INNOVATIONS & INDUSTRY

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INTRODUCTION

High-power ultrafast lasers are one of the greatest achievements of the past decade. Finding new ways to use them to develop innovative technologies is the subject of the highest level research in both science and industry. The plan for the near future is to offer stable, compact and affordable laser systems generating X-rays, plasma, or accelerated particles for a wide range of industrial applications.

Scientific research is about increasing the knowledge of humanity and is driven by curiosity. The application of said knowledge is driven by wisdom – understanding how to apply what we know to give us the greatest benefit. ELI Beamlines recognises the strength of applied research, as it plays a vital role in achieving successful research outcomes and applying innovation to the community of industrial users.

The laser is a unique tool that has uncovered many mysteries and solved many of society's challenges since its invention. Even as lasers solve existing challenges in the medical, environmental and advanced materials industries (to name a few; lasers have a place in almost every market), new challenges and possibilities arise. We approach these with our extensive library of knowledge, and our continuously growing understanding of the world that our use of lasers as precision tools has enabled. Investment into research at ELI Beamlines dramatically increases the quality, competitiveness, and range of services offered by the European photonics industry.

We are always looking for others who are interested in solving problems that are critical to humanity and, in turn, we are continuously discovering new ways to apply our facilities and expertise to the benefit of society. We look forward to hearing how you would like to collaborate with us.

LASER SYSTEMS

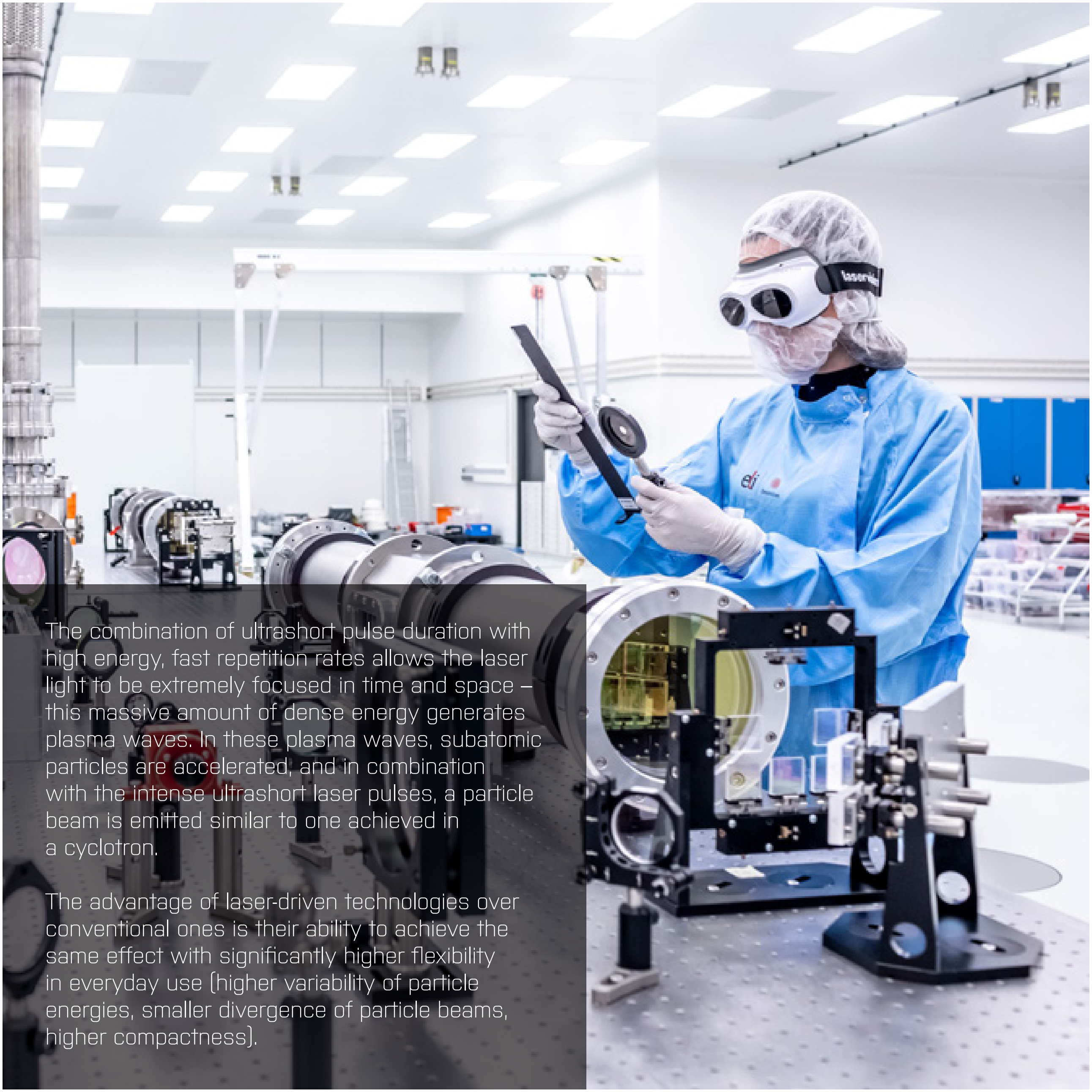
ELI Beamlines lasers deliver ultrashort pulses at repetition rates that are orders of magnitude greater than previous petawatt class lasers. Enabled by new technology and dedicated research, we offer direct access to new insights in medicine, energy sources and materials development, to name a few key examples.

In collaboration with Lawrence Livermore National Laboratory and National Energetics (USA), STFC (UK) and EKSPLA (Lithuania), the ELI Beamlines teams have developed, assembled and tested unique high repetition rate laser systems based on diode-pumped solid-state lasers (DPSSL) and flashlamp-pumped Nd:glass amplifier technologies.

KEY LASER FEATURES

- Ultrashort pulse duration (femtoseconds)
- Peak powers of up to 10 PW
- High repetition rates
- High pulse to pulse stability

Beamline	Laser 1 Allegra	Laser 2 Amos	Laser 3 HAPLS	Laser 4 Aton
Peak power	15 TW	> 0.1 PW	≥ 1 PW	10 PW
Pulse energy	200 mJ	> 3 J	≥ 30 J	≥ 1.5 kJ
Pulse duration	< 12 fs	25 fs	≤ 30 fs	≤ 150 fs
Rep rate	1 kHz	50 Hz	10 Hz	1 per min
Laser pumping methods	Diode-Pumped Solid-State Lasers (DPSSL)	Diode-Pumped Solid-State Lasers (DPSSL)	Diode-Pumped Solid-State Lasers (DPSSL)	Flashlamp-pumped Nd:glass amplifiers
Investment (mil. EUR)	7.5	12.5	39	37



The combination of ultrashort pulse duration with high energy, fast repetition rates allows the laser light to be extremely focused in time and space – this massive amount of dense energy generates plasma waves. In these plasma waves, subatomic particles are accelerated, and in combination with the intense ultrashort laser pulses, a particle beam is emitted similar to one achieved in a cyclotron.

The advantage of laser-driven technologies over conventional ones is their ability to achieve the same effect with significantly higher flexibility in everyday use (higher variability of particle energies, smaller divergence of particle beams, higher compactness).

LASER 1 ALLEGRA

LASER 3 HAPLS

LASER 4 ATON

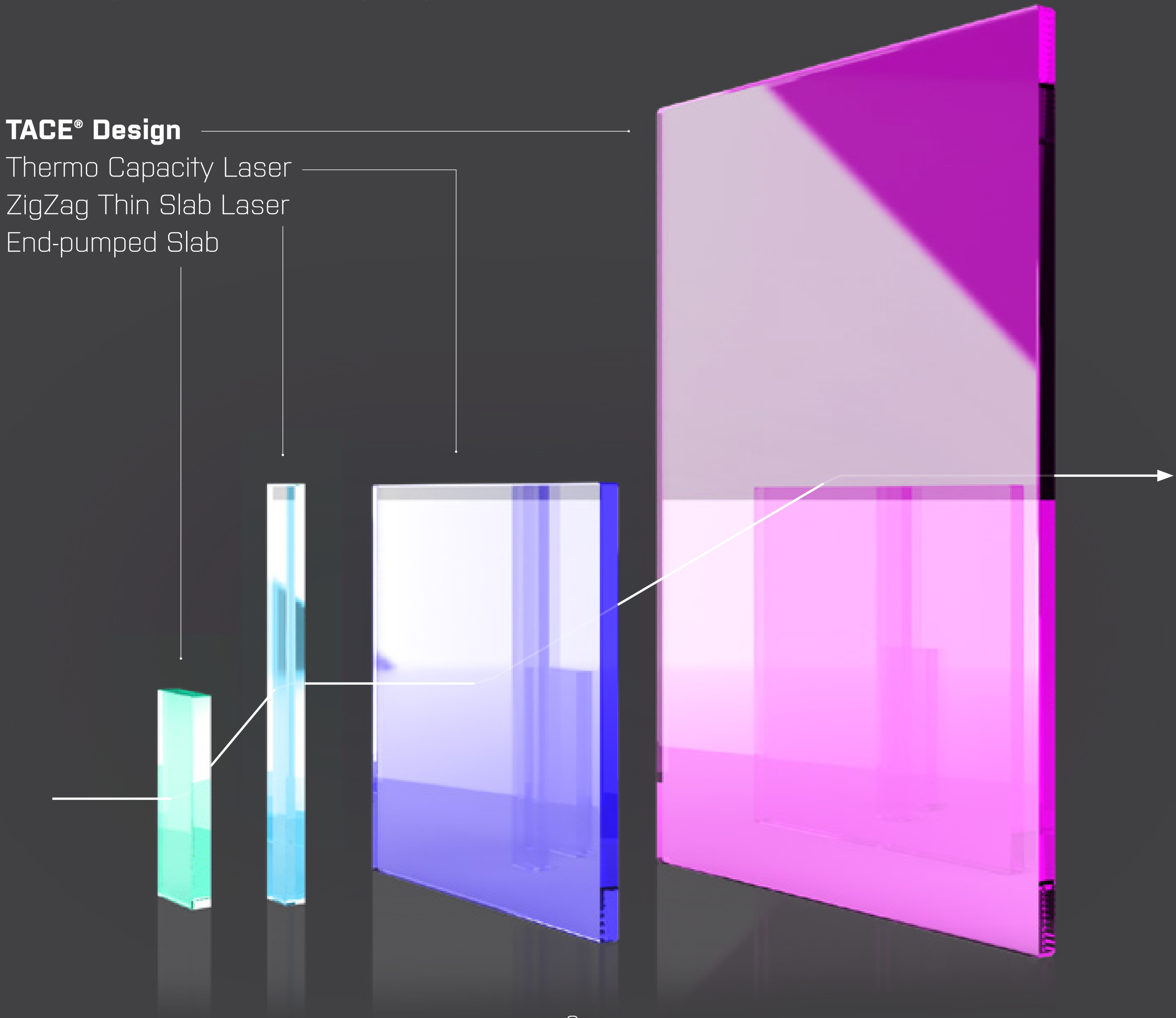
DEVELOPMENT OF LARGE LASER SYSTEMS

Research into lasers is a complicated endeavour, due to the large range of technologies involved in their operation and development. These technologies range from cryogenics, vacuum technology, electronics and computing, and they also naturally include a broad range of optical technologies, such as laser amplifier design, pulse synchronisation and diagnostic systems, optical component design and manufacturing, and optical modelling.

At ELI Beamlines, we have a diverse team dedicated to the development of our facility, consisting of researchers from countries such as the Czech Republic, US, UK, Italy, Germany, France, South Korea and many others. These highly skilled researchers are involved in areas linked with high-power laser research. Their work includes developing new techniques for growing laser crystals, new solutions for the cryogenic cooling of high-power high repetition rate laser amplifiers, new techniques for femtosecond synchronisation of laser pulses, advanced repetition rate diagnostics of femtosecond pulses, and parametric chirped-pulse amplification (OPCPA) pulse chain design, to name a few.

TACE

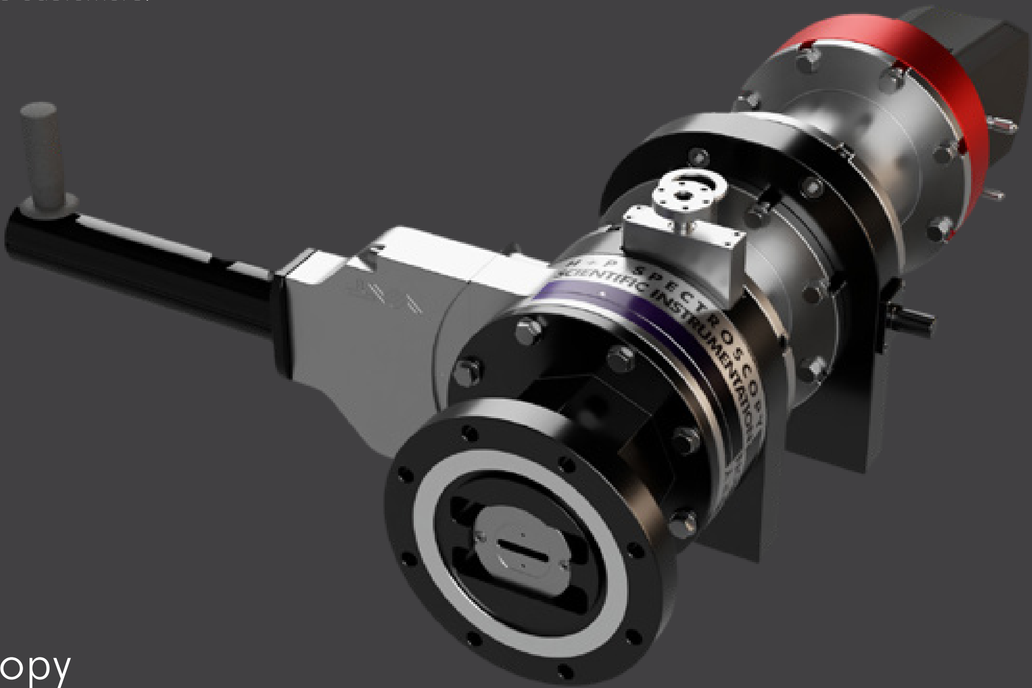
TACE – Twin Active Crystal Element – is a laser gain medium design technique developed by ELI Beamlines. The TACE design creates a larger active area, which allows higher average and peak energy up to 10 times that of current laser systems. This technique cuts the crystal boule along its length instead of its width, and uses the crystals in opposing pairs, so that their doping gradients compensate each other. The technology has been patented in the US, Europe, Japan and Israel.



XUV CHARACTERISATION

The method of XUV beam characterisation using a new instrument that combines spectrometer and beam profiler functions was originally created to resolve some internal needs of the X-ray sources department at ELI Beamlines. The invention led to a novel optical design that allowed the beam intensity profile and spectrum to be measured using a single detector.

This solution considerably simplified the diagnostic setup. It replaced a spectrometer and a beam profiler, each with its own detector. This detector was usually an X-ray camera costing tens of thousands of euros. In 2019, the German company HP Spectroscopy GmbH included this technology in its product portfolio and currently offers it to its customers.

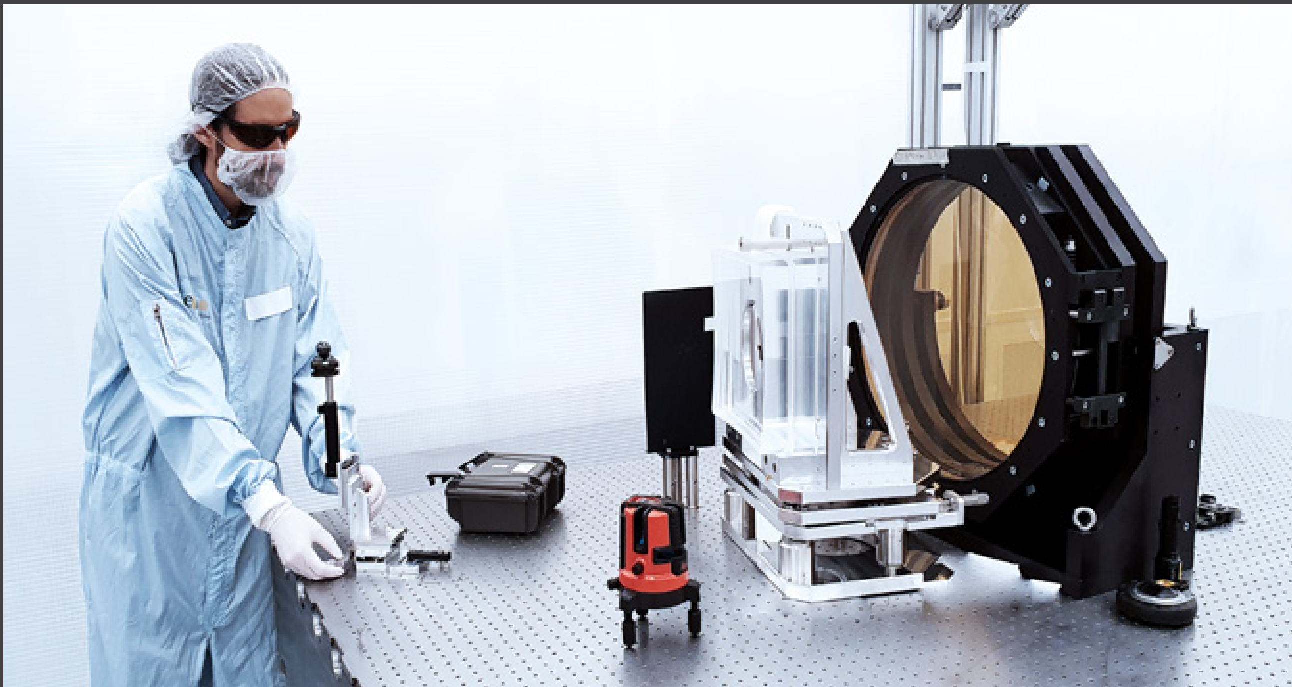


hpspectroscopy

OPTICS FOR EXTREME INTENSITIES

High-performance large ultrafast optics designed for extreme beam intensities is one of the key elements of ELI Beamlines. In order to achieve and maintain its high performance, ELI Beamlines is creating a unique optical coating lab using advanced ion sources and electron beam evaporation.

This lab provides the opportunity to develop and supply high LIDT broadband coatings for optical elements up to 1.5 metres in diameter. The related metrology lab offers characterisation of thin layers and surfaces up to 500 mm in diameter. The coatings are tested with a reliable ultrafast LIDT vacuum setup located at ELI Beamlines.



BENEFITS FOR SOCIETY

The most important thing about laser science is how it impacts the world and our everyday lives. Below you can find highlights of what we believe to be our greatest legacy for our society, which are further developed by the dedicated staff at ELI Beamlines. For more information about all our applications, please visit our website: www.eli-beams.eu.

At ELI Beamlines, we use our laser systems and expertise to solve critical issues in the health, environmental and advanced materials industries that could not be solved without such ground-breaking systems and cutting edge laser research. By tackling global issues using our extensive expertise, we have a bright vision of the future in the coming decade.

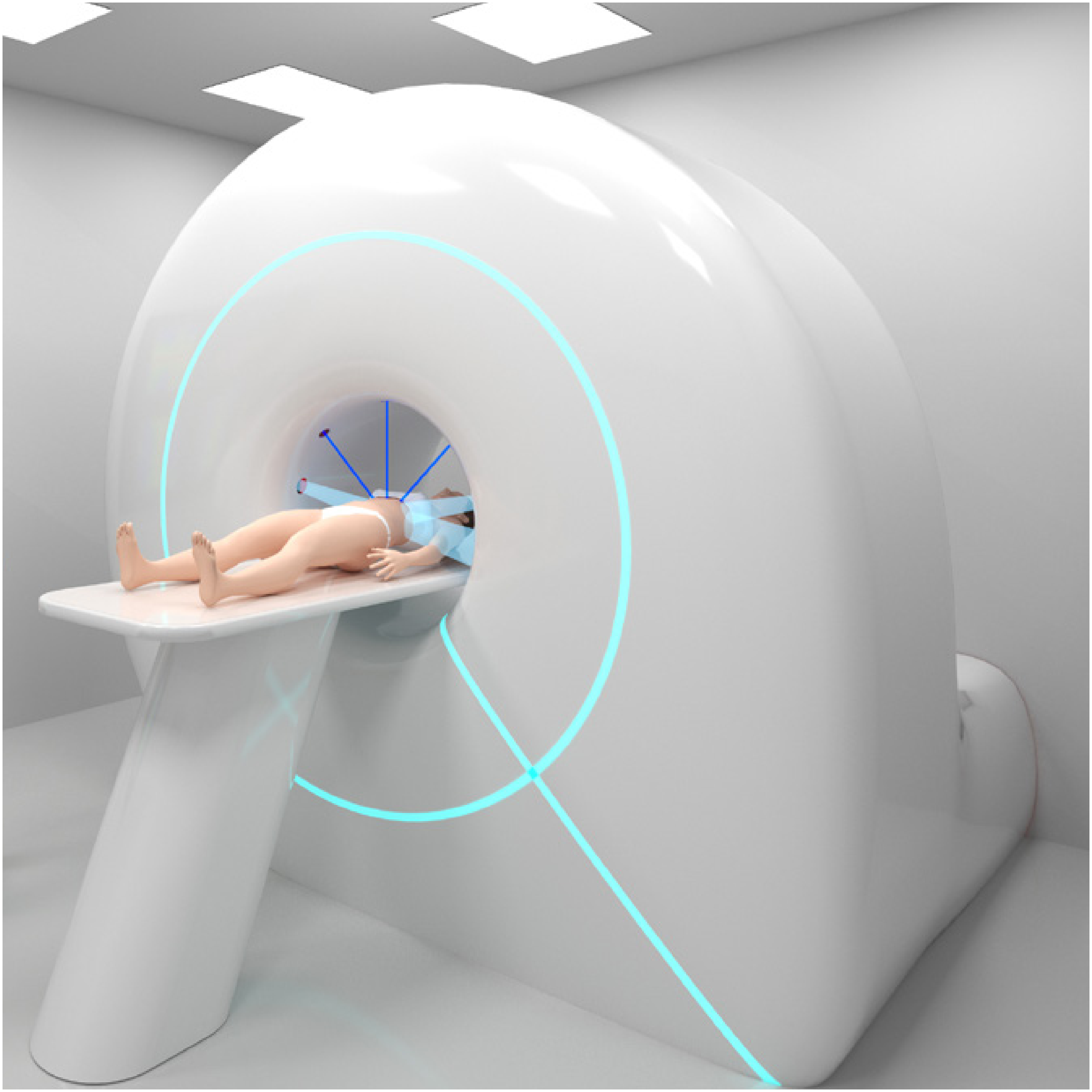
CANCER TREATMENT

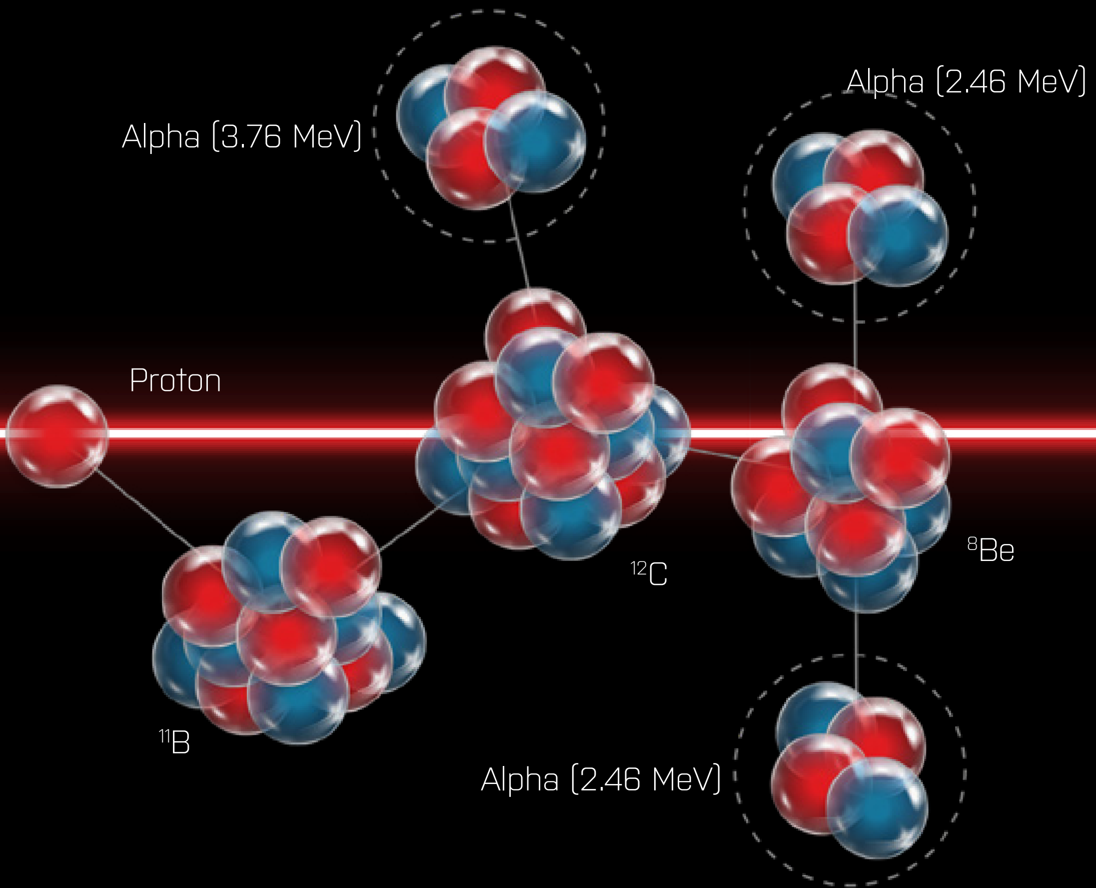
Particle physics provides diagnosis and therapy to tens of thousands of patients worldwide each year. The main challenge that reduces the availability of tumour radiotherapy is the size and costs associated with the particle sources principally used.

The major advantage offered by the high-power lasers from ELI Beamlines, via its ELIMAIA ion acceleration program, is the delivery of accelerated particles for tumour radiotherapy in a more effective and economical way. This will enable tumour radiotherapy treatment to be available in smaller hospitals and less developed countries.

In terms of medical effect, accelerated particle beams from a laser are more focused than treatment in conventional radiotherapy methods, interacting only in the diseased area and minimising damage to sensitive surrounding tissues.

The worldwide radiotherapy market is currently formed of many hundreds of existing independent radiotherapy centres. Increasingly compact, with decreasing manufacturing costs, portable laser-driven accelerators will increase the availability of advanced radiotherapy equipment in both developed and developing regions. The public commitment to equipping cancer treatment centres with newer, more advanced radiotherapy systems supports the integration of this technology around the world.



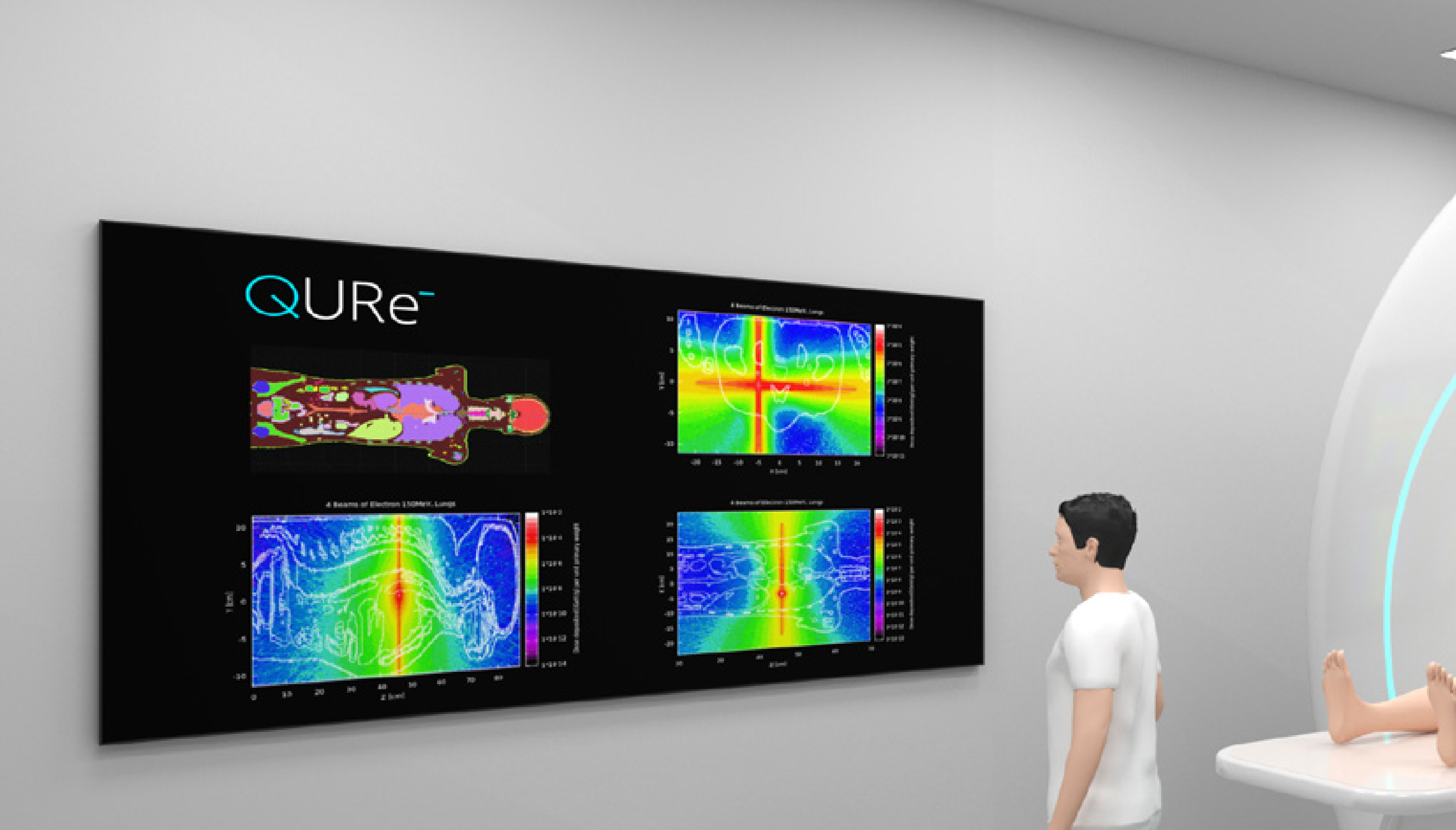


CANCER TREATMENT

PROTON–BORON CAPTURE THERAPY

The Proton-Boron Capture Therapy (PBCT) method developed at ELI Beamlines significantly improves the accuracy of the bombardment of tumours compared to existing proton therapy methods. In addition to its improved accuracy, the PBCT method also allows online imaging of treatment by monitoring the gamma rays generated by the proton-boron nuclear reactions. The PBCT method enhances the relative biological efficacy of proton therapy while preserving the unique physical properties of accelerated protons, and thus paving the way for the treatment of radioresistant tumours such as gliomas or pancreatic tumours.

The innovative PBCT method uses molecules containing the boron ^{11}B nuclei that can penetrate deep into tissue in order to reach a tumour. In combination with a proton beam, a proton-boron interaction generates three low energy alpha particles (about 4 MeV) that release their energy into individual tumour cells. Unused boron is eliminated from the body and is non-toxic.



CANCER TREATMENT

INSTANTDOSE

LASER PLASMA ACCELERATOR FOR RADIOTHERAPY

Tumours can be treated by high-power lasers focused on micrometric gas targets which produce beams of high-energy electrons. These pulsed electron beams have significant advantages over the medical linear accelerators currently being used, notably a flat depth dose curve combined with durations much shorter than those of a human movement.

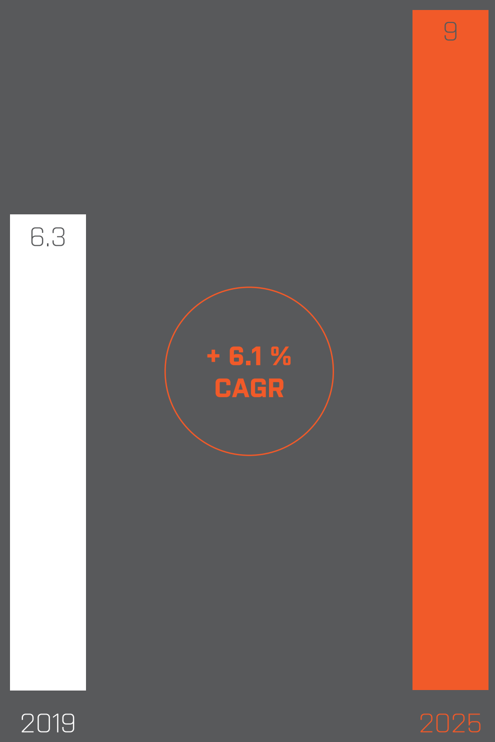
InstantDose is the first type of radiotherapy machine designed by ELI Beamlines to combine high energy electrons generated by high-power lasers with real-time imaging of the treatment. The state-of-the-art commercial X-ray tube that is synchronised with the laser source makes it possible to image the planned target volume in less than 100 ms. Such fast imaging is clearly beneficial, while monitoring human body parts in motion during the treatment significantly reduces the necessary irradiation time (up to 20 seconds) and assures accurate dose delivery and precise dose administration.

MARKET ANALYSIS

Radiotherapy is one of the most widespread cancer treatments. The linear accelerator market is currently worth 6.3 billion USD (as of 2019), with an average annual growth rate of 7%.

High-energy electrons are a radiotherapy subtype which is seeing constant growth. The electron accelerator market totalled 2.8 billion USD in 2019.

GLOBAL RADIOTHERAPY DEVICES MARKET (BILLION USD)



BIOPHARMACEUTICAL ANALYSIS

Researchers are regularly developing new chemical compounds and medicines, which have to be comprehensively tested for efficacy and side effects. ELI Beamlines' ultra short laser pulses are designed to provide X-ray radiation at sub-picosecond durations, which might help to make this development process easier to use for applications in imaging and analytical procedures. End user stations for X-ray sciences at ELI Beamlines offer applications in scattering and diffraction (XRD), absorption spectroscopy (XAS) or imaging techniques.

A promising use of X-ray radiation is in phase contrast imaging. This technique provides high resolution images of the inside of the body.

Monitoring the distribution of a drug while it is being delivered to various parts of a human body can identify which organs are affected, and enables biopharmaceutical analysis during the drug-approval process or drug-related scanning.

At ELI Beamlines, we are developing phase contrast imaging with high resolution, accomplished with a laser-driven betatron source, using the highly energetic, ultrashort (30 fs) laser pulses generated by our laser systems. The end result is fast, high resolution X-ray imaging, enabling biopharmaceutical analysis during the drug-approval process or drug-related scanning.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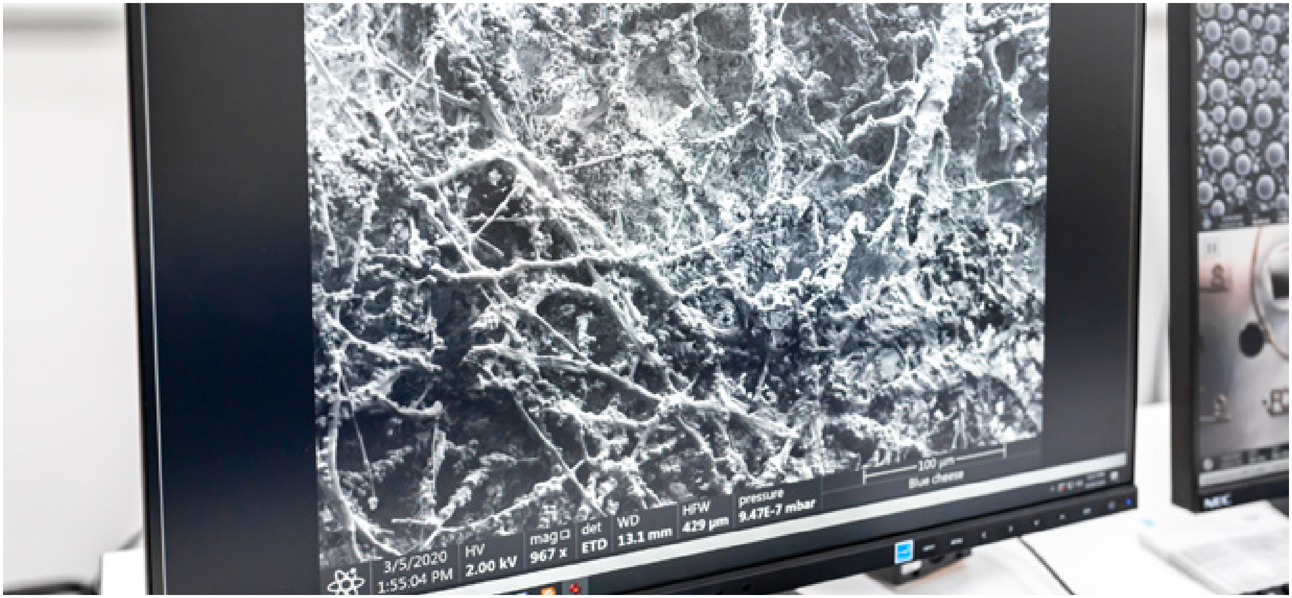
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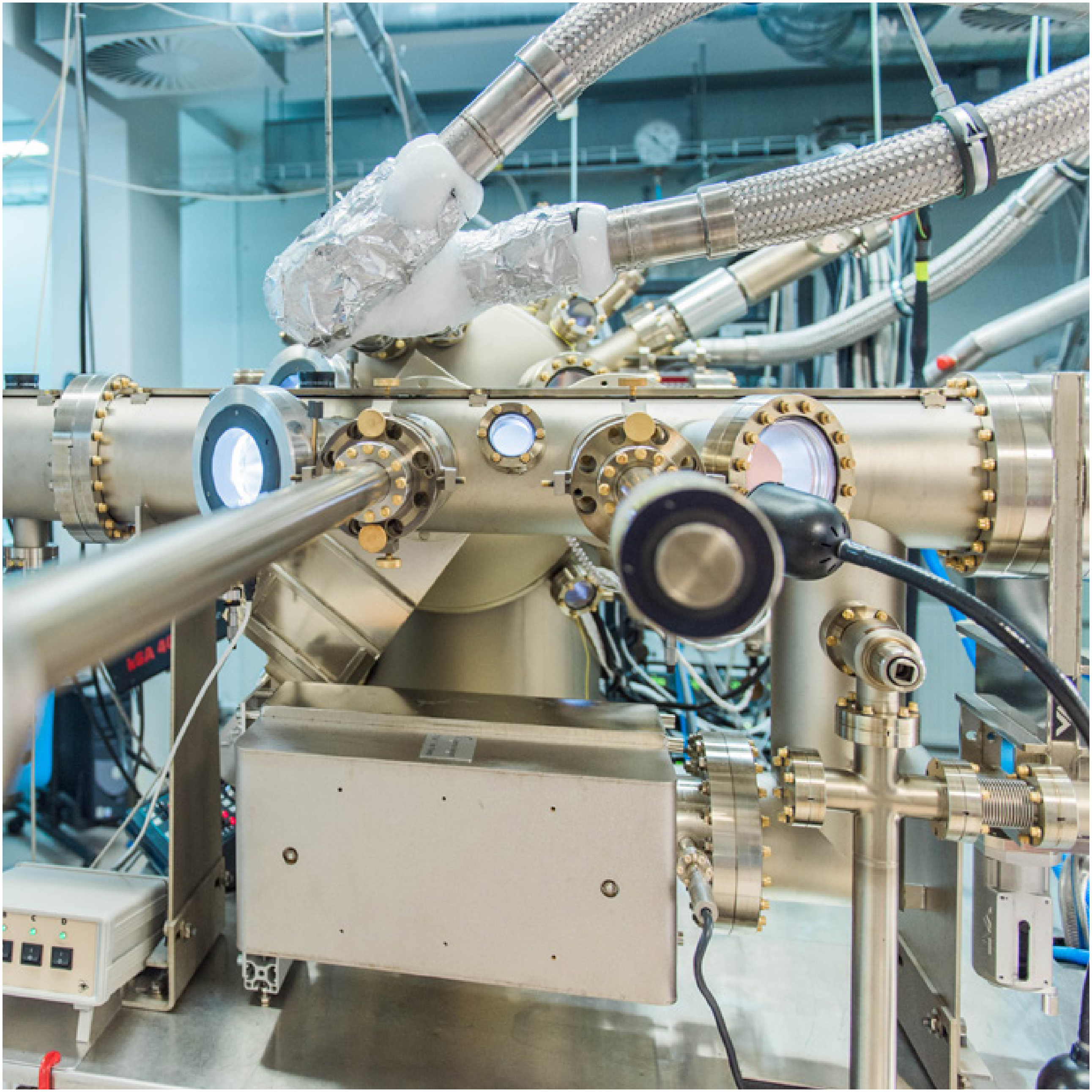
NEW ENERGY SOURCES

Creating sustainable energy sources is a vital mission for humanity. It is important that new energy sources have sustainable markets, and in order to do so they need to generate energy efficiently, in a way that does not harm the environment.

Nuclear fusion power is considered to be a future inexhaustible source of clean energy. In exothermic nuclear fusion reactions, electricity is generated by capturing the massive release of binding energy from the starting particles. The main challenge of nuclear fusion power is being able to generate more energy than has been spent creating the fusion reaction.

The secondary challenge is posed by the extremely high temperatures required to trigger the fusion reaction. Due to the intense energy available from the lasers at ELI Beamlines, a new method of efficient initiation of nuclear fusion is made possible. Proton-Boron interactions are a relatively clean way to conduct nuclear fusion reactions (with no radioactive products and no high energy neutrons being produced), however they require the primary particle to be accelerated to 600 – 700 keV in order to be energetically efficient, otherwise more energy will be spent in the process than earned. The lasers at ELI Beamlines have the power required to reach such extreme temperatures and to support reactions that result in a new positive balance in the production of electrical energy



ANALYSIS OF CULTURAL HERITAGE

The non-invasive and non-destructive techniques developed at ELI Beamlines using laser-accelerated protons for testing, and the protection of cultural heritage this affords, will enable accurate verification and documentation of ancient and historical artefacts. Their use serves to prove originality, detect forgeries, and provide information about original materials and artistic techniques. These facts are highly relevant for indirect dating and provenance studies.

Non-destructive PIXE and DPAA technologies use laser-driven protons to identify the elemental composition (ranging from sodium to uranium) even with low ppm concentrations and at different layers of the object. These methods are suitable for (but not limited to) painted and glazed ceramics, statues, glass, jewellery, paintings, inks, and icons. As there is no need to use a vacuum for testing, there is no risk of degradation caused by outgassing or dehydration of the tested items. Another advantage is that any size or shape of sample can be tested.

PIXE & DPAA

ELI Beamlines is developing Proton Induced X-ray Emission (PIXE) and Deep Proton Activation Analysis (DPAA) methods using laser-driven protons. These two methods can be combined to obtain data about the elemental composition of an item's surface and even of deeper layers (e.g. behind the corrosion). The advantage is that no vacuum is needed for testing; it also provides an opportunity to benefit from the various energies of laser-driven protons or ions.

These methods have been developed for testing heritage, however the laser-driven PIXE can also be used for studying aerosols in environmental science, biological samples, or trace elements for forensic purposes and quality control in industries.

SUPPORT TO INDUSTRIAL USERS

Alongside intense application-oriented research comes the need for scientific, operational and administrative support. ELI Beamlines offers experimental halls devoted to self-arranged proprietary access and joint collaborative projects with industry. The access parameters for industrial users are always designed in accordance with specific user preferences.

Discussions about the further direction and development of ELI Beamlines' technologies also take place at numerous international user workshops, which are held regularly as part of all ELI Beamlines research programs. The development of the centre's technologies and the direction this takes is also monitored by the International Scientific Advisory Board (ISAC), which evaluates the centre's operations twice a year.

- Senior scientific team ready to co-design and assist with conducting users' experiments
- Experienced technicians and engineers, with bio labs, chemistry labs and a well-equipped mechanical workshop
- Administration and management staff, who handle finances and public-funded projects
- Safety department dedicated to the training of employees and the public
- Innovation management including patent attorney, legal advisory and technology transfer processes

WORK WITH US AT THE CUTTING EDGE OF SCIENCE

Since the establishment of ELI Beamlines, extensive cooperation with the international laser community has been initiated and is continuously strengthened through new cooperation agreements. Over the last decade, ELI Beamlines has significantly contributed to the technological excellence of instrumentation suppliers from Europe, North America and Asia.

Innovative technologies allowed these companies to become world market leaders in high-power lasers. In the field of science, ELI Beamlines currently has more than fifty cooperation agreements with prestigious scientific institutions from around the world.

ELI Beamlines is primarily a user facility. As users, industrial companies can get access to technologies, know-how and services to verify new technologies and innovations. Access to state-of-the-art technologies with no obligation to publicly share results of experiments allows us to push boundaries in industrial research, and find solutions to industrial challenges.

Unique research infrastructure
World-class equipment capable of generating extremely short, high-power laser pulses at a high repetition rate, for use in many fields of application.

Excellent science
Leading research is a key driver for an attractive industrial collaboration. Providing state-of-the-art experimental equipment and laboratories brings a significant benefit to each collaboration partner.

Broad range of expertise
A team of experienced scientists, researchers and technicians is able to help configure user experiments and design instrumentation. ELI Beamlines supports the exchange of personnel with industrial partners.

Targeted access
Allocated beamtime and experimental halls for industrial proprietary use.

Financial and legal stability
The high level of priority given by the EU and national governments to R&D provides the basic prerequisites for financial stability.

Education
ELI Beamlines staff members share and spread knowledge and experience. Training and education is provided to industrial partners and users of laser devices.

We look forward to hearing how you would like to collaborate with us!
Contact us at citt@eli-beams.eu.

eli | beamlines

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