light to control cellular functions. Furthermore, the ability to capture these dynamics at such a detailed level opens new avenues for studying other photoactive proteins and their roles in various biological systems.

Kaziannis, Spyridon, et al. "Multiple Retinal Isomerizations during the Early Phase of the Bestrhodopsin Photoreaction." Proceedings of the National Academy of Sciences, vol. 121, no. 12, 2024, e2318996121. DOI: 10.1073/pnas.2318996121.

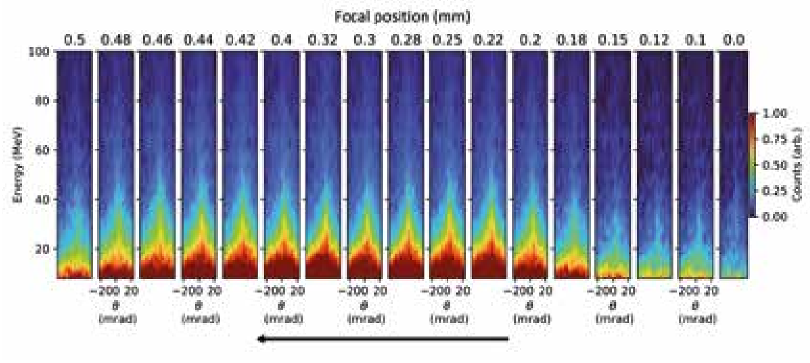
Acceleration of 50MeV Electron Beams at 10Hz in eSYLOS Beamline

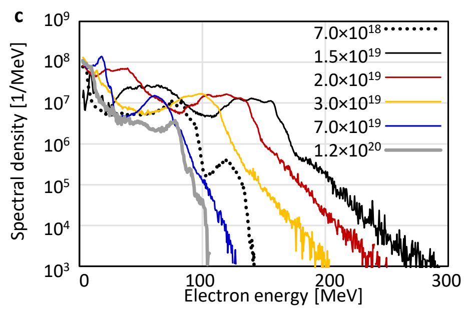
The eSYLOS beamline of ELI ALPS is a laser wakefield accelerator (LWFA) aims to provide 1 kHz relativistic electroan beams for various applications including radiation sciences (radiobiology, radiation chemistry and physics), ultrafast positron beam generation or generation of ultrafast x-ray radiation.

Commissioning of eSYLOS began using the SEA (SYLOS Experimental Alignment) laser system, which delivers 40 mJ pulses of 12 fs duration. As a next step the team is working on integrating the SYLOS3 laser system, capable of delivering 120 mJ pulses of 8 fs duration at a 1 kHz repetition rate.

Driven by the SEA laser system, eSYLOS generated electron beams with energies up to 50 MeV at 10 Hz repetition rate, with only a few-mrad beam divergence angle and approx. 2 pC of charge per shot. The production of electron beams was highly sensitive to the focal position of the laser relative to the gas target. Experiments demonstrated that adjusting the laser focal point relative to the gas cell entrance significantly influenced the electron beam energy spectra, with electrons reaching energies up to 50 MeV.

Three-dimensional Particle-In-Cell simulations predict that driving eSYLOS with the SYLOS3 laser system could produce electron beams with energies up to 300 MeV at 1kHz repetition rate. Achieving this would place eSYLOS amongst the world's most powerful laser-driven plasma accelerators. Potential applications would have a significant impact in areas such as radiotherapy, micro-computed tomography and X-ray imaging etc.





[Left] eSYLOS Electron beam energy spectra for various longitudinal positions of the laser focus with respect to the gas target entrance. Beams are observed in eSYLOS beamline driven by SEA laser at 10 Hz. Each spectrum is averaged over 200 shots. [Right] 3D simulations of electron beams driven by the SYLOS3 laser, with peak energies above 100 MeV Daniel Papp et al 2021 Plasma Phys. Control. Fusion 63 065019
DOI 10.1088/1361-6587/abf80d

L3 HAPLS Laser offers unmatched opportunites in Laser Plasma Acceleration on ELBA

The L3 HAPLS (High-repetition-rate Advanced Petawatt Laser System) is a significant advancement in laser technology. Developed at Lawrence Livermore National Laboratory, the L3 HAPLS is redefining the landscape of laser plasma acceleration with its unparalleled capabilities.

The system, designed to deliver petawatt (PW) pulses of about 30 joules in less than 30 femtoseconds at a 10 Hz repetition rate. Featuring a state-of-the-art pump engine with a 200 J design pulse energy it utilises two Nd-doped glass amplifiers cooled by helium gas. The amplifiers are powered by the world's highest peak-power pulsed laser diode arrays, each providing 800 kW peak power. This makes the L3 HAPLS a leader in high-power laser systems, currently capable of delivering 0.4 PW peak power pulses on target at a repetition rate of up to 3.3 Hz. These capabilities are offered to the user community through the excellence-based access, also taking advantage of dedicated target areas and secondary sources (electrons and ions) based on the interaction of relativistic intensity laser pulses with under-critical and over-critical density plasma (gas and solid targets, respectively).

The system achieved acceleration of GeV-class electron bunches at up to 3.3 Hz on ELBA (Electron Beamline for fundamental science) in a collaborative effort with an international teams. The experimental run was conducted in the framework of a user-assisted commissioning with teams from Queen's University Belfast (UK), University of Michigan (USA), and Kansai Institute for Photon Science (Japan). ELBA is designed to enable users to carry out relativistic electron-laser collision experiments fully exploiting the high-repetition rate capability. The experimental campaign demonstrated that the L3 HAPLS laser system can sustain high-power operations for a net time of 67-hours (maintenance free) delivering over 60 thousand shots on target in 15-days.

Previously, L3 HAPLS demonstrated its technical prowess by driving the ELIMAIA (ELI Multidisciplinary Applications of laser-Ion Acceleration) beamline, accelerating protons to energies up to 40 MeV at a 0.5 Hz repetition rate through the interaction of ultrahigh intensity pulses (>3×10^21 W/cm2) with thin foil targets. These achievements pave the way for a variety of scientific applications and exploration both for fundamental science and societal applications.

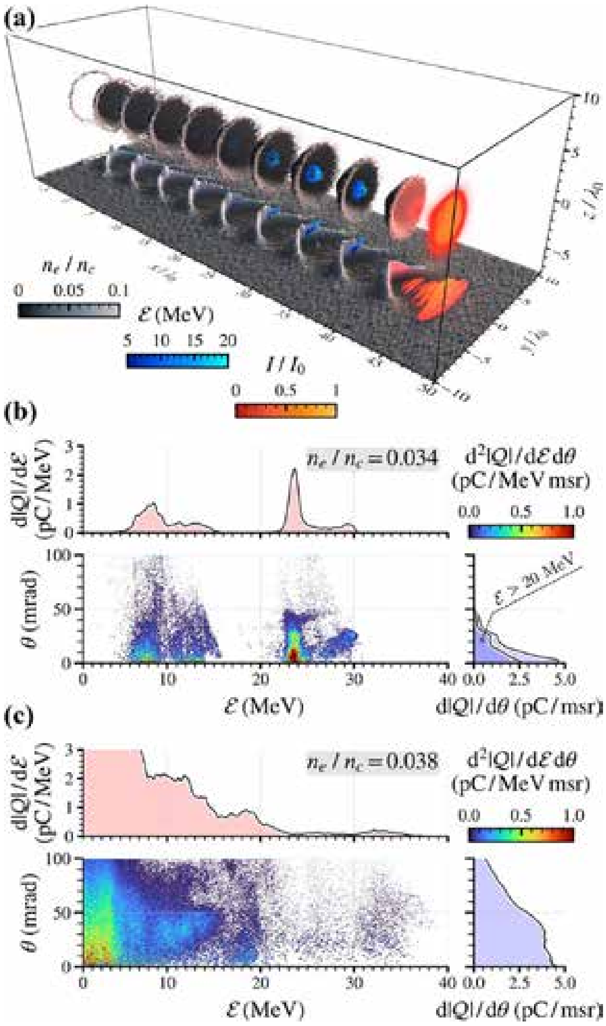
High-Energy Electron Beams Accelerated by Scalable kHz Laser Technology

The ALFA beamline at the ELI Beamlines Facility has achieved the generation of ultrarelativistic electron beams with energies up to 50 MeV using a high-repetition rate (1 kHz) laser system. This has significant implications for medical imaging and beyond.

Using the L1 Allegra system, a state-of-the-art laser employing optical parametric chirped pulse amplification, the experiment achieved unparalleled control and quality in electron beam production. The laser system, capable of delivering multi-cycle pulses (15 fs duration at 820 nm wavelength) at 1.7 terawatts, played a pivotal role in obtaining the most energetic and collimated electron beams recorded at such a high repetition rate.

The experiment utilised a novel mix of helium and nitrogen gases to optimise the conditions for electron acceleration at lower densities, enhancing the beam's energy and focus. This setup allowed the team to push the boundaries of current technology, suggesting the potential for future enhancements that could see electron energies scaled up even further.

The collaborative experiment between ELI Beamlines, the Czech Technical University, Charles University, and the Kansai Photon Science Institute showcases the importance of laser-driven wakefield acceleration (LWFA) technology in advancing the capabilities of electron accelerators. By achieving a kHz repetition rate further enhances the practicality and stability of these sources, making them increasingly viable for a range of applications that benefit from high repetition rates. Such capabilities are expected to revolutionise applications offering more compact and efficient alternatives to traditional radio-frequency acceleration methods.



C. M. Lazzarini Physics of Plasmas 2024; DOI 10.1063/10.0025639

Cutting-edge Radiobiology with Laser-Driven Ion Beams

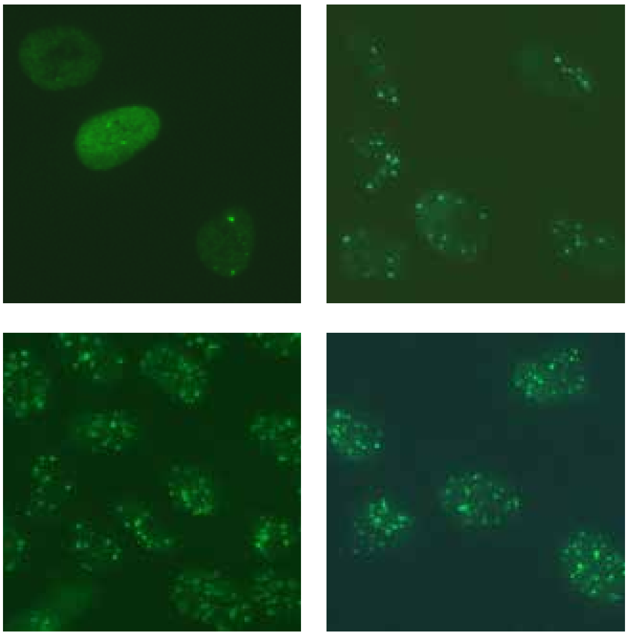
A ubiquitous application of high-power lasers and a driving force of ELI, particularly ELI Beamlines, is the generation of secondary particle and radiation sources. Proton and ion acceleration are particularly interesting for biological and medical applications. The FLAIM (Flash and ultrahigh dose-rate radiobiology with Laser Accelerated Ions for Medical research) experiment explores this and is the first case of a biological sample being irradiated by ions at ELI Beamlines.

"Our goal was to study the biological response of cells to ultrashort ion bursts unique to the laser-driven sources at ELI Beamlines, and understand how oxygen presence affects ultra-high dose rate radiobiology," explains Professor Marco Borghesi from Queen's University Belfast.

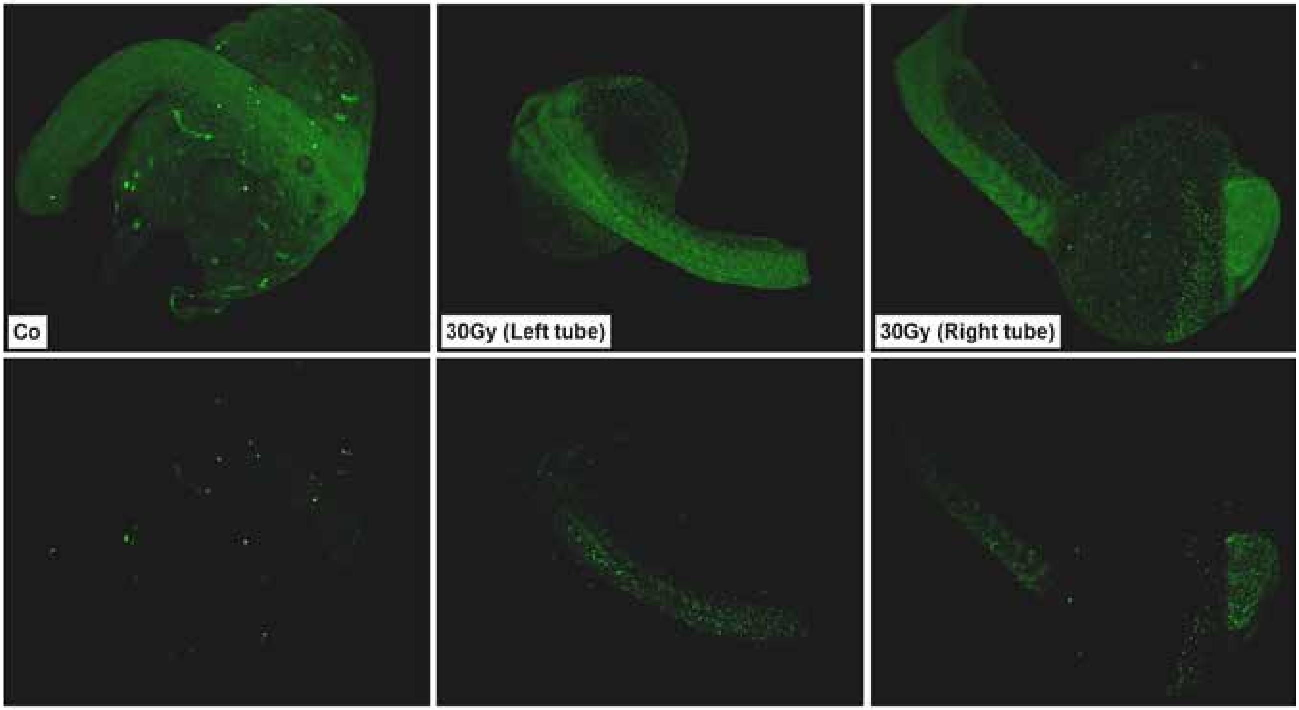
The experiment used the L3 HAPLS laser-driven ELIMAIA ion acceleration beamline and ELIMED ion transport section. The preparatory phase involved characterising the ion beam and transporting 20 MeV protons through a kapton window to the experimental point. The primary biological sample used in this study was AG01522, a type of normal skin fibroblast. These cells were cultivated in a monolayer on a 3 μm mylar foil within a stainless-steel dish, designed for hypoxia experiments. The cell samples were positioned at the endpoint of the ELIMED beamline, accompanied by Radio Chromic Ffilms for dose measurement and an Ion Current Transformer (ICT) for real-time ion current measurement.

Preliminary data analysis revealed that irradiated cell samples showed significantly more DNA damage, indicated by double strand breaks (DSBs), compared to control samples. This suggests a substantial impact of laser-driven ion pulses on cellular DNA, with further analysis expected to provide detailed insights into the extent and nature of the damage.

FLAIM is a flagship experiment of ELI, supported by the EU funded IMPULSE project, involving Queen's University Belfast, INFN-LNS, Naples University, Nuclear Physics Institute CAS, Laboratory of Immunotherapy CAS, ELI ALPS, ELI-NP, and ELI Beamlines. The experiment advances the application of high-power lasers for medical research, in the field of cancer therapy, demonstrating the potential of ultrahigh dose-rate laser-driven ion sources in studying and treating biological systems.



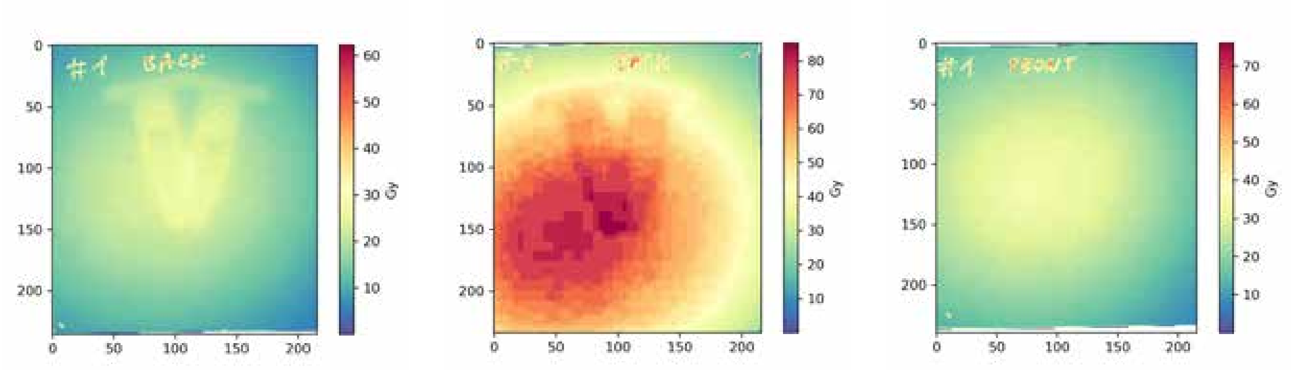
Innovative In Vivo Radiobiology Using Zebrafish Embryos



As advancements in oncology progress, the effectiveness of diagnostic tools and therapeutic methods continues to improve. Radiotherapy remains a cornerstone of cancer treatment, with innovative techniques showing promise. At ELI, laser-driven particle beams are used to refine these therapies.

The experiment performed as part of the excellence-based access was led by a team from ELI ALPS and perfomed on ELI Beamline's ALFA, a laser plasma electron accelerator. The objective of the study assesses the effects of laser-driven electron irradiation on zebrafish embryos at varying doses, comparing these effects to conventional LINAC-based electron irradiation.

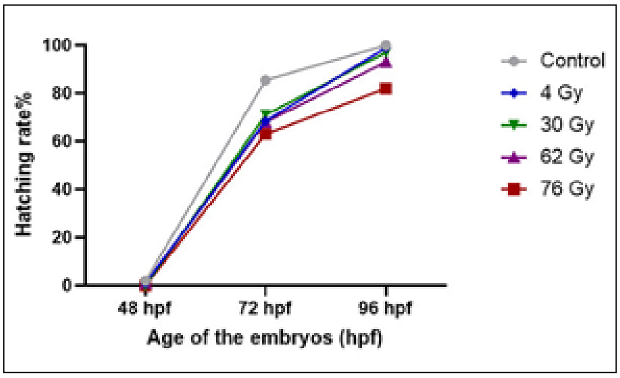
Zebrafish embryos were selected for this study due to their transparency, rapid reproduction, and ease of observation. The experiment revealed several critical findings that offer insight into the biological effects of electron irradiation. Survival rates were found to decrease in a dose-dependent manner, underscoring the importance of precise dosing in radiotherapy to balance effectiveness and safety. Hatching rates were also affected, with higher doses resulting in delayed hatching times. This suggests a clear dose-response relationship where increased radiation exposure disrupts the normal development timeline of the embryos. Morphological assessments showed significant deteriorations at higher doses. Embryos exposed to these higher levels of radiation exhibited reduced body length and smaller eye diameter, along with increased spine curvature and pericardial edema. These physical changes highlight the detrimental impact of high-dose radiation on the developmental processes. The experiment also

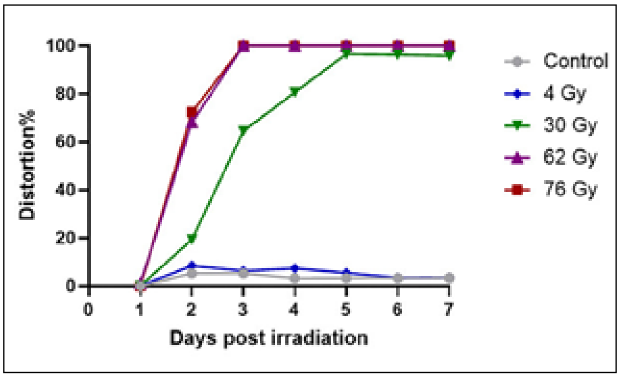


demonstrated increased apoptosis, or programmed cell death, at higher doses. On a molecular level, the study found that higher doses of irradiation caused significant DNA damage, particularly in the form of double-strand breaks (DSBs). This molecular disruption showcases the extent of damage that high-dose radiation can inflict on cellular structures.

This benchmark experiment successfully established the conditions for biological sample irradiation and demonstrated the dose-dependent biological effects of electron irradiation on zebrafish embryos. The findings provide valuable data for further research in radiobiology.

The research aims to develop universal measurement and parameterization methods applicable across various settings, contributing to more tailored and effective radiotherapy treatments.





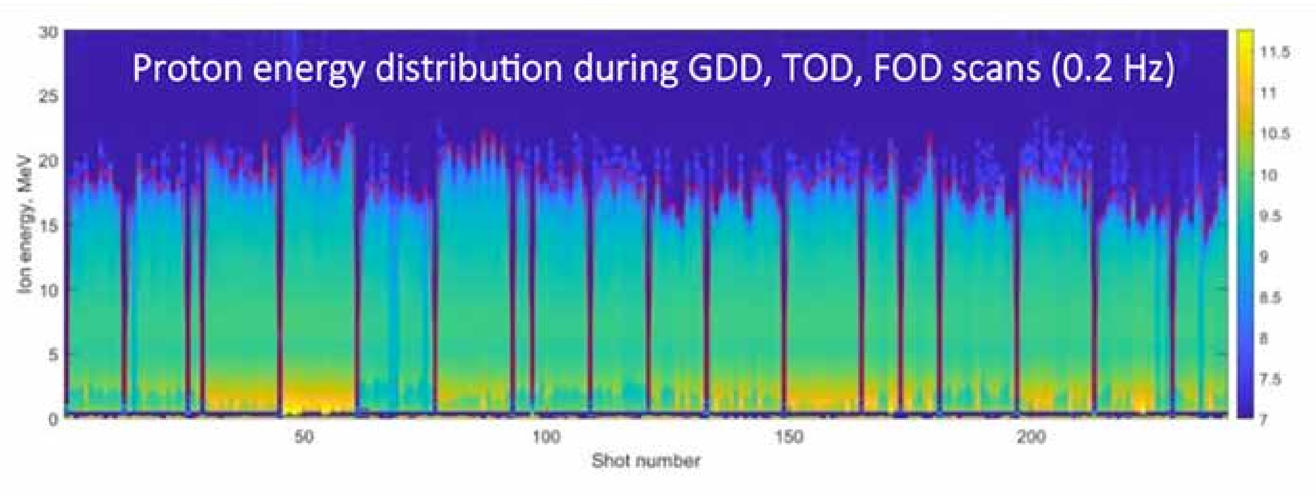
Harnessing Machine Learning for Breakthroughs with High-Power Lasers

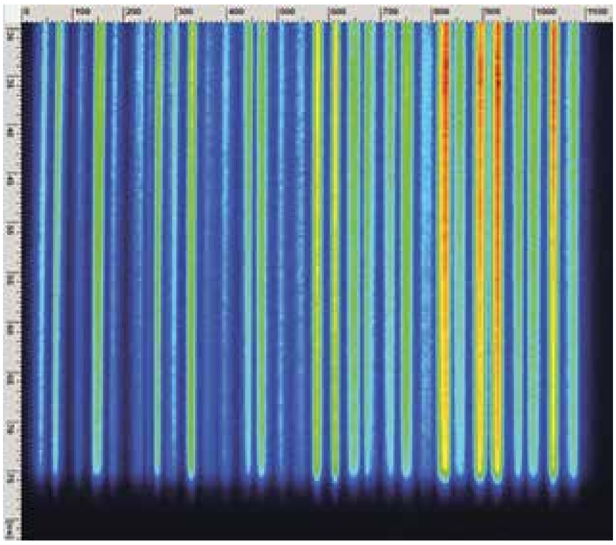
A team of international scientists from Lawrence Livermore National Laboratory (LLNL), Fraunhofer Institute for Laser Technology ILT, and ELI collaborated on an experiment to optimise high-intensity high-repetition rate laser technology using machine learning. The experiment represents a significant leap forward in the study, understanding, and practical application of high-intensity lasers.

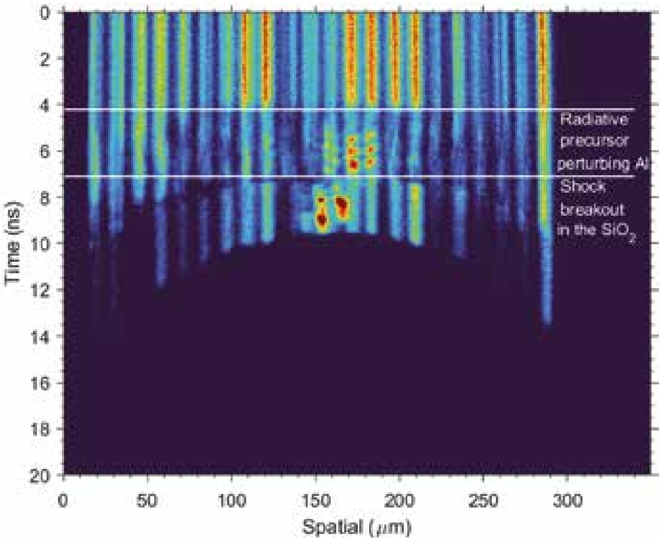
"Our goal was to demonstrate robust diagnosis of laser-accelerated ions and electrons from solid targets at a high intensity and repetition rate," explains Matthew Hill of LLNL, the lead researcher. "Supported by rapid feedback from a machine-learning optimisation algorithm to the laser front end, it was possible to maximise the total ion yield of the system."

Over 4000 shots fired during the campaign, which consistently exceeded laser intensities of 3x10^21 W/cm² onto solid targets, demonstrated optimisation of ion yield above the nominal baseline performance. The experiment utilised the state-of-the-art High-Repetition-Rate Advanced Petawatt Laser System (L3 HAPLS) to generate protons in the ELIMAIA Laser-Plasma Ion accelerator. The L3 HAPLS laser is renowned for its laser performance repeatability, precision, beam quality, and the ability to generate intense laser pulses at a high repetition rate to drive the generation of secondary sources such as electrons, ions, and x-rays. The unprecedented shot-to-shot repeatability of L3 HAPLS allows scientists to focus on the understanding of laser-plasma interaction physics.

The coupling of state-of-the-art laser technology with machine learning has opened new avenues for advancements in various fields such as medical therapy, materials science, and non-destructive analysis in the field of cultural heritage and archaeology. The collaborative effort is a significant milestone for ELI and the wider high energy density science community.







Mimicking Planetary Interiors and Synthesizing Nanodiamonds: Advances in Shock-Compressed Plastics

The exploration of laser-driven shocks in solid targets is a fundamental aspect of High-Energy Density Physics (HEDP), with critical applications in Inertial Confinement Fusion (ICF) and laboratory astrophysics. These studies replicate planetary interiors, enhancing our understanding of solar system formation and Earth's core.

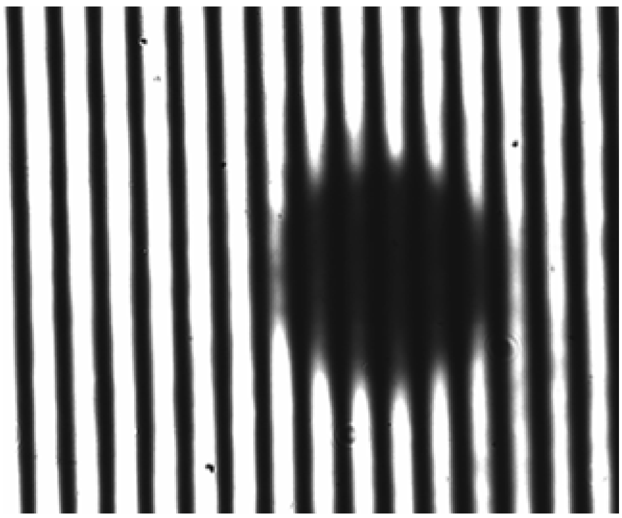
The L4n beamline at ELI Beamlines enables experiments at an unprecedented repetition rate of one shot every three minutes, a significant improvement over the typical hourly frequency at other facilities. Awarded as part of the excellence-based access, the project is also selected as a Flagship experiment supported by the IMPULSE project.

Essential diagnostic tools, developed in cooperation with SLAC-MEC (Stanford, California), include the Velocity Interferometer System for Any Reflector (VISAR) and the Streaked Optical Pyrometer (SOP). These tools are crucial for measuring shock velocities, pressures, and temperatures under extreme conditions.

In the experiments, the temporal characteristics of the driven shock are recorded. When the laser hits the target, the material properties suffer dramatic changes due to the extremely high-pressures (> Mbar) induced by the laser pulse.

The experiment led by Prof. Dominik Kraus of the University of Rostock, demonstrated the beam's delivery to multi-layer targets (one shot every three minutes). A high-repetition rate tape target system was installed to observe the generation of nanodiamonds, a phenomenon requiring substantial statistical data. The initial phase involved 520 high-energy shots (exceeding 200J at 1w) over 12 days, with a peak of 133 shots in a single day. The L4n beamline's capabilities allows for significant progress in understanding shock-compressed materials.

Above (Left) VISAR fringes reference before a shot (50ns time window)
(Right) VISAR image of a 75μm CH / 8μm Al / 50μm SiO_2 shocked by a 1.88ns flat-top pulse. A 500μm Gaussian profile DPP is used, explaining the breakout shapes. The laser energy on target is 240J. (20ns time window)



40um pinhole placed at TCC and imaged by one of the interferometer diagnostics setup.

Unveiling the Mysteries of Plasmons

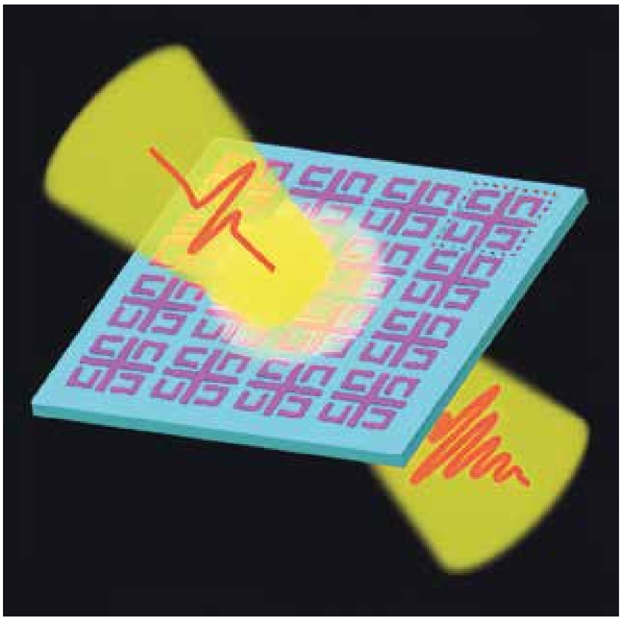
An experiment performed on the NanoESCA endstation of ELI ALPS provided new insights into the intricate dynamics of plasmon excitations in graphite. Using advanced attosecond laser pulses, a team lead by Alessandra Bellissimo, a solid-state physicist from the Vienna University of Technology, investigated the behavior of inelastically scattered electrons, aiming to resolve the dynamics of photoemission events and understand the fundamental processes governing electron interactions in solid surfaces.

The experiment explores the world of plasmons—collective oscillations of electrons in a material that can profoundly affect its electronic properties. Graphite was chosen for its well-known electronic structure and relevance to modern technological applications. The goal was to uncover the details of the formation, evolution, and disruption of plasmon interactions by examining photoemission events at various high symmetry points in the valence band of graphite

The research is poised to make significant contributions to the field of plasmonics, with potential applications in energy-harvesting photovoltaic devices and advanced optical technologies. By understanding the fundamental processes underlying plasmon excitations, scientists can develop new materials and devices that harness these effects for practical applications.

The experimental results not only advance our understanding of plasmons but also exemplifies how the world-class research infrastructures of ELI can be leveraged to explore new questions in solid-state physics. The success of this experiment was made possible through the collaborative efforts between the research team and facility staff and highlights the importance of shared resources and expertise in advancing scientific knowledge. The work promises to inspire future discoveries and technological advancements, solidifying ELI ALPS' position at the forefront of laser physics research.

Terahertz Self-induced Dynamic Slow-light Behaviour in Metasurfaces



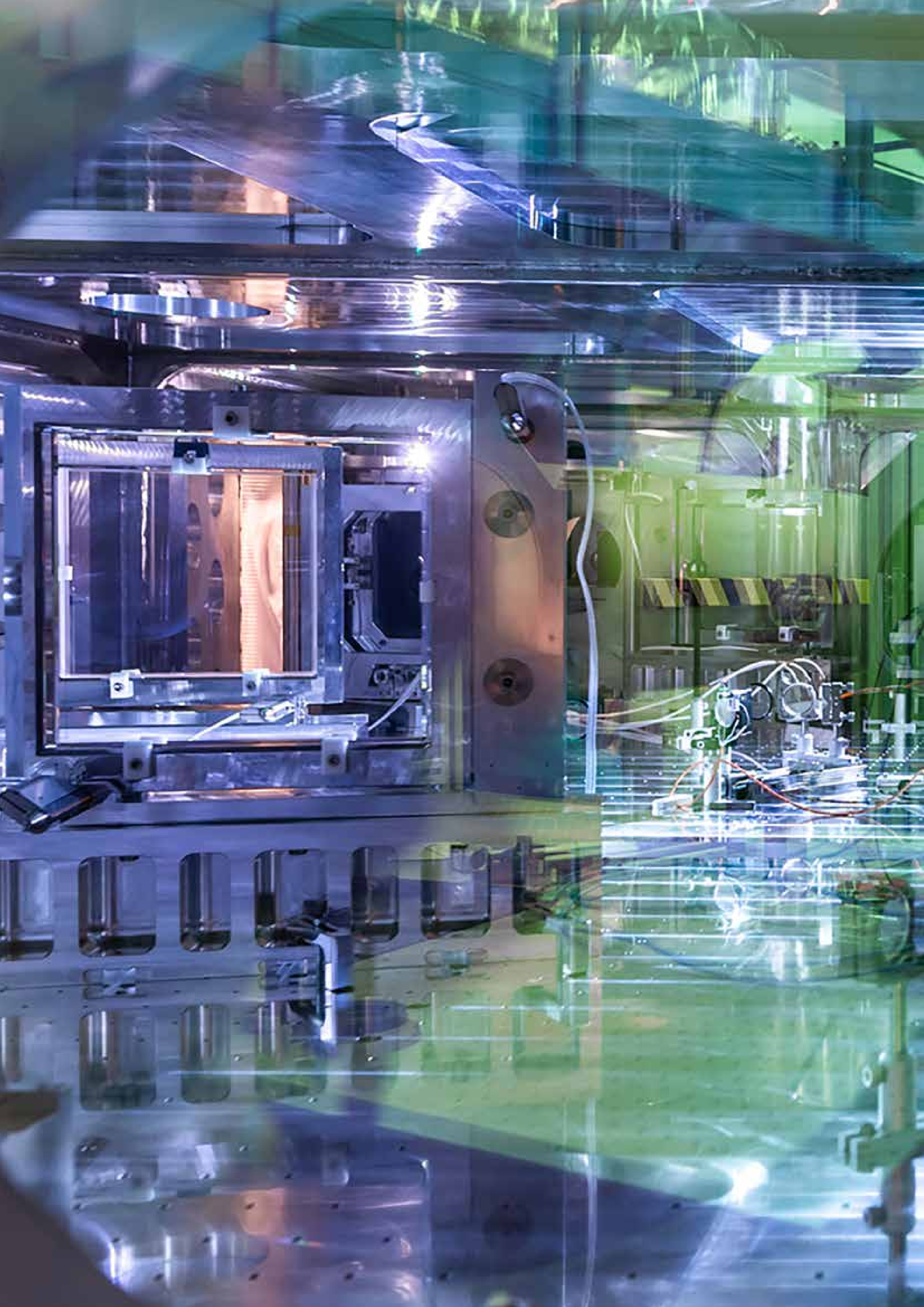
Metamaterials are artificial photonic structures with component dimensions much smaller than the wavelength of the electromagnetic radiation they are designed to interact with. They resemble artificial photonic materials with engineered properties such as negative index, self-focusing, cloaking, etc., which cannot be found in natural materials. Metasurfaces are two-dimensional metamaterials, working on the principle of introducing engineered abrupt phase changes, which can be used to build very compact and versatile devices. Typical wavelengths of terahertz (THz) radiation are on the 100 µm scale, and metasurfaces with precisely controlled geometry can be constructed on this scale.

The Nonlinear Terahertz Spectroscopy Facility (NLTSF) of ELI ALPS enables THz pump—THz probe measurements up to 0.5 MV/cm peak electric field. An experimental team lead by D. Roy Chowdhury from Mahindra University, Hyderabad, India performed an experiment exploring the nonlinear response from metal-on-silicon metasurfaces upon exposing them to intense single-cycle THz pulses.

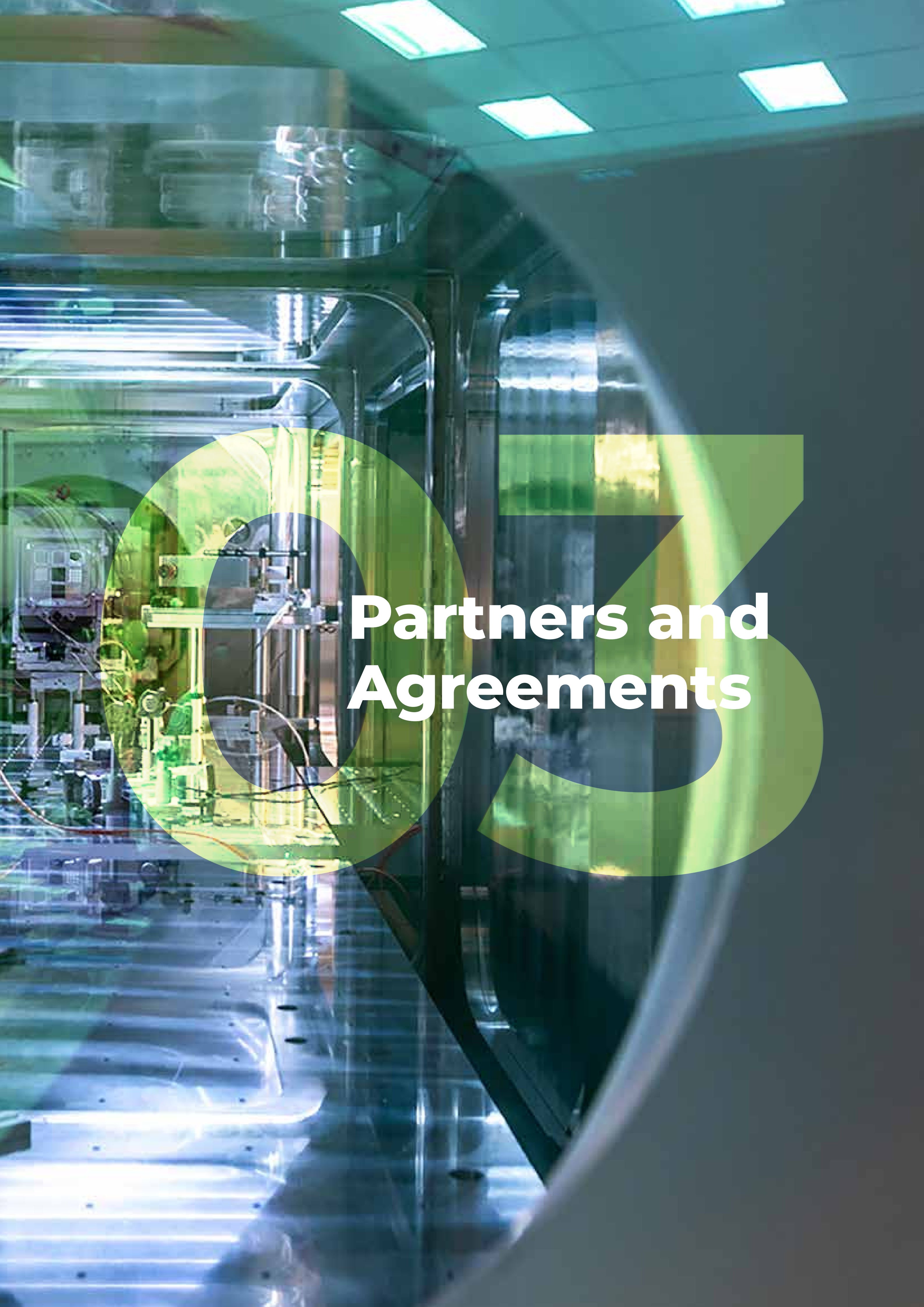
Dynamically reconfigurable metasurfaces have emerged as a practical platform to manipulate THz radiations, despite being complex and difficult to realise because they require exotic materials and external stimuli. This experiment demonstrated a simple metal-on-silicon metasurface framework to achieve reconfigurability that is exempted from such complexity. The plasmonic metasurface very strongly localises and enhances the THz field. The intense THz transient modifies the conductivity of the resistive substrate through impact ionization. Through nonlinear self-action, this results in dynamically tuneable electromagnetically induced transparency (EIT) effect. Such dynamic tuning of EIT enables the self-induced control of the slow-light characteristics, with a modulation of the group-delay and the group-velocity by more than 6 times.

The experiment demonstrated for the first time the self-induced control of the slow-light characteristics by utilising THz-driven impact ionization in the substrate. Dynamically tuneable compact devices, based on the demonstrated metasurface framework, can enable versatile applications in future 6G communications and on-chip silicon-based integrated photonics.

S. Mallick, N. Acharyya, V. Gupta, S. Rane, K. M. Devi, A. Sharma, J. A. Fülöp, D. R. Chowdhury, "Terahertz self-induced dynamic slow-light behaviour in metasurfaces," submitted.



03 Partners and Agreements



ELI's Partnerships and Collaborations

Scientific research thrives on collaboration. The exchange of ideas across disciplines speeds up discoveries, and enhances the collective impact of diverse expertise. In today's interconnected world, where scientific challenges are increasingly complex, collaboration is indispensable for research facilities like ELI. It enables scientists to combine resources, share innovative ideas, and address significant challenges that would be impossible to tackle alone. ELI is committed to fostering a collaborative environment with a wide range of partners.

Cooperating with strategic partners and growing the ELI ERIC member base is also crucial for the long-term sustainability of the organisation. Engaging potential new Member and Observer countries and cooperation with partners enables the diversification of activities and funding ensuring continuous support for ELI's research initiatives and strengthening its position as a leading international R&I organisation.

Revolutionising Muon Imaging with High-Power Lasers

The ability to peer into structures as dense as nuclear reactors and ancient pyramids is being transformed by an innovative project called Intense and Compact Muon Sources for Science and Security (ICMuS2), led by Lawrence Livermore National Laboratory (LLNL). Funded by the U.S. Defense Advanced Research Projects Agency's Muons for Science and Security Program, this initiative is set to enhance muon imaging, traditionally limited by the slow accumulation of naturally occurring muons.

Muon imaging uses muons—subatomic particles similar to electrons but 200 times heavier—to penetrate and image objects up to 30 meters thick, a task impossible for x-rays. However, the natural flux of muons is so low that capturing useful images can take months. ICMuS2 aims to change this by rapidly generating muons with high-power lasers, significantly speeding up the process.

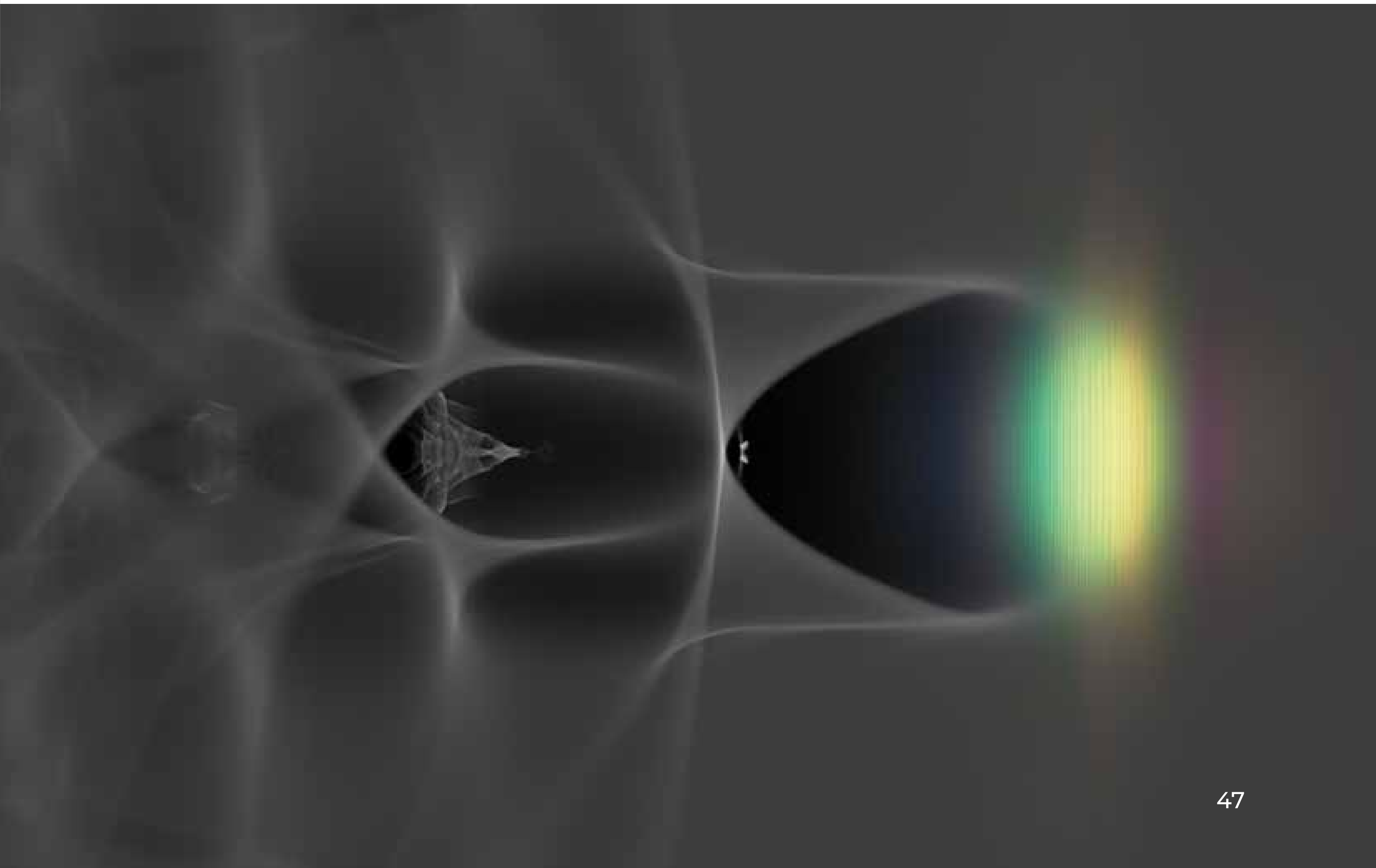
The project is a collaborative effort with industry and academic leaders, utilising the world-class L4 ATON 10 PW laser system at the ELI Beamlines Facility. This laser, one of the world's most powerful, is ideally suited for creating the extreme conditions necessary for laser wakefield acceleration (LWFA), a method that promises to generate electron energies as high as 100 GeV—optimal for muon production.

ICMuS2 project is distinguished by its comprehensive approach, which merges high-power laser development, high-energy particle physics, plasma physics, and advanced numerical simulations. The initial experiments will utilise plasma waveguides developed at the University of Maryland and conducted at Colorado State University's Advanced Laser for Extreme Photonics facility.

A team of world leaders in the fields was assembled to meet the ambitious goals of DARPA's MuS2 Program. The multi-faceted project combines their expertise to push the boundaries of what is possible with muon imaging.

This strategic advancement not only extends scientific frontiers but also bolsters the collaboration between ELI and its US partners, fostering a dynamic environment for knowledge exchange and innovation.

As the project moves from proof-of-principle experiments to the demonstration of high-energy muon production, it continues to showcase the potential of international cooperation in high-stakes scientific research, enhancing both national security and scientific discovery.



The EuPRAXIA Project: Spearheading Plasma-Based Particle Accelerators

The EuPRAXIA project is set to revolutionise particle accelerator technology by developing the world's first GeV plasma-based accelerator. The project aims to bridge the gap between conventional particle accelerators and next-generation laser-driven plasma accelerators, promising compact, cost-effective solutions for widespread use in industry and medicine.

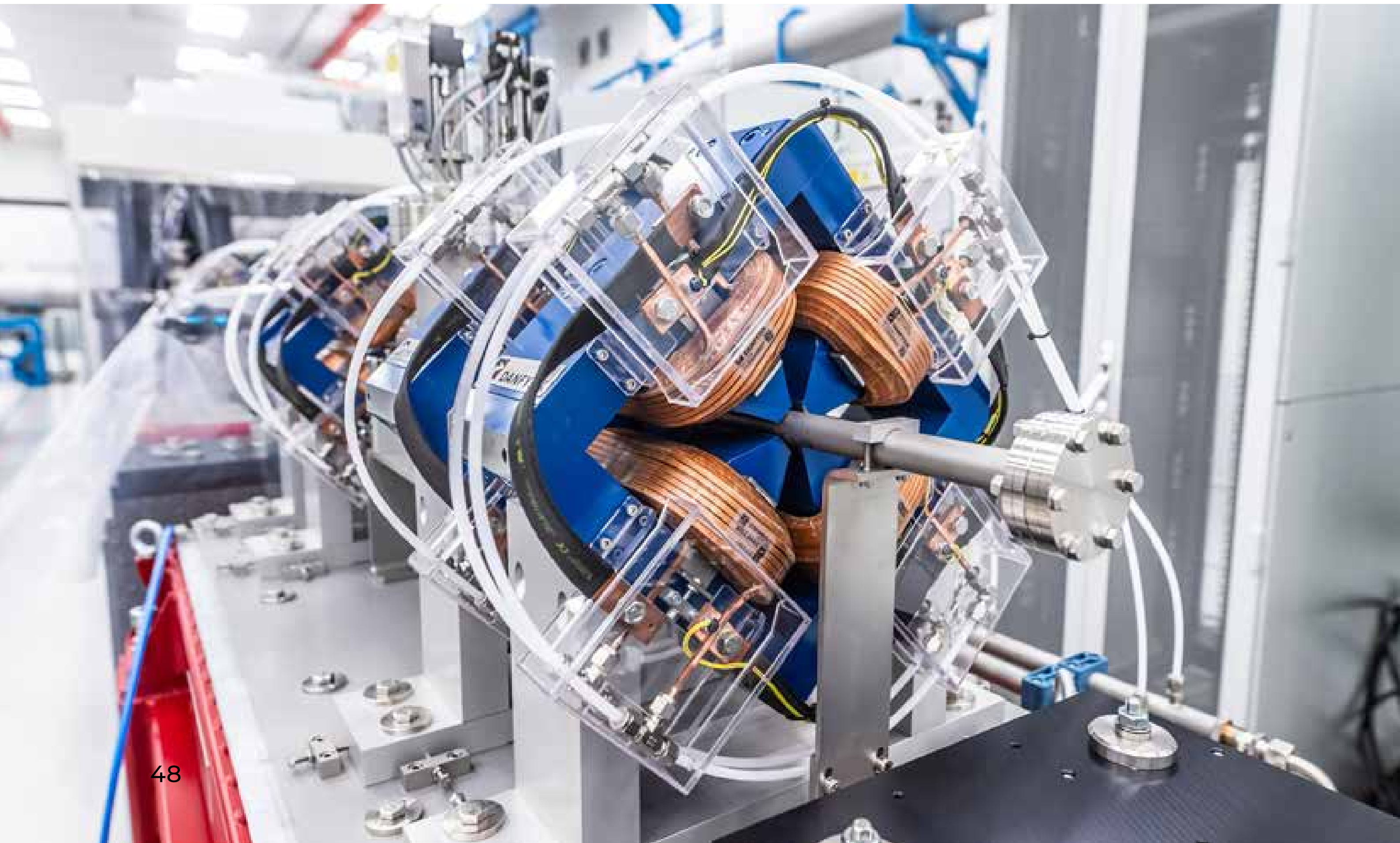
Particle accelerators are fundamental in various sectors, from scientific research to medical applications. However, traditional accelerators are often large and costly, limiting their practicality and accessibility. The EuPRAXIA project, involving multiple European research sites and coordinated in Frascati, Italy, seeks to leverage advancements in Laser Wakefield Acceleration (LWFA) and Plasma Wakefield Acceleration (PWFA) technologies to create more accessible accelerators.

The proposed plasma-based accelerators aim to drastically reduce the size and cost of current systems. These accelerators could be up to 1,000 times more efficient, reducing the need for kilometer-long facilities to something that could fit within a standard laboratory space. This dramatic reduction is made possible by using plasma rather than conventional radiofrequency technology to accelerate particles, which allows for much higher acceleration gradients.

EuPRAXIA's goal is to develop a 1 to 5 GeV accelerator with a footprint of about 250 meters, making it feasible for installation in smaller industrial and medical settings. Such accelerators could change cancer therapy with more accessible radiation treatment options and support high-impact engineering and manufacturing processes. The project is backed by a consortium, including major European research centers and significant EU funding.

The ELI Beamlines Facility in the Czech Republic is considered a potential site for the laser-driven plasma acceleration facility, leveraging its existing infrastructure and technological capabilities. The integration of this facility would enhance ELI's role in global scientific and technological developments.

With operations expected to begin by 2028 for the electron-driven facility and the laser-driven facility planned for later, EuPRAXIA is on track to becoming a pivotal element in the future of particle acceleration technology. This project not only promises to enhance scientific research and industrial applications but also sets the stage for new medical technologies that could change the landscape of healthcare and treatment methodologies worldwide.



ELI's Strategic Initiatives in Laser-driven Fusion and ICF Research

In its pursuit of excellence and innovation, ELI is not only offering open excellence-based access but is also actively advancing several mission-based projects. Among these, Laser-driven Fusion (LDF) is a key focus. This initiative is supported by the German Ministry of Education and Research (BMBF),

To launch this activity a comprehensive LDF workshop held on 28-29 November 2023. The workshop brought together over 100 experts from academia, industry, and leading research institutes to forge paths in Laser Fusion Energy (LFE). The primary goal of the gathering was to address the pivotal challenges in harnessing laser technology for energy production and to define ELI's role in advancing LDF within Europe and beyond. The discussions focused on enhancing ELI's high-power laser capabilities to better suit Inertial Confinement Fusion (ICF) research, with a vision of developing new laser structures and target materials that could significantly improve laser fusion yield.

A short-term action plan was established, prioritising the development of a cohesive science programme across ELI's facilities, which will focus on high-intensity laser-plasma interactions crucial for particle acceleration and High Energy Density (HED) science. This plan includes launching a thematic 'Mission' call to integrate efforts and to refine ELI's existing technological frameworks to support advanced LDF research.

In the longer term, ELI aims to address the skills shortage in Europe by initiating international training programmes in partnership with academic and industrial entities. This will not only strengthen expertise in high-power laser applications but also bolster ELI's technical offerings, particularly through the P3 high energy density physics platform and the L4n laser at ELI Beamlines, the HF laser system at ELI ALPS, and the dual 10-PW system at ELI-NP.

These strategic dialogues and partnerships highlight ELI's potential for becoming a central hub for LDF research by leveraging its advanced laser technologies and collaborative network. This effort is expected to lead to significant advancements in clean energy production, a venture beyond the capacity of any single European country or company.

Project information

Project acronym: IMPULSE

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

Grant Agreement number: 871161

Beginning of project: November 2020

End of project: April 2024

Total budget: ~ 20,000,000 EUR

Website: **impulse-project.eu/**

The Extreme Light Infrastructure (ELI) has transitioned from construction into sustainable operations enabled by the IMPULSE (Integrated Management and Reliable Operations for User–based Laser Scientific Excellence) project. The nearly 20 million EUR project, funded by the European Union's Horizon 2020 program, fostered key scientific and technological advancements, and core missions for ELI, including the integration of the Facilities and the establishment of the user access programme.

The completion of the 42-month IMPULSE project not only facilitated high-quality scientific activities but also paved the way for future research that leverages the unique capabilities of the ELI Facilities. The project's conclusion heralds continued innovation and collaboration in close cooperation with a network of 14 partners from 9 countries.

The support from the European Commission was instrumental for the integration of the ELI ERIC Facilities under a unified governance and single management structure, for their joint operations according to standardised practices across the organisation, and for launching ELI's joint user programme, together with ELI NP. The project provided an avenue for cooperation between the ELI Facilities and key laser research institutes in Europe.

In terms of outreach, IMPULSE facilitated more than 250 activities during the project period in total: 23 conferences and 18 workshops organised, participation in 64 scientific conferences, 15 exhibitions, and 10 trade fairs, more than 20 pitch events organised reaching countless number of people in person and online,

The IMPULSE project may have reached its conclusion, but the shared activities will continue to shape the landscape of high-power laser science in Europe. As the project's efforts unify the ELI Facilities, it promises to enhance the scientific discourse and foster innovation. The collaborative spirit ignited by IMPULSE is set to persist, amplifying the project's impact well beyond its scope. and nurturing future cooperation.

“While IMPULSE is coming to an end the momentum will propel ELI for the future”
Prof. Zeyrek, Expert reviewer

IMPULSE PROJECT

ELI ERIC	(Extreme Light Infrastructure European Research Infrastructure Consortium)
ELI ALPS	(ELI-HU Kutatási és Fejlesztési Nonprofit Közhasznú Korlátolt Felelősségű Társaság)
ELI-NP	(Institutul National De Cercetare-Dezvoltare Pentru Fizica Si Inginerienucleara-Horia Hulubei)
TUDA	(Technische Universitat Darmstadt)
STFC	(Science and Technology Facilities Council)
LMU	(Ludwig-Maximilians-Universität München)
CLPU	(Consorcio Para El Diseno, Construccion, Equipamiento y Explotacion Del Centro De Laseres Pulsados Ultracortes Ultraintensos)
CNR	(Consiglio Nazionale delle Ricerche)
ELETTRA	(Elettra Sincrotrone Trieste)
HZDR	(Helmholtz-Zentrum Dresden-Rossendorf)
IST	(Instituto Superior Tecnico)
INFN	(Istituto Nazionale di Fisica Nucleare)
QUB	(The Queen’s University of Belfast)
FORTH	(Idryma Technologias Kai Erevnas)

EU Projects & Grants

The European Research Infrastructure Consortium (ERIC) legal framework was introduced in 2009 to support the establishment and operation of large-scale European Research Infrastructures. The ERIC community has expanded in 10 years with 23 established ERICs. The variety and diversity of ERICs make them important players in European science excellence that respond to various societal challenges, which leads to groundbreaking scientific achievements in different domains. This supports science diplomacy, and creates bridges between research communities within Europe and worldwide.

The ERIC Forum implementation project ended in 2021 which was followed by the ERIC Forum 2 launched in 2023. ELI ERIC is a participating member and ELI ERIC Director General was elected as Vice-Chair in October 2022.

European network for developing new horizons for Ris The EU funded project EURIZON is about European scientific and technical collaboration in the field of research infrastructures (RIs), and it includes a special focus on coordination and support measures dedicated to support Ukrainian scientists and Ukrainian RIs as well as strengthening the RI landscape in Europe. The project promotes technology development and strengthening the RI landscape in Ukraine. The 26 European participants of the project have come together to build the broad and balanced consortium. They are the relevant entities in the domain of research infrastructures in Europe, and thus provide the necessary strength, commitment and power to implement the project plan.

Lasers4EU

Lasers4EU, the successor of the Laserlab-Europe project will launch 1 October 2024, ensuring that users can apply for transnational access projects on a large variety of scientific topics during the next five years. Lasers4EU's main objectives are to provide coordinated access to high-quality services based on a coherent and comprehensive consortium of 27 leading European laser installations offering to users from academia as well as from industry cutting-edge performances at the forefront of laser technologies. The project will also continue to structure the European landscape of laser Research Infrastructure through enhanced access, extended geographical coverage, novel science diplomacy activities, improved synergies with other European networks and projects and increase European human resources in the field of laser science by implementing training activities towards researchers from new domains of science and technology and from geographical regions where laser communities are still less developed.

IMPRESS is an EU-funded scientific project coordinated by CNR (Italy), which aims to revolutionise the field of transmission electron microscopy. This groundbreaking scientific project aims to advance the field of transmission electron microscopy (TEM) by co-developing and delivering new and sophisticated instrumentation, methods and tools, which will change how TEMs are used by both well established and new scientific communities. IMPRESS brings together 19 partners from 11 European countries, comprising scientists, companies, experts in the field of electron microscopy and research infrastructures, who will collaborate to address needs that are not yet satisfied by commercially-available electron microscopes. ELI ERIC is involved in a Pre-commercial procurement (PCP) procedure for the design, development and testing of an interoperable platform for TEM, the co-development of novel experimental techniques for in situ/operando/correlative using the study of laser induced phase transformations in materials used as photoconductive switches.

The THRILL (Technology for High-Repetition-rate Intense Laser Laboratories) project, funded by HORIZON EUROPE, aims at providing new designs and high-performance components for high-energy high-repetition-rate lasers, enabling the technical readiness level required to specify and build the needed devices. This work improves the performance, the energy efficiency and reliability in operation of such lasers at the partnering research institutions. Nine companies and research institutes participate in the project. The project is not only pushing technology, it is also offering an outstanding opportunity to train a qualified work force for RIs and industry. With this in mind, the structure of THRILL promotes synergies, fast transfer to industry and integrated research activities at the European level.

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

The 3-year FlexRICAN project, coordinated by ESS, has the ambitious goal of revolutionising energy consumption patterns within large research infrastructures across Europe. By harnessing the diverse expertise and resources of its partners, the project endeavours to develop sustainable energy solutions that will not only benefit the European grid but also local heating networks.

The RADNEXT (Radiation Facility Network for the Exploration of Effects for Industry and Research) project running from 2021 to 2025 aims to establish a coordinated network of irradiation testing facilities in Europe and streamline user access to them. The goal is to establish a unified entry point, enabling users to seamlessly define, prepare and conduct irradiation campaigns. RADNEXT brings together a diverse collection of irradiation testing facilities and expertise to address user needs for space and high-reliability ground-level applications, including automotive, medical and high-energy physics accelerators. RADNEXT facilitates high-quality user access to irradiation beams for academia and industry to advance research on radiation effects on electronics

STEFF

The STEFF (Strong-Field Electrodynamics in Flying Focus Pulses) project, coordinated by ELI ERIC, runs from 2023 to 2025. The initiative aims to conduct a theoretical investigation of charged particle behaviour in external laser fields using the flying focus regime, a laser field setup that allows precise control of the position and velocity of its focus. This regime enables adjustments of the laser focus so that it co-propagates with the particle, even when the particle is moving against the laser phase fronts. The resulting prolonged laser-particle interaction time, facilitated by flying focus pulses, is expected to significantly enhance radiation reaction, methods of particle beam control, and cumulative magnetic moment effects along the particle trajectories.

The PROton BOron Nuclear fusion: from energy production to medical applicatiOns project supports new studies on pB fusion. The project will aim at understanding the physics involved in the emerging topic of laser-driven pB fusion, facilitating access to experimental infrastructures, maximising production of new knowledge and achieving breakthrough discoveries, boosting career of young researchers by fostering opportunities for training, and finally interconnecting researchers across countries building a well-organised community focused on pB research.

LOW TOXICITY RADIOTHERAPY (LOTO)

The Low Toxicity Radiotherapy (LOTO) project aims to develop a novel irradiation device using laser-plasma acceleration for precise and low-toxicity cancer treatment. By delivering high-energy electrons, LOTO offers superior dose accuracy and real-time tumor tracking, minimising damage to healthy tissues. The project's preclinical phase involves testing the device on living cells and comparing its efficacy to conventional radiation sources. LOTO has the potential to revolutionise radiation oncology, providing highly effective and safe treatment options.

04 Innovation

Innovation at ELI

Innovation is at the heart of ELI's mission and sustainability is a key consideration in all ELI activities. ELI is committed to developing a sustainable innovation ecosystem that promotes cutting-edge research and fosters collaboration with industry partners. ELI ERIC's innovation ecosystem is designed to harness the full potential of its research capabilities and push the boundaries of scientific and technological innovation.

Strategic Innovation Management

To manage and oversee its innovation activities, ELI has established a comprehensive structure involving the ELI Innovation Board and the ELI Industry Panel. The Innovation Board is responsible for implementing innovation-related processes, such as funding schemes, proprietary access for industry, and technology transfer initiatives. The Industry Panel, an external advisory body, provides valuable feedback on the industrial impact of ELI's developments and suggests additional areas for growth. Together, these bodies ensure that ELI's innovation strategy remains aligned with industry needs and technological trends.

Innovation Processes and Industry Collaboration

ELI offers proprietary access to its state-of-the-art laser instrumentation and other scientific equipment. Collaborations with industry are critical for ELI, leading to the co-creation of new technologies and the identification of novel application areas. A concrete examples for this includes the activities around the Laser-driven Fusion Programme. ELI's evolving Industrial Liaison network also plays a key role in building partnerships with the industrial community across Europe and beyond. Under the IMPRESS project, ELI has embraced pre-commercial procurement practices to foster innovation and collaboration with industry partners.

Promoting Sustainability and Synergies

The ELI Facilities have integrated under a single legal entity to secure the sustainability of the initial investment. Operating as a unified organisation enables opportunities for technical synergies, sharing of standards and knowledge exchange. An extensive partner network and participation in a range of grants and collaborative projects contribute to mitigating the risk of operating state-of-the-art, high-power, high-repetition laser systems. ELI additionally implements several energy-saving measures across the organisation to further enhance sustainability.

Sustainability at ELI

Solar Park at the ELI ALPS Facility

The electricity needed to provide the constant temperature and humidity required in the experimental rooms accounts for a significant part of the operating costs at ELI. A construction of a solar farm which can provide around 40 percent of the annual electricity demand is foreseen to mitigate these costs. With this investment, ELI ALPS will benefit from a significant proportion of renewable energy. This is particularly relevant because Szeged is also known for the high hours of sunlight reported annually earning it the nickname “City of Sunshine”.

Solar panels will be installed on the surface of the one-hectare reservoir to the south of the main facility building, while the 0.45 hectare area to the south will be equipped with solar tracking elements. Solar panels will also be placed over the employee parking spaces. The highest output is expected from the solar system on the 3.2 hectare area to the north of the building. The total installed capacity will be 5 MVA.

The public procurement procedure has been completed and the plans have been drawn up. The energy grid connection contract was signed at the end of 2023, and the building permit was issued in May 2024. Construction of the will start in summer 2024.

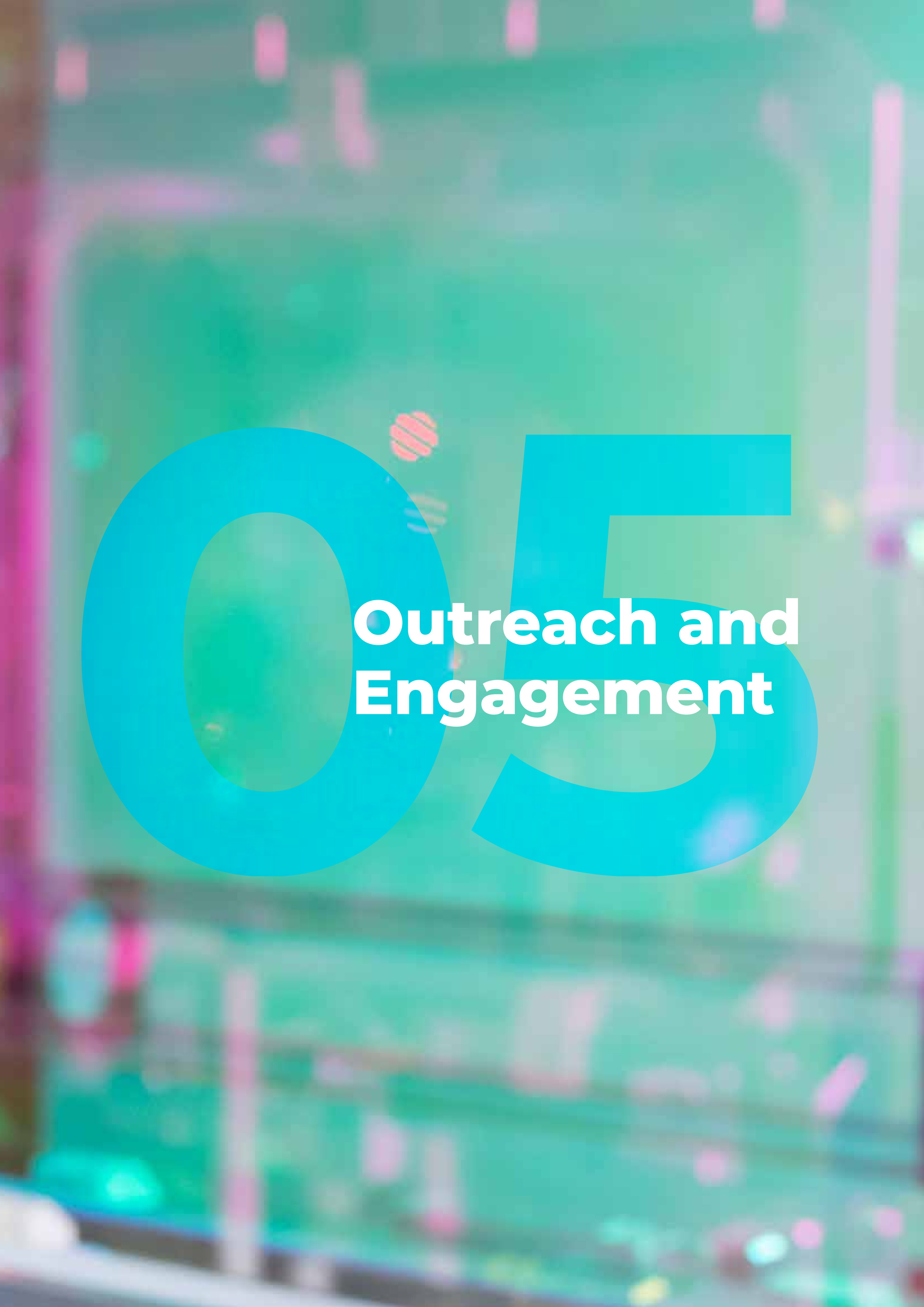
Photovoltaic power plant at the ELI Beamlines Facility

ELI is committed to sustainable and cost-effective energy solutions. As part of the facility optimisation efforts, 665 solar panels have been installed on the building roof. This installation is a key component of the renewable energy sources initiative, aimed at reducing the environmental footprint and enhancing energy efficiency.

The photovoltaic panels (PVP) provide an electrical output of 312.5 kWp, resulting in significant annual energy savings of approximately 1.5 million CZK. Alongside the solar panels, we have also invested in a Combined Heat and Power Unit (CHPU) with a heat output of 630 kWt and an electrical output of 530 kWe.

In addition to these installations, a comprehensive set of cost-saving measures implemented between 2022 and 2023 has led to substantial reductions in energy consumption and costs. A 50% saving in heat consumption, equivalent to 2.5 million kWh, translating to a cost saving of around 7.5 million CZK per year. Similarly, electricity consumption has been reduced by 17% (2.1 million kWh), resulting in an annual saving of approximately 12.2 million CZK.

Through these initiatives, ELI is not only advancing towards its sustainability goals but exploring and implementing innovative energy solutions to further enhance the operational efficiency and environmental responsibility.



05 Outreach and Engagement

User Community Outreach and Scientific Engagement

The annual ELI User Meeting, held on December 4-5, 2023, at the ELI ALPS Facility in Szeged, Hungary, is a cornerstone event for engaging with ELI's diverse and growing scientific community. This year's meeting drew nearly 150 attendees from 22 countries, offering them a comprehensive overview of ELI's expanding scientific capabilities and the latest achievements from user experiments. The event also highlighted the progress and future directions of ELI's evolving User Programme. A new addition was the Joint ELI Workshop on Advanced Technologies, aimed at fostering stronger collaborations with the User community through enhanced use of ELI's cutting-edge instruments. Key to the event's success were the vibrant discussions and Q&A sessions, which provided invaluable feedback from participants, enriching the ELI User community's scientific endeavors.

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.

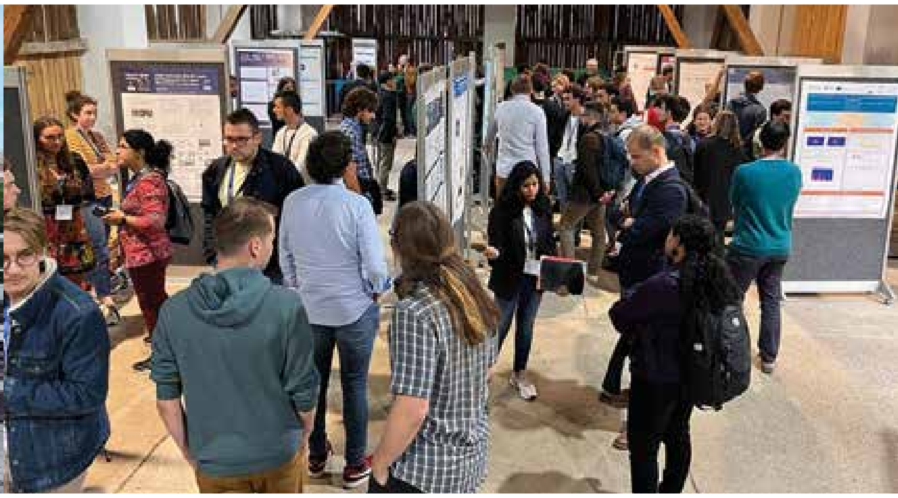
Participation in these events not only highlights ELI's cutting-edge research but also reinforces the cooperative ties with the global scientific community. In addition to the academic forums, ELI showcased its research and collaborative opportunities at major industrial exhibitions. ELI welcomes a rich exchange and interactions with scientists from all over the world.

ELI Summer School 2023

ELISS2023
Extreme Light Infrastructure Summer School

The ELI Summer School (ELISS), held annually at one of the ELI Facilities, is a core educational event designed to engage and inspire students in the field of laser science. This outreach activity supports young scientists in exploring ELI research topics and envisioning future careers in the field. The 8th iteration of this series, hosted at the ELI Beamlines Facility from August 29 to September 1, 2023, provided an opportunity for students to delve into the generation and application of intense laser pulses and laser-driven particle and radiation sources.

ELISS welcomed a record number of 120 students from 24 diverse countries—including Poland, Germany, France, Italy, Greece, China, India, Israel, Pakistan, and Ukraine—making it the summer school with the highest and most diverst number of participants since the inception of the event. The 2023 session featured a rich curriculum encompassing ultrafast imaging techniques, high-power ultrafast lasers, femto science, and attoscience photonics. Highlights included vibrant social events, enlightening lab visits, and a poster session where nearly 40 student participants showcased their research, fostering an unprecedented exchange of knowledge and ideas.



Education and Training Initiatives

ELI's relationship with universities is multifaceted, encompassing education, research, and innovation. In 2023, ELI supported the academic and professional growth of 39 PhD candidates and facilitated internships for 38 students. These programs not only contribute to the development of future scientists but also strengthen the connections with academic institutions worldwide.

Building on the foundation of strategic partnerships, a new series of student training activities were launched at ELI ERIC, with funding from the IMPULSE and EURIZON projects. An online ELI lecture course for Ukrainian students was organised as a joint effort between ELI ERIC, Sumy State University, and Kharkiv National University of Radio Electronics to address the pressing need for accessible and impactful educational opportunities for the country's young scientists, as well as to help establish and develop contacts with the Ukrainian science and educational system. More than 200 participants joined the online courses altogether. A similar lecture series was offered supported by the Candela Foundation to give insight into research opportunities for modern science and technology using high-power pulsed lasers to students in Poland. These efforts aim to offer training opportunities in the areas of science relevant for ELI and support interested students in persuing a career in the field.

Outreach in a Nutshell

Student visitors

80
Total School Groups

266
Students
Kindergarten + Elementary school

3202
Students
Secondary school

477
Students
University

8052
Total visitors welcomed in 2023

New Talents on the Horizon

The ELI Facilities also established yearly activities for primary and secondary school students to present science in an engaging way to young minds. ELI ALPS hosts a Summer Camp with students from all over Hungary. The Talent Academy and Science Challenge are programmes that welcome high school students to ELI Beamlines and lets them explore hands-on activities together with mentors and scientific coordinaters from staff giving them a unique experience of world of science.

Making Science Accessible for All

The ELI Facilities open their doors twice a year to the general public local audiences and the general public and showing the exciting world of ELI, lasers, and optics. The International Day of Light in May is an annual observance of UNESCO and is celebrated across all ELI Facilities. ELI ALPS welcomed the general public with lectures, programmes for children and special facility visits. ELI Beamlines hosts various events for the whole family and with a spectacular light installation. Another popular activity is connected to the Researchers' Night in late September. This initiative is a Europe-wide public event, which displays the diversity of science and its impact on the daily lives of citizens in fun and inspiring ways. The ELI Facilities planned behind-the-scenes facility tours, lectures, insightful presentations and spectacular experiments for a wide audience.

ELI's Women in Science

The Women in Science at ELI are pioneering work which is not only expanding the frontiers of knowledge but also inspiring a new generation of young women to pursue careers in STEM (Science, Technology, Engineering, and Mathematics). Their achievements and results are recognised at ELI every single day, from supporting work-life balance to celebrating the International Day of Women and Girls in Science each year. These pages present some of their experiences working in science and at ELI and their ambitions for the future.

"I really like the power and joy in our daily work. As a woman scientist, my biggest fear related to my career was the break for maternity leave. My son was born last year, and I'm so lucky that ELI allowed me to come back part-time after six months. All my colleagues and superiors were very supportive in this situation. Furthermore, I can share the parental duties with my husband, who also works as a scientist at ELI ALPS."

Zsuzsanna Pápa, ELI ALPS Facility
Senior research fellow/ Ultrafast Nanoscience Group/ Ultrafast Science & Applications Division

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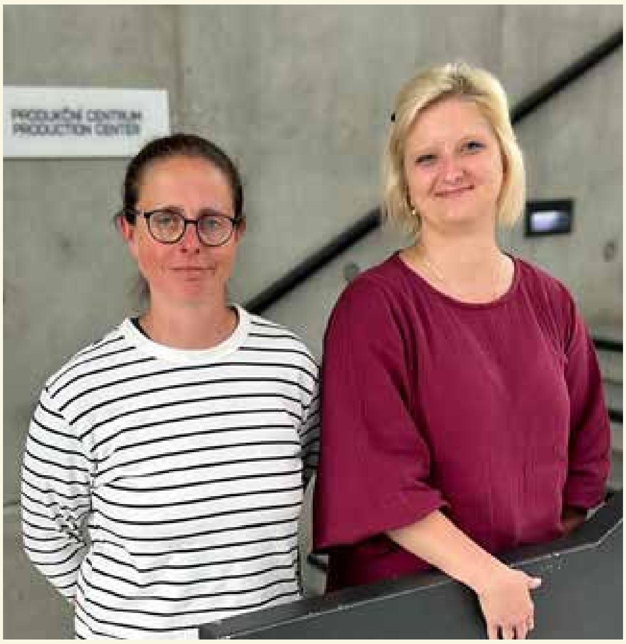
"To me, science is peace of mind. My thoughts spiral between everyday tasks and the ultrafast motion of the tiniest particles (electron) within the smallest unit (atom) building our world. Wow. If I could tell my 15-year-old self that this would be my work, it would deeply impress her. That feeling alone is extraordinary to me."

Krisztina Trényi-Sárosi, ELI ALPS Facility
Early stage researcher/ Ultrafast Chemical Dynamics Group/ Ultrafast Science & Applications Division



"Being a woman in science is a challenging journey, balancing research and family. Sometimes I feel I'm juggling too many things at once, but having a supportive boss, family, and institution makes all the difference. Despite the ups and downs, there's a deep sense of satisfaction in the learning and exploring that comes with my work."

Uzma Bano Memon, ELI ALPS Facility
Research fellow/ Technical department

"Being a woman in science is not just about breaking barriers; it is about shattering the walls and paving the way for future generations. It is about embracing curiosity, intellect, and perseverance in a field that has historically been dominated by men. As a woman in science, I have the power to challenge stereotypes and contribute invaluable insights to the scientific community. Being a part of ELI Beamlines allows me to stand up for these ideas in practice."

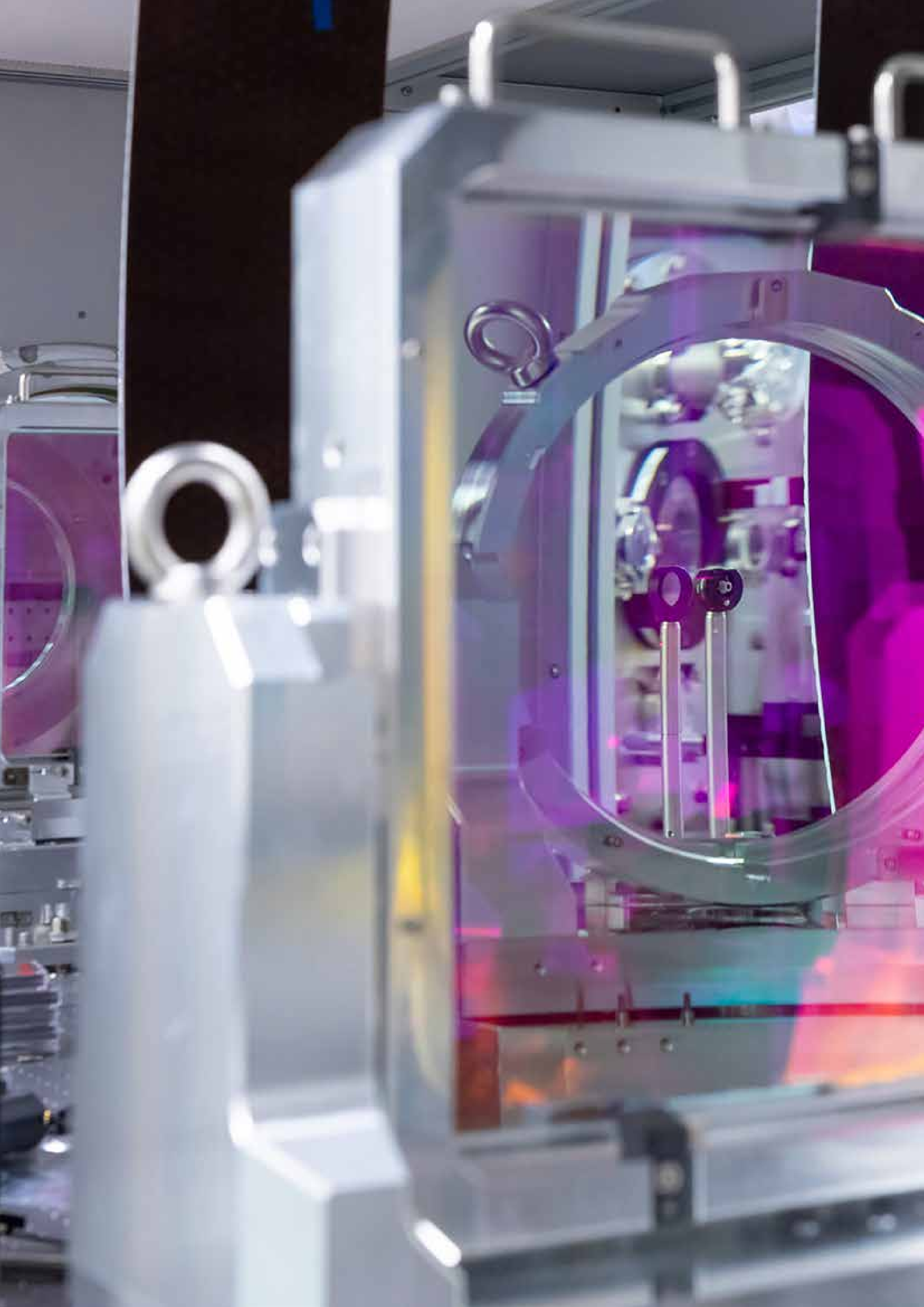
Michaela Kozlová, ELI Beamlines Facility
Senior scientist/ Department of Laser Systems

"For me, a scientific experiment has some sacred parts. There might be a tiny piece of the world for which you will become the first observer. This already happened to me, and it was stunning. As a beamlines scientist, I enjoy implementing users' research ideas as a beamline, which brings diversity to my work life. Even though our individual efforts seem small, all of them together make up scientific progress. I feel like I am a part of this global team and know that what I do matters."

Yelizaveta Pulnova, ELI Beamlines Facility
Graduate student/ Experimental Group of X-ray Sources

"When I am in the laser lab, I feel completely myself – this is what I am good at. I love being an engineer and a mom to my 1.5-year-old son. Both are hard and fulfilling full-time jobs. I'm grateful that ELI offers flexible hours and working from home. It's important for our sons and daughters to see that women are not just moms and wives but can be whatever they dream of."

Lucia Jarboe, ELI Beamlines Facility
Laser engineer/ Department of Laser Systems



06 Governance

ELI ERIC 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 ERIC) with founding members Czech Republic, Hungary, Italy, and Lithuania. Germany, Bulgaria and Romania participate as founding observers with the Czech Republic acting as the host Member State of ELI ERIC. The ELI ERIC is governed according to the Statutes by the ELI ERIC 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 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 ERIC General Assembly

Chair: Caterina Petrillo

Founding Members

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

Hungary
Ferenc Nagy-Rébék (Delegate), Ministry of Culture and Innovation (KIM)
István Szabó (Delegate), HUN-REN Hungarian Research Network

Italy
Michele Crisafi (Delegate), Ministry of Education, Universities and Research
Sandro De Silvestri (Delegate), National Research Council
Eugenio Nappi (Expert advisor), National Institute for Nuclear Physics
Giorgio Rossi (Expert advisor), University of Milan "Statale"

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

Founding Observers

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

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

Romania:
Mihnea Cosmin Costoiu (delegate), National University of Science and Technology

Administrative and Finance Committee (AFC)

The AFC advises the GA on all matters relating to administrative and legal issues and financial management. The AFC Chair is appointed by the GA. The AFC oversees all major administrative and


ELI ERIC General Assembly

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.

Chair: László Bódis

Members

Czech Republic
Jan Buriánek, Ministry of Education, Youth and ports
Petr Lukáš, Nuclear Physics Institute, Academy of Sciences

Hungary
László Lengyel, National Research, Development, and Innovation Office

Italy
Veronica Buccheri (Delegate), Istituto Nazionale di Fisica Nucleare

Lithuania
Artūras Malysis, Ministry of Education, Science and Sport
Indrė Nazarenko, Research Council of Lithuania

Founding Observers:

Bulgaria
Zornitsa Georgieva (Delegate), Ministry of Education and Science

Germany
Bernadette Klose (Delegate), DLR Project Management Agency
Barbara Schramm (Delegate), Helmholtz-Zentrum Dresden-Rossendorf

Romania
Andreea Crupa (Delegate), Ministry of Research, Innovation and Digitalization

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

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

Members

Angela Bracco - Università degli Studi di Milano
Francesca Calegari - Center for Free-Electron Laser Science - CFEL
John Collier - Central Laser Facility, STFC Rutherford Appleton Laboratory
Colin Danson - AWE, United Kingdom
Marta Fajardo - Istituto Superior Tecnico, Lisbon
Roger Falcone - University of California, Berkeley
Sylvie Jacquemot - École Polytechnique
Wim Leemans - Deutsches Elektronen-Synchrotron -DESY
Claudio Masciovecchio - Elettra-Sincrotrone Trieste S.C.p.A. (Fermi)
Mauro Nisoli - Politecnico di Milano
Ulrich Schramm - Helmholtz-Zentrum Dresden-Rossendorf
Thomas Tschentscher - European XFEL
Arūnas Varanavičius - University of Vilnius
Jonathan Zuegel - University of Rochester

07 Finance Report

Notes to the Financial Statements as of 31 December 2023

General Content

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

The Extreme Light Infrastructure (hereinafter referred to as 'ELI ERIC'), Company ID: 10974938,

Tax No.: CZ10974938, with its registered office at Za radnicí 835, 252 41 Dolní Břežany, was established for an initial period of twenty years, which may be extended by decision of the ELI ERIC General Assembly.

The Founding Members of ELI ERIC are the Czech Republic, Hungary, Italy and Lithuania. Bulgaria and Germany are Founding Observers. Romania has been accepted as Founding Observer with effect as of 1 January 2024.

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

Purpose of Establishment

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

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

Plan issued by the Director General of ELI ERIC.

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

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

To ensure and process accounting, accounting records are made in the economic information system IFIS by BBM spol. s r. o. that is a member of the Gordic group. Electronic accounting data files are stored at SSČ AV ČR v.v.i cloud solution backup server and backed up daily. The initial documents are archived in a separate accounting archive of ELI ERIC.

The accounting period is the calendar year.

Valuation method:

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

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

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

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

The notes below show values for the previous year of 2022 and for the current year of 2023.

All financial values in this note to the Financial Statements of 2023 has been converted to EUR using CNB´s year end rate 1 EUR = 24.725 CZK

The ELI ERIC General Assembly, on their 6th meeting on 17-18 October 2022. in Brno, Czech Republic, approved the contractual agreements organising and regulating the transfer of the ELI Beamlines Facility to ELI ERIC. On 18 October 2022, the Institute of Physics of the Czech Academy of Sciences (IoP), a public research institution, and ELI ERIC signed a series of agreements organising the transfer of the ELI Beamlines Facility, which had been operated as a division of IoP until then, to ELI ERIC. Under this transaction, it was agreed that all assets and liabilities (including movable and immovable assets), contracts and agreements, rights and duties, activities, employees, intellectual property rights associated with ELI Beamlines will be transferred to and placed under the ownership of ELI ERIC. According to the terms and conditions of this transaction, the transfer of ELI Beamlines happened as of 1 January 2023. As of this date, ELI ERIC is the only owner and operator of ELI Beamlines Facility. The transfer and integration of ELI Beamlines Facility into ELI ERIC had a major impact on the ELI ERIC´s accounting books. The transfer itself has been booked into the opening balances of 2023

Additional information to the Balance Sheet

Fixed assets, as of the Balance Sheet date at acquisition costs and historical prices:

Fixed assets	2022 (k€)	2023 (k€)
Buildings and structures	0	107 655
Machinery and equipment	35	235 477
Software and valuable rights	0	2 409
Land	0	8 669
Tangible fixed assets in progress	1 584	0
Intangible fixed assets in progress	49	0
Advances paid on tangible fixed assets	14	6
Accumulated depreciation	-20	-102 808
Total	**1 663**	**251 408**

Due to the ELI Beamlines integration the value of equipment substantially changed from 2022 to 2023. Transfer included buildings, land, software, and rights. Transfer of assets has been done in historic values and ELI ERIC is continuing in depreciations of assets transferred from IoP. All assets have been activated, there is no assets in commissioning at the end of 2023.

Long-term financial assets

Long-term financial assets	2022 (k€)	2023 (k€)
Shares - controlled entities	0	3
Total	**0**	**3**

The ELI ERIC General Assembly, on their 9th meeting on 9-10 October 2023, in Prague, Czech Republic, authorized the ELI ERIC Director General to complete the purchase of the Municipality of Szeged's shares in ELI-HU Non-profit Ltd and further capitalise ELI-HU Non-profit Ltd to the extent necessary for ELI ERIC to acquire a controlling share in that company. The value in the 2023 Balance Sheet represents the first payment of the acquisition of shares in ELI-HU Non-profit Ltd.

Receivables

The total receivables on the Balance Sheet date amount to 5,810 k€, including the following significant items:

Receivables	2022 (k€)	2023 (k€)
Trade receivables	0	133
Operational advances granted	5	169
Other receivables	561	96
Excess VAT deduction	3 413	5 412
Membership fees	0	0
Total	**3 979**	**5 810**

In 2023 ELI ERIC already performed limited economic activity and trade receivables is also partly the result of this activity. Trade receivables have been settled in 2024. Operational advances are related to supply of material and services that were delivered in 2024. These advances were cleared in 2024. VAT deduction represents requests for the refund of VAT incurred in 2023 in the Czech Republic and Hungary in application of ELI ERIC's exemption from VAT.

Short-term financial assets

Total short-term assets amount to 19,616 k€ on current accounts with ČSOB a.s.

Short-term financial assets	2022 (k€)	2023 (k€)
Cash on accounts	8 511	19 616
Petty cash	0	0
Total	**8 511**	**19 616**

Other assets

Other assets	2022 (k€)	2023 (k€)
Prepaid expenses	177	296
Accrued renenues	882	1 985
Total	**1 059**	**2 281**

Prepaid expenses of 2023, besides the current year-end prepayment, mainly include prepaid software licenses and services for next periods in amount of 296 k€. Accrued revenues represent the expected revenues from Czech and EU grants in amount of 1,985 k€.

Liabilities

The entity records liabilities to employees, suppliers and authorities that were paid on due dates in 2024.

Liabilities	2022 (k€)	2023 (k€)
Liabilities to suppliers in the main activity	690	2 132
Liabilities to employees	88	830
Liabilities to social security and health insurance institutions	36	419
Liabilities due to other direct taxes	16	110
Payables for subsidy and other dues to state	0	118
Other liabilities	3	57
Accrued costs	104	381
Deferred expenses	0	1 582
Deferred revenue	202	37
Total	**1 138**	**5 666**

Liabilities towards trade suppliers with the due date over 30 days amount to 107 k€, all other supplier liabilities are under due date of 30 days. Liabilities to employees are related to liabilities to social security and health insurance as well as other direct taxes linked to payroll for December 2023. Payables to subsidy represent amounts to be returned to grant providers in relation to unused grant resources. Accrued costs for 2023 have to do with the untaken holiday entitlements of employees in all jurisdictions where ELI ERIC has activities and employs staff. Deferred expenses of 1,582 k€ have all been paid in the 1st quarter of 2024 and mainly relate to operating costs of the ELI ALPS Facility for November and December 2023.

Funds

Funds as of the Balance Sheet date amounted to 273,452 k€

Own equity and funds	2022 (k€)	2023 (k€)
Own equity	0	246 305
Funds for EU and other programmes	106	2 671
ELI ERIC members' contribution fund	13 942	19 057
Other funds	0	5 420
Provisions	25	0
Total	**14 074**	**273 452**

Assets (mainly fixed assets, land and related accumulated depreciation) have been transferred from the Institute of Physics of the Czech Academy of Science based on historic prices. This means that ELI ERIC booked all assets in the purchase values and booked also the accumulated depreciation. ELI ERIC continues with the booking of depreciation in line with the depreciation plans of the assets that were transferred from the Institute of Physics. Due to the fact that the transfer was made on a non-monetary basis, tangible and intangible assets in the assets section of the Balance Sheet are balanced by an increased Own equity in amount of 246,305 k€. Further, there are mainly funds of membership contributions in amount of 19,057 k€ and EU and other grant projects in amount of 2,671 k€ that are intended for use in the next period. The item 'Other funds', which amounts 5,420 k€, includes items settled from membership funding that are classified as investments according to the law and will be depreciated as per the depreciation planning in the following years.

Additional information on the Profit and Loss Statement

Costs and revenues of ELI ERIC for the years 2022 and 2023 differ significantly due to the transfer and integration of the ELI Beamlines Facility into ELI ERIC as of 1 January 2023.

The profit or loss was established as the difference between the costs and revenues of the main and economic activities and is shown in the Profit and Loss Statement. Loss of the main activity for 2022 is 70 k€ and profit in the economic activity 70 k€. This results in a zero balance. There is no profit or loss reported in 2023.

Revenues	2022 (k€)	2023 (k€)
Main activity revenues	34 358	66 688
Economic activity revenues	0	208
Total	**34 358**	**66 896**

Expenses	2022 (k€)	2023 (k€)
Main activity expenses	34 358	66 758
Economic activity expenses	0	138
Total	**34 358**	**66 896**

Revenues - breakdown	2022 (k€)	2023 (k€)
Operation subsidies	0	1 987
Members of ELI ERIC	31 070	40 940
Revenues from EU and others grants	2 390	4 114
Revenues from own services	0	167
Contractual fines and interest	0	61
Other revenues	0	17 086
Interest on deposits	169	1 312
Exchange rate gain	729	1 229
Total	**34 358**	**66 896**

Operation subsidies - breakdown	2022 (k€)	2023 (k€)
Czech Science Foundation	0	432
Other operational subsidies	0	19
Ministry of Education, Youth and Sport of the Czech Republic	0	1 536
Total	**0**	**1 987**

Source analysis of expenses	2022 (k€)	2023 (k€)
Institutional	31 964	59 479
EU projects	2 394	7 417
Total	**34 358**	**66 896**

Cost type breakdown	2022 (k€)	2023 (k€)
Personnel costs	1 535	17 554
Other goods and services	31 321	30 979
Depreciation and activation of long term assets	-612	15 804
Travel expenses	128	526
Other expenses	1 986	2 019
Income tax	0	14
Total	**34 358**	**66 896**

Personnel data

Changes in headcount	2022	2023
January opening balance	10	370
On boarding	5	50
Departures	1	51
December closing balance	14	369
Total	**14**	**369**

Breakdown of personnel costs	2022 (k€)	2023 (k€)
Gross wages of employees	1 193	13 013
Statutory social security and health insurance	342	4 135
Other social expenses	1	406
Total	**1 535**	**17 554**

These figures account only for staff directly employed by ELI ERIC. The difference between 2022 and 2023 factors in the transfer of the staff of ELI Beamlines previously employed by FZU. The staff employed by ELI-HU non-profit Ltd, which is responsible for the operation of ELI ALPS and in which ELI ERIC acquired a controlling share effective 1 January 2024, are not reported in this table yet.

No remuneration, advances or loans were paid to the members of the bodies of ELI ERIC in the 2023 accounting period.

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

Other information

ELI ERIC:

1. Is not encumbered by loans.
2. Does not organise any public charity under a special law.
3. Has no financial or other liabilities not included in the Balance Sheet at the time of its compilation.
4. Auditor's remuneration – the total remuneration of the auditor for 2023 was below the materiality level.
5. Note on the ransomware attack in 2023
   On 28 March 2023, the ELI Beamlines network experienced a ransomware attack. Servers and workstations were impacted, and the attack had a severe impact on the operations of the Facility for two weeks. Servers, network infrastructure, and services were gradually restored. As a result of the attack, part of the company data was encrypted, but there was no evidence of data extraction. Data have been gradually restored from existing backups or from other sources. Impact on the laser control system network and user operations was limited due to the separation between the networks used for research infrastructure operations and administration. This event had no impact on the liabilities of the organisation.
   In terms of follow-up actions, counter-measures have been taken based on the conclusions and recommendations of external experts. A deep security analysis has been carried out and a long-term strategy is being implemented to minimise cybersecurity risks at ELI Beamlines.
6. No significant events occurred after the date of the financial statements.

Balance Sheet
as of December 31st, 2023

ASSETS		Row number	Balance on the first day of accounting period (k€)	Balance on the last day of accounting period (k€)
A. Long-term Assets		**1**	**253 572**	**251 411**
I. Intangible Fixed Assets		**2**	**2 409**	**2 409**
1	Inangible research and development outcomes	3	0	0
2	Software	4	2 353	2 401
3	Valuable rights	5	8	8
4	Low-value intangible fixed assets	6	0	0
5	Other intangible fixed assets	7	0	0
6	Intangible fixed assets in progress	8	48	0
7	Advanve payments for intangible fixed assets	9	0	0
II. Tangible Fixed Assets		**10**	**338 128**	**351 807**
1	Land	11	8 669	8 669
2	Works of art and collections	12	0	0
3	Buildings and structures	13	104 821	107 655
4	Equipment, furniture and fixtures	14	222 615	235 453
5	Perennial crops	15	0	0
6	Breeding and draught animals	16	0	0
7	Low-value tangible fixed assets	17	23	23
8	Other tangible fixed assets	18	0	0
9	Tangible fixed assets in progress	19	1 754	0
10	Advanved payments for tangible fixed assets	20	246	6
III. Long-term Financial Assets		**21**	**0**	**3**
1	Shares - controlled / controlling entities	22	0	3
2	Shares - substantial influence	23	0	0
3	Debenture loans until maturity	24	0	0
4	Loans to organizational units	25	0	0
5	Other long-term loans	26	0	0
6	Other long-term financial assets	27	0	0
IV. Accumulated Depreciations to Fixed Assets		**28**	**-86 965**	**-102 808**
1	Accumulated depreciations - intangible research outcomes	29	0	0
2	Accumulated depreciations - software	30	-2 155	-2 316
3	Accumulated depreciations - valuable rights	31	-8	-8

4	Accumulated depreciations - low-value intangible fixed assets	32	0	0
5	Accumulated depreciations - other intangible fixed assets	33	0	0
6	Accumulated depreciations - buildings and constructions	34	-13 283	-15 383
7	Accumulated depreciations - equipment, furniture and fixtures	35	-71 495	-85 078
8	Accumulated depreciations - perennial crops	36	0	0
9	Accumulated depreciations - breeding and draught animals	37	0	0
10	Accumulated depreciations - low-value tangible fixed assets	38	-23	-23
11	Accumulated depreciations - other tangible fixed assets	39	0	0

ASSETS		Row number	Balance on the first day of accounting period (k€)	Balance on the last day of accounting period (k€)
B. Short-term Assets		**40**	**21 543**	**27 707**
I. Inventory		**41**	**0**	**0**
1	Material in store	42	0	0
2	Material in transit	43	0	0
3	Work-in-progres	44	0	0
4	Semi-finished products	45	0	0
5	Finished products	46	0	0
6	Animals	47	0	0
7	Merchandise in store	48	0	0
8	Merchandise in transit	49	0	0
9	Advance payments for inventory	50	0	0
II. Receivables		**51**	**12 208**	**5 810**
1	Trade receivables	52	0	133
2	Exchange bills receivable	53	0	0
3	Receivables for discounted notes	54	0	0
4	Advance payments made	55	24	169
5	Other receivables	56	1	1
6	Receivables from employees	57	35	61
7	Receivables from social security and health insurance	58	0	0
8	Income tax receivables	59	0	0
9	Other direct taxes receivables	60	0	0
10	VAT receivables	61	3 329	5 412
11	Other taxes and fees receivables	62	0	0

12	Receivables for subsidy and other dues from state	63	0	0
13	Receivables for subsidy from municipalities	64	0	0
14	Receivables from shareholders and partners in an association	65	0	0
15	Receivables from long-term deposits and options	66	0	0
16	Receivables from issued bonds	67	0	0
17	Other receivables	68	8 819	33
18	Estimated accrued expenses	69	0	0
19	Adjustment to receivables	70	0	0
III. Short-term Financial Assets		**71**	**8 301**	**19 616**
1	Petty cash	72	0	0
2	Liquid valuables (stamps and vouchers)	73	0	0
3	Bank accounts	74	8 301	19 616
4	Shares and similar securities	75	0	0
5	Bonds, debentures and similar securities	76	0	0
6	Other securities	77	0	0
7	Cash in transit	78	0	0
IV. Other Assets		**79**	**1 033**	**2 281**
1	Prepaid expenses	80	173	296
2	Accrued renenues	81	860	1 985
TOTAL ASSETS		**82**	**275 115**	**279 118**

LIABILITIES		Row number	Balance on the first day of accounting period (k€)	Balance on the last day of accounting period (k€)
A. Own Resources		**83**	**273 361**	**273 452**
I. Equity		**84**	**273 361**	**273 452**
1	Own equity	85	251 951	246 305
2	Funds	86	21 410	27 147
3	Gains and losses from revaluation of assets	87	0	0
II. Profit and loss for the period		**88**	**0**	**0**
1	Profit / loss account	89	0	0
2	Profit / loss in distribution	90	0	0
3	Retained earnings, accumulated loss from previous years	91	0	0
B. External resources		**92**	**1 754**	**5 666**
I. Provision / Reserves		**93**	**25**	**0**
1	Provisions / reserves	94	25	0
II. Long-term Liabilities		**95**	**0**	**0**
1	Long-term bank loans	96	0	0

2	Issued bonds	97	0	0
3	Liabilities from rent	98	0	0
4	Long-term advance payments received	99	0	0
5	Long-term notes payable	100	0	0
6	Estimated accrued expenses	101	0	0
7	Other long-term liabilities	102	0	0
III. Short-term liabilities		**103**	**1 533**	**4 047**
1	Trade suppliers	104	673	2 132
2	Exchange bills payable	105	0	0
3	Advance payments received	106	0	35
4	Other payables	107	1	0
5	Wages payable	108	85	814
6	Other payables to employee	109	0	15
7	Payables to social security instutitions and public health insurance companies	110	35	419
8	Income tax payables	111	0	0
9	Other direct tax payables	112	16	110
10	VAT payables	113	0	0
11	Other taxes and fees payable	114	0	0
12	Payables for subsidy and other dues to state	115	0	118
13	Payables for subsidy to municipalities	116	0	0
14	Shares / securities payable	117	0	0
15	Payables to shareholders and partners in an association	118	0	0
16	Payables for long-term deposits and options	119	0	0
17	Other payables	120	660	22
18	Short-term bank loans	121	0	0
19	Credit for discounted notes	122	0	0
20	Short-term bonds issued	123	0	0
21	Own bonds issued	124	0	0
22	Estimated accrued expenses	125	62	381
23	Other short-term financial assistance	126	0	0
IV. Short-term liabilities		**127**	**197**	**1 619**
1	Defferred expenses	128	0	1 582
2	Deferred revenues	129	197	37
TOTAL LIABILITIES		**130**	**275 115**	**279 118**

Profit and Loss Statement

as of December 31, 2023

		Figures at balancing day		
		Main activity (k€)	Economic activity (k€)	Total (k€)
		1	2	3
A. Expenses				
I. Purchase and Services Consumption		**31 444**	**61**	**31 505**
1	Consumption of material, energy	8 529	58	**8 587**
2	Cost of goods sold	0	0	**0**
3	Repairs and maintenance	624	0	**625**
4	Travel expenses	526	0	**526**
5	Hospitality	130	0	**130**
6	Other services	21 635	3	**21 638**
II. Change in inventory of own products and capitalization		**-359**	**0**	**-359**
7	Change in inventory of own products	0	0	**0**
8	Capitalization of material, goods and services	0	0	**0**
9	Capitalization of fixed assets	-359	0	**-359**
III. Personel Expenses		**17 517**	**37**	**17 554**
10	Wages and salaries	12 985	28	**13 013**
11	Legal social insurance	4 126	9	**4 135**
12	Other social insurance	0	0	**0**
13	Legal social security expenses	406	0	**406**
14	Other social security expenses	0	0	**0**
IV. Taxes and Fees		**10**	**0**	**10**
15	Taxes and Fees	10	0	**10**
V. Other Expenses		**1 969**	**40**	**2 009**
16	Contractual fines and interest on late payments	0	0	**0**
17	Receivables written off	0	0	**0**
18	Expenses Interest	0	0	**0**
19	Foreign exchange losses	382	0	**382**
20	Gifts	0	0	**0**
21	Shortages and damages	0	0	**0**
22	Other operating expenses	1 587	39	**1 626**
VI. Depreciation, Assets Sold, Provisions and Adjustments		**16 163**	**0**	**16 163**
23	Depreciation of fixed assets	16 188	0	**16 188**
24	Net book value of fixed assets sold	0	0	**0**
25	Cost of revenue from stock	0	0	**0**
26	Net book value of material sold	0	0	**0**
27	Creation and use of reserves and provisions	-25	0	**-25**
VII. Contributions Granted		**0**	**0**	**0**
28	Membership fees	0	0	**0**
VIII. Income Tax		**14**	**0**	**14**

29	Income tax	14	0	**14**
EXPENSES TOTAL		**66 758**	**138**	**66 896**

		Figures at balancing day		
		Main activity (k€)	Economic activity (k€)	Total (k€)
		1	2	3
B. REVENUES				
I. Operation Subsidies		**1 987**	**0**	**1 987**
1	Operation subsidies	1 987	0	**1 987**
II. Contributions Received		**40 940**	**0**	**40 940**
2	Contributions received among organisational units	0	0	**0**
3	Contributions received (gifts)	0	0	**0**
4	Membership fees received	40 940	0	**40 940**
III. Revenues from sales of own products and services		**23**	**144**	**167**
IV. Other Revenues		**23 738**	**63**	**23 802**
5	Contractual fines and interest on late payments	61	0	**61**
6	Payments for receivables written off	0	0	**0**
7	Interest income	1 312	0	**1 312**
8	Foreign exchange gains	1 228	0	**1 229**
9	Funds	4 114	0	**4 114**
10	Other revenues	17 023	63	**17 086**
V. Revenues from Assets Sold		**0**	**0**	**0**
11	Revenues from long-term intangible and tangible assets sold	0	0	**0**
12	Revenues from securities and shares sold	0	0	**0**
13	Revenues from material sold	0	0	**0**
14	Revenues from short-term financial assets	0	0	**0**
15	Revenues from long-term financial assets	0	0	**0**
REVENUES TOTAL		**66 688**	**208**	**66 896**
C. PROFIT (+) / LOSS (-) BEFORE TAX		**-55**	**70**	**14**
D. PROFIT (+) / LOSS (-) AFTER TAX		**-70**	**70**	**0**

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