Light Sources for Europe

Strengthening Europe's leading role in science and innovation

LEAPS
League of European Accelerator-based Photon Sources

League of European Accelerator-based Photon Sources (LEAPS)

LEAPS is a collaboration that brings together light sources that each produce exceptionally intense beams of X-rays, ultraviolet, and infrared light. These enable insights, which are not possible with more conventional equipment for both basic and applied research, covering virtually all fields of science from physics, chemistry, and biology, to energy, medicine, cultural heritage, and engineering. They can be compared to 'super microscopes,' which enable research on samples in the tiniest detail, helping make invisible information strikingly visible.

Light sources encompass both the synchrotron light source community, which produce highly intense continuous beams, and the free-electron lasers community, producing high intensity short pulsed laser-like beams. Both types of light source complement one another.

Light source facilities have been working alongside each other in Europe successfully for years, supporting world-class science. In the past 5 years alone, LEAPS members have welcomed over 24 000 direct users, who have had an impact on a wider network of greater than 35 000 researchers, with more than 23 400 unique articles published in peer-reviewed journals.

The future holds great promise too: new technologies to produce and exploit yet more powerful sources of light have been conceived, with the potential to transform the impact on increasingly complex scientific and societal problems. Realising this promise in the face of rising international competition requires facilities across Europe to draw even more effectively on their collective strengths, and to do so swiftly.

The collaboration offers a step change in European cooperation, uniting 16 organisations representing 19 facilities through a common vision of enabling scientific excellence solving global challenges, and boosting European competitiveness and integration. This will be achieved through a common sustainable strategy developed in consultation with all stakeholders, including national policy makers, user communities and the European Commission.

LEAPS members will produce a road map for the development of the next-generation light sources and instrument technologies, advocate for its funding and together address the big data challenge.

LEAPS will also:

- Play to the strengths of individual facilities through smart specialisation, recognising strengths in a more coordinated way to better serve the future needs of the user community
- Strengthen and expand services to industry to trigger innovation more widely and effectively
- Standardise and improve access modes for users, capture and map socio-economic impact, enhance training and outreach programmes
- Strengthen scientific integration, both across Europe and globally

Vision

A world where European science is a catalyst for solving global challenges, a key driver for competitveness and a compelling force for closer integration and peace through scientific collaboration.

Mission

LEAPS will use the power of its combined voice to ensure that member light source facilities continue to be world - leading, to act as a powerful tool for the development and integration of skills with a view to address 21st century global challenges, and to consolidate Europe's leadership in the field.

› 5 Nobel Prizes directly linked to our research infrastructures

› Over 23 400 unique articles published in peer reviewed journals in the last 5 years from diverse fields of science, making Europe a world leader in research

› More than 24 000 direct users and a wider network of over 35 000 researchers

Working together to form LEAPS

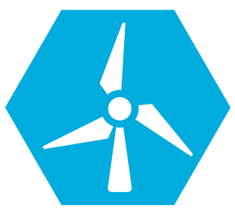
Scientific excellence for societal challenges

The health, prosperity, and security of European citizens today and in the future depend on meeting increasingly demanding challenges. These can be found in energy and transport, healthcare and food safety, and sustainable living, and all must be tackled within a thriving, inclusive economy. This demands new technology, new treatments and a better understanding of the world around us, all of which point to an increased role and reliance on highly sophisticated analytical tools like accelerator-based light sources to provide the most incisive means of measuring and unravelling atomic and molecular structures of the world around us. The information revealed at this scale can have a transformational effect on science and technology.

Health

With a global population expected to rise to 9.7 billion by 2050, with 2 billion over the age of 60, health challenges are immense and require investment from basic research and new treatments through to preventative healthcare. **On average just over 18% of all scientific articles published by light sources in Europe over the past five years are related to biological research.** This is primarily the result of highly standardised and well-coordinated EU-funded efforts from the structural biology community. These researchers are working on a wide range of health challenges, from infectious diseases, and drug development, through to age-related diseases, and cancer research. For Europe, an ageing population presents increasingly urgent challenges that are driving research into new biomaterials from heart valves to prosthetics. In addition, infectious diseases are the second leading cause of death in the world after cardiovascular diseases. Much has been achieved in the past decade in terms of prevention and control, but it remains clear that the swift and effective design of therapeutic agents will play a critical role in disease control. Light sources across the world have been involved in programmes of research to better understand basic processes behind pathogenic processes and the emergence of drug resistance, with a view to improve treatments.

Recent successes by researchers include a new synthetic vaccine for polio, a range of therapeutic drugs for breast cancer, new materials for prosthetics and pushed the boundaries of 3D imaging down to the cellular level. In the future, LEAPS members will enable whole cell imaging to understand the development of disease at this level, while the free-electron lasers (FELs) will allow the investigation of the dynamics of biological processes on the atomic scale.



Energy

This sector provides a unique opportunity to become a global leader in research and development establishing the EU as leading the world in sustainable and cleaner energy production.
For example, the growth in renewable energy has increased the demand for efficient and sustainable electrical storage. Rechargeable lithium-ion batteries have facilitated the development of mobile phones and other portable devices, and there is increasing commercial pressure to improve the design of batteries for vehicles and for storage of electricity generated from renewable sources.
The LEAPS members have been at the forefront of efforts to develop advanced energy materials such as those involved in the new generations of solar cells, new energy efficient information technologies and solutions for energy storage. Already the collaboration has improved the design of lithium-ion batteries and investigated alternatives such as sodium-ion batteries. In addition, significant research continues to be directed towards novel fuel cells, which offer the potential of 'zero emission' energy sources. In the future, brighter light sources and FELs in particular, will enable more measurements to study the dynamics and function of cleaner energy devices to optimise their development under realistic conditions.

Environment

Understanding and minimising the impact of humanity on the natural environment is one of the biggest challenges facing society. Light sources have made a major impact in the field of environmental science in the last decade. High resolution visualisation allows the study of ultra-dilute substances, identification of trace elements, better understanding of hydrogen generation systems as an alternative to fossil fuel systems and the ability to track pollutants as they move through the environment. They have also heavily contributed to the monitoring of the effect of human activity both locally and globally. **This knowledge is critical in decision-making and in the development of strategies to reduce the overall impact on the environment.**

In the future, much more sensitive elemental analyses will be possible in order to trace and control pollutants, which will enable the development of more sustainable methods of mining, farming and manufacturing industries.

Food security

The food and drink industry is a major contributor to Europe's economy, with an industry turnover exceeding €1.2 trillion in 2013. With rising costs around the world and increasing pressure for local food supplies, sustainability and waste reduction are key drivers for industry. Following food scares, consumers are demanding higher levels of quality control and traceability for food security, which is of great importance in a very competitive market with new products frequently introduced.

Innovation requires a multidisciplinary approach, a good understanding of the science behind the product or process, and access to the widest possible variety of research and development tools. **The LEAPS collaboration offers specialist analytical techniques for the microscale to atomic characterisation of materials ranging from fertilisers, food ingredients and formulations through to packaging and food processing components.**

Engineering & manufacturing

Europe is a global heavyweight in advanced manufacturing technologies, manufacturing 39% of the world's machine tools. Europe's strength lies in the development and supply of advanced production technologies, which have so far underpinned the competitiveness of the entire European manufacturing base.

LEAPS gathers facilities unique in the world, which are available for the detailed study of engineering and manufacturing processes. For example, X-ray beams allow for detailed analysis and modelling of strain, cracks and corrosion as well as *in situ* study of materials during production processes. This research is vital for the development of high performance materials and their use in innovative products and large-scale structures.

By studying the behaviour of a material at different stages of degradation, light sources can map the relationship between microstructure, degradation and ultimate mechanical response. This enables the rational design of microstructures with desired properties, which leads to further innovation.

Heritage science

Europe is the region which hosts about 50% of the total world heritage including museums, theatres, archaeological sites and historical cities. It is a long-standing destination of choice for cultural tourism.

It is estimated that this accounts for 40% of all European tourism, with tourists choosing their destination based on its cultural offering. The preservation of artworks, artefacts and architecture enabled by science carried out at European light sources plays a key part in this. Although heritage science represents a small fraction of the usage of light sources in Europe, the field has always had a high profile in their portfolio.

Research undertaken at light sources across Europe ranges from palaeontology, and the preservation of medieval ships such as the Vasa and the Mary Rose, to understanding the processes of paint degradation in famous artworks from the likes of Van Gogh and Rembrandt.

Industrial engagement supporting economic growth

› Hundreds of companies benefiting from access and driving innovation to key economic industry sectors

Whilst the majority of the research performed at light sources is undertaken by academia, typically around 30% of this usage is indirectly linked to science that benefits industry.

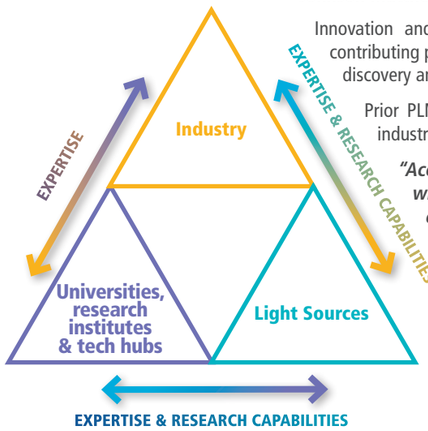
Currently, around 3–5% of the overall experimental time across Europe is being directly bought by several hundred regular customers from industry. They are using light source facilities to advance their R&D programmes across a range of sectors including pharmaceuticals, biotechnology, chemicals, oil, and engineering, and play a major role in keeping a strong R&D base in Europe.

Overall 80% of the usage by industry of light sources has traditionally been in the pharmaceutical sector. In the past decade, they have embedded their access to light sources into their internal R&D programmes, and are strong advocates for new advances in techniques, data analysis and automation. They are interested in the structure of disease pathogens and drug compounds with a view to developing new therapies.

"The academic contribution made by light sources in structural biology is huge, with over 14 500 protein structures deposited in the open access Worldwide Protein Databank in the last 5 years by LEAPS members. For industry, our work has thus far concentrated on exploiting protein crystallography to assist drug discovery programmes. Understanding how potential new medicines interact with proteins, which are implicated in prevalent diseases provides us with valuable insights. As such, timely access via cutting edge interfaces to these light source facilities is vital to our research and innovation. In addition, we foresee several other challenging research questions relevant to address using these facilities in a collaborative setting, in order to bring the next generation of therapies to patients." **Astra Zeneca**

Other sectors have also benefited greatly from access to advanced light source facilities. Johnson Matthey is a global leader in sustainable technologies. They operate across Europe and have been a long-standing user of European light sources. The catalysts produced by Johnson Matthey and other companies are used to create products, which most European citizens interact with in their daily lives.

"Accessing light sources in Europe allows us to gain a unique and detailed understanding of how catalysts work at the atomic level, which enables us to speed up innovation and consolidate our position as a global leader in science that enables cleaner air, improved health and more efficient use of natural resources." **Johnson Matthey**



Innovation and industry are central to the LEAPS collaboration. Light sources are contributing product insight across technology readiness levels, ranging from early stage discovery and development through to market-ready technologies.

Prior PLM Medical is a company that supports the medical and pharmaceutical industry to develop new high performance drug delivery devices.

"Access to light sources facilities has allowed us, for example, to see what's happening inside both development stage and off-the-shelf commercial inhaler devices, which has enabled our clients to make informed design decisions. Access is also part of our own internal R&D programmes to help us innovate and remain ahead of the market." **Prior PLM Medical.**

LEAPS will drastically change this for the better, reducing barriers to access for industry and simultaneously increasing industry's potential to take advantage of the available instruments and techniques to better react to the rapidly changing economic environment.

Innovation driving competitiveness

Light sources across Europe collectively commission technology worth over €100 million every year, without taking into account major machine upgrades. With increased pressure from international competitors, it is now more important than ever that light sources rationalise expenditure by exploiting, for example, collective buying power, with a view to boost innovation of European key industrial partners and thus support their endeavours to keep a global leading position.

DECTRIS - A spin-off company from Paul-Scherrer Institute (PSI)

The development of key technology at a research infrastructure led to the founding of a spin-off company with worldwide customers and applications beyond purely scientific instrumentation, for example in medical applications.

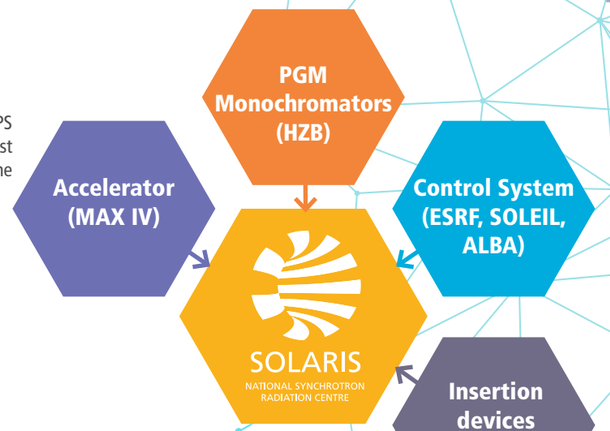
"While DECTRIS drew on its expertise in constructing tailored vacuum-compatible detectors, we have gained extensive experience by working with a wide range of light sources across Europe, and we feel rewarded after all the hard work and the various bespoke designs; we managed to benefit the light source community whilst ensuring that the various innovations positioned our company as a leader in the wider global market" **DECTRIS**

SOLARIS - Fostering innovation amongst the facilities

The technologies developed in the LEAPS facilities enabled the creation of the first Polish synchrotron, which is based on the design of the 1.5 GeV ring of MAX IV.

Innovation for the future

One example out of many is the ultra-precision of mirrors required by all light source facilities, with the community fully dependent on a single supplier from outside Europe. This represents a single point of failure, and an opportunity for change by reaching out to European providers to develop X-ray optical elements and instrumentation to meet the future needs for nanoscale resolution.



Access & integration

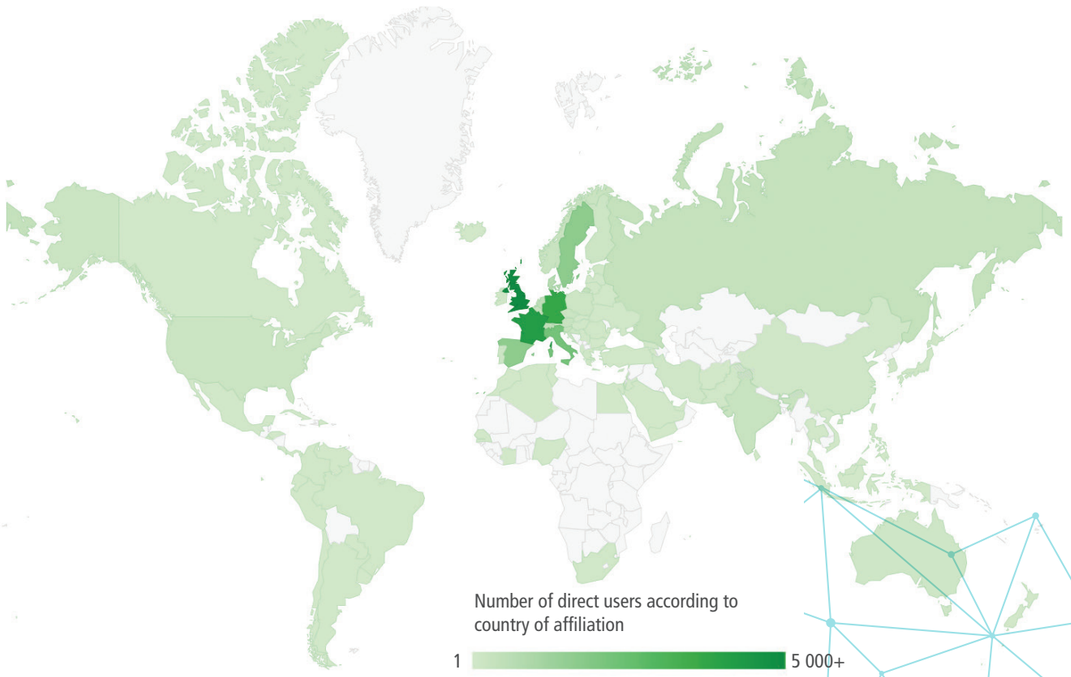
LEAPS members embrace and deliver the key European values of Open Science, Open Innovation, and Open to the World, as they welcome academic and industrial users from all over the world, and share their achievements for the benefit of all. This is based on well-established international peer review processes, which attract the best scientific questions from around the globe. In addition, together we have provided a fertile environment and played a key part in equipping students and early career researchers with the multidisciplinary skills required for addressing global challenges.

LEAPS members aspire to, and are collectively working towards, a realisation of the EU's Fifth Freedom; to create free movement of knowledge equipping members to better engage with new initiatives. They will provide better access for developing scientific communities and accelerate their growth.

LEAPS members are working to create a united and proactive community to consolidate and grow our reach, ensuring science dissemination is maximised, and impact is measured, so that stakeholders and organisations like the European Commission and national funding agencies have a strong appreciation of value for money and return on their investment. These can be seen in diverse ways, from the benefits to the local economy through job creation, supply chain innovation, all the way through to the positive impact of the science delivered by the facilities in the fields of healthcare, environment and technology.

› Over 24 000 direct users in 93 countries

› More than 220 operational Beamlines



Together, we will be stronger and engage further with the rest of the world

Skills & outreach

For advanced facilities, training and skills development is vital, maximising return on investment by equipping researchers to use new developments and bringing new talents into the field. For the LEAPS collaboration, sharing training and skills programmes will lower barriers to accessing light sources at all levels, from inspiring schoolchildren to delivering advanced software training and valuable hands-on experience to post-graduate students.

The development of tools such as online learning environments, virtual beamlines and central registers of LEAPS training opportunities, will reduce duplication of effort and bring the best possible training experiences to those looking to advance their skills across Europe.

Every member already undertakes dedicated training and outreach programmes, which meet the needs of local, national or international audiences, reaching a combined 70 000 visitors per annum. There is a huge opportunity for members to learn from one another, share best practice, and allow researchers to seamlessly access the best training programmes for them at various facilities, offering bespoke training for groups working in diverse fields. Working with universities across Europe, we can access leading teachers and talented students, and in return, they can access cutting-edge technology and applications in photon science.

For staff based at facilities, the opportunities to gain skills through greater collaboration are also huge. From software developers being better connected and integrated, to engineering apprentices shadowing their European colleagues, there are a myriad of opportunities available through closer collaboration.

Key areas for collaboration:

- PhD students – supporting the world -leading HERCULES course
- Computing graduate scheme with clear career paths across Europe
- Undergraduates – linking universities across Europe with light sources
- Virtual learning resources accessible for all
- Exchange programmes for facility staff and researchers
- Mentoring and networking for researchers and facility staff

› More than 70 000 external visitors in the past year through

Open Days
VIP visits
Workshops
Conferences
School visits
Students

Together, we will be a catalyst for European Research

Looking to the future

The LEAPS members are committed to working in an even more coordinated way in the future, so that collectively they can solve increasingly challenging technological, scientific and societal problems, boost European competitiveness and integration and extend global outreach. There has never been a more important time to do this, both because of the urgency of the challenges themselves, and the massive investment that is boosting the performance and delivery of such facilities elsewhere in the world.

The LEAPS strategy is to:

- Develop and implement next-generation technology for light sources in order to provide Europe with a world-leading network of high-level storage rings and FELs
- Drive forward the development of enabling technology for beamlines to attract and enable new science and meet the challenge of handling and processing increasingly large and complex sets of data
- Base developments on road maps that include smart specialisation, with each facility developing individual strengths in science and technology in a coherent manner so that together they provide Europe with optimum capacity and capability
- Improve the strength and breadth of engagement with industry both as service providers and as the inspiration for new technology, to increase European competitiveness and productivity and ultimately strengthen economies and create jobs
- Enhance access modes and develop new user communities that will aid further integration of European and ultimately global science
- Inspire and develop the next generation of scientists, engineers, technicians and technologists through better outreach, education and training and with enhanced mobility boost the availability of skills and expertise across Europe

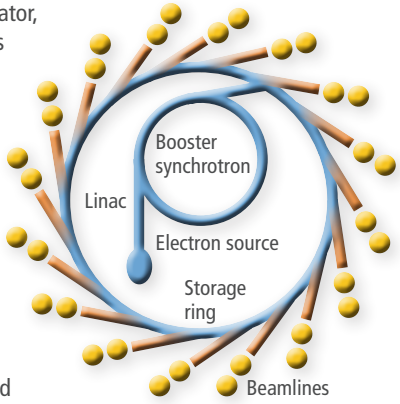
The action plan to achieve these aims has been elaborated in much greater detail through six expert working groups as illustrated on page 11.

STRATEGIC PRIORITIES

- Drive forward the development of common enabling technology, from accelerators, beamlines and detectors, to the challenge of 'big data'. (1-3)
- Harness the unique strengths of the members of LEAPS for industry and innovation both as service providers and as the inspiration for new technology, to increase European competitiveness and productivity, strengthen the economies and create jobs. (4)
- Create a seamless and unified user experience between facilities, to foster regional development and to map in detail the wider socio-economic impact. (5)
- Inspire and develop the next generation of scientists, engineers, technicians, technologists, and specialists through better education, training and mobility of skills and expertise around Europe. (6)

What is a synchrotron light source?

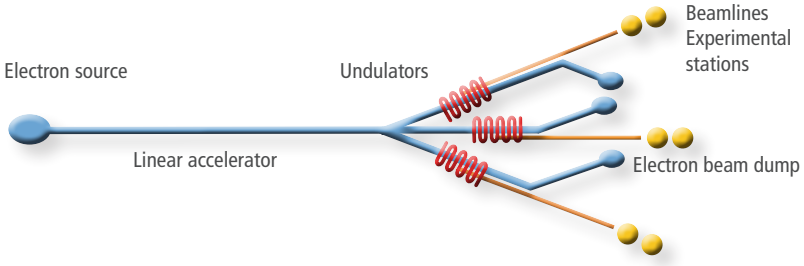
A synchrotron light source is made up of several key components: a source of electrons, a linear accelerator, a booster synchrotron and a storage ring. Electrons are generated in an electron gun, and accelerated in bunches of several billion in the linear accelerator before continuing their journey into the booster synchrotron where they are further energised. Once the right energy is reached, the electrons are injected into the storage ring where several hundred bunches of electrons race around at just under the speed of light. At various points around the storage ring, these electrons pass through specially designed magnets and emit brilliant synchrotron light. This light is channelled down to the experimental stations, which are called beamlines. Many experiments can run simultaneously making a synchrotron a high-throughput environment with the ability to support a large community of scientists.



What is a free-electron laser?

Free-electron lasers (FELs) are also accelerator-based light sources, utilising electrons to generate beams of light with unique properties. Unlike circular synchrotrons, FELs are based on a linear accelerating structure.

The electron beam is passed through magnetic undulators up to 300 m long. These arrays of magnets can be manipulated to produce the required light for a given experiment. Through complex interactions between the photons and electrons in the undulator, the electrons arrange themselves into thin disks which emit light in a highly synchronised way. The resulting light from these minute electron disks is pulsed and laser-like. This enables the study of processes at the atomic scale across a range of timescales, reaching the femtosecond, which was previously inaccessible to researchers. Each FEL possesses a number of beamlines enabling research into physical and life sciences.



For further information please visit the LEAPS website or email: info@leaps-initiative.eu

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