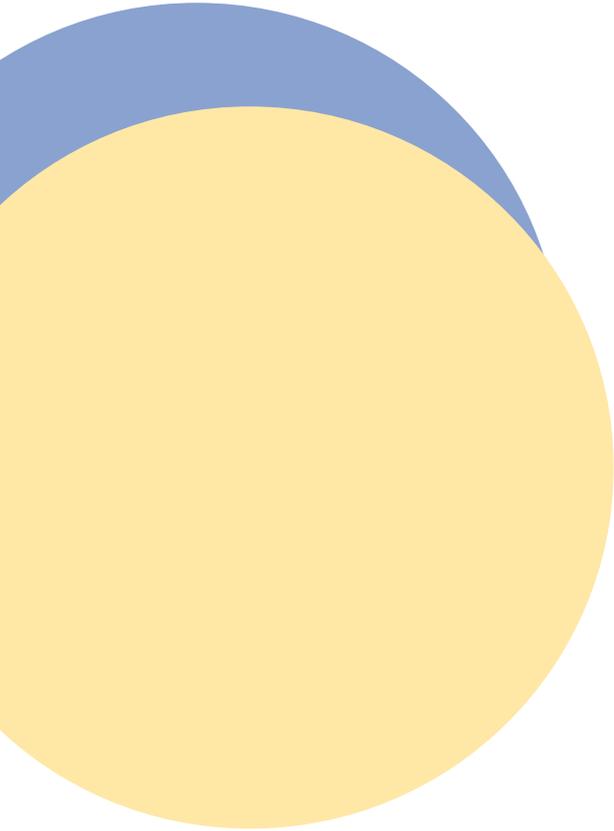




# Laserlab-Europe for a better future

Position Paper





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## Preamble

Laser science, as the core of photonics, is a unique tool for observing and understanding the microcosmos and for controlling the macroscopic material properties that are underlying the Grand Societal Challenges, as well as for expanding the many laser applications that have become essential to the fabric of our daily lives and for the European economy. Lasers are crucial tools for the way we retrieve and transmit information, and how we analyse minute or complex systems, from the interior of human cells to our global environment, with direct relevance to, for example, human health and climate change. They are also enabling the prompt creation of precise and valuable tools; light, and laser light in particular, is replacing electronics in many key technologies and provides innovations which will have a tremendous impact on European sustainable development and prosperity. Demand- and curiosity-driven laser research offer both immediate solutions and future technologies, thus strengthening European science, innovation, industry and economy.

A scientific and technological lead in laser-based research and applications is essential for Europe to face the parallel global challenges of health, climate and economy. The emerging environment created by the digital transformation and the 'Fourth Industrial Revolution' requires in addition the intensification of knowledge-based solutions. In response to these Grand Societal Challenges, the European Union launched the framework programme Horizon Europe, with its three Pillars: Excellent Science, Global Challenges and European Industrial Competitiveness, and Innovation.

Laserlab-Europe, a consortium of leading national laser research infrastructures, provides a unique integrated, cross-domain and multi-faceted approach to the complex scientific and technological questions inherent in the Grand Societal Challenges. With its extensive set of advanced laser research infrastructures, scientific expertise, innovative research and services, this consortium addresses all three Pillars of Horizon Europe. It promotes new horizons for the European Green Deal, Europe's Beating Cancer Plan and the UN's Sustainable Development Goals. It will, in particular, contribute to the five Missions identified by the European Union to face these Challenges, with capabilities exemplified in this document.

Laserlab-Europe's broader quest is aligned with the European guidelines in the pursuit of excellence in scientific research, global challenges and industrial competitiveness and promoting innovative Europe, in tune with the scope of the Pillars of Horizon Europe.

## Laserlab-Europe

Laserlab-Europe is a consortium of 45 national laser research infrastructures in 22 European countries. This consortium is a long-lasting sustainable alliance. It provides leadership in laser-based and photonics research, and in related technologies, through a wide range of world-leading investigative capabilities, user training, and services.

Laserlab-Europe understands itself as the home for laser-based research in Europe, formulating and promoting new developments in laser-based research that are pursued in a flexible and co-ordinated fashion beyond the potential of a national scale.

>100  
ERC Grants  
awarded to  
Laserlab-Europe  
scientists



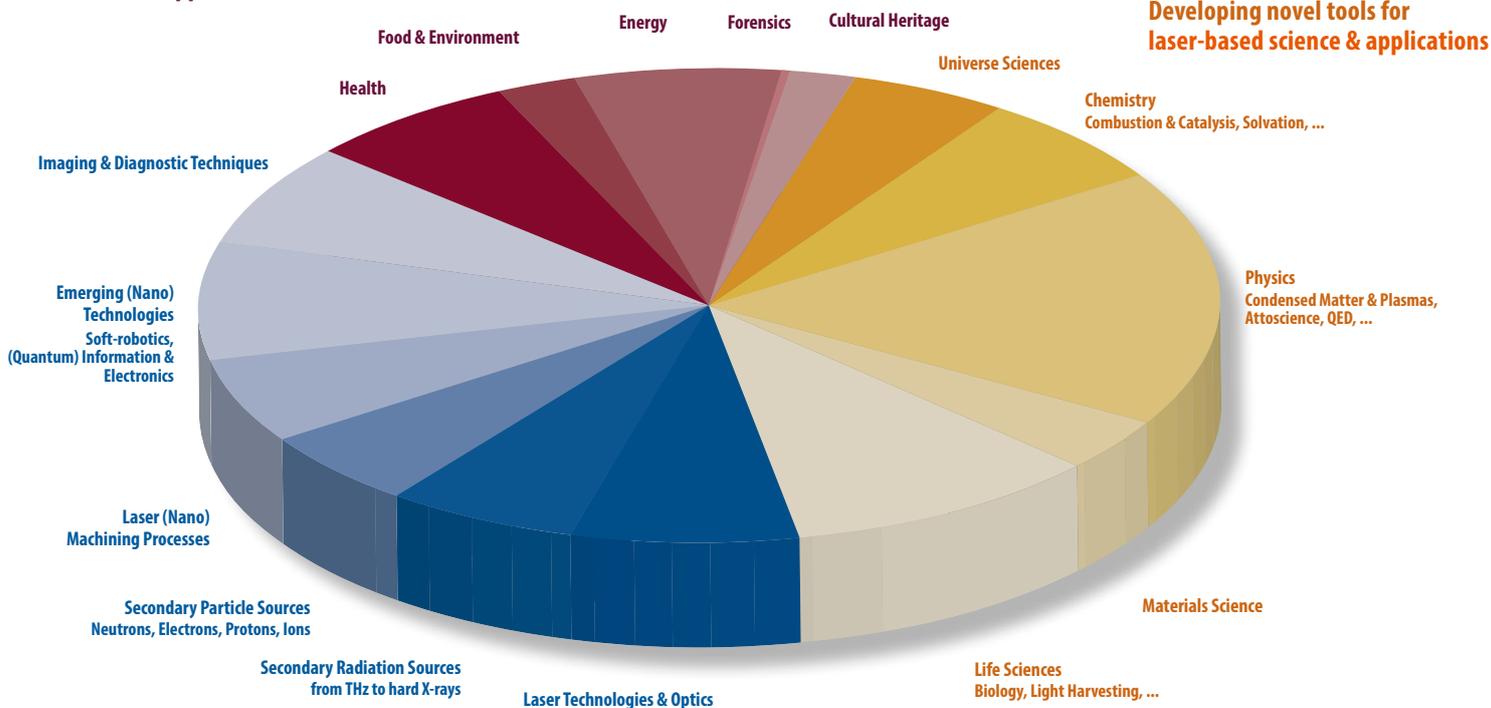
Laserlab-Europe research infrastructures encompass photonics research and technologies ranging from hard X-rays to THz radiation, with systems ranging from the most potent high-power laser sources that drive secondary sources and particle beams, to small single quantum emitters. The consortium utilizes a wide range of advanced metrology, quantum-limited sensing, and imaging capabilities.

Laserlab-Europe offers access to international users from academia and industry for wide-ranging inter-disciplinary research in most photon science domains. In doing so, it reaches and trains future researchers and engineers, from within and beyond Europe. In fact, more than 50% of the international users are young researchers below the age of 35. The consortium's effective network of partners provides complementary capacities covering all aspects of excellent forefront laser-based science. This is impressively underlined by Laserlab-Europe scientists securing, to date, more than 100 ERC Grants.

Laserlab-Europe supports demand-driven research responding to the current needs of society and the economy of today, as well as curiosity-driven research addressing the needs of tomorrow and transforming the economy. Through its strategic approach, Laserlab-Europe strengthens Europe's leading position and long-term competitiveness in key scientific and industrial areas.



### Exploring demand-driven societal applications



### Developing novel tools for laser-based science & applications

### Deepening curiosity-driven fundamental knowledge

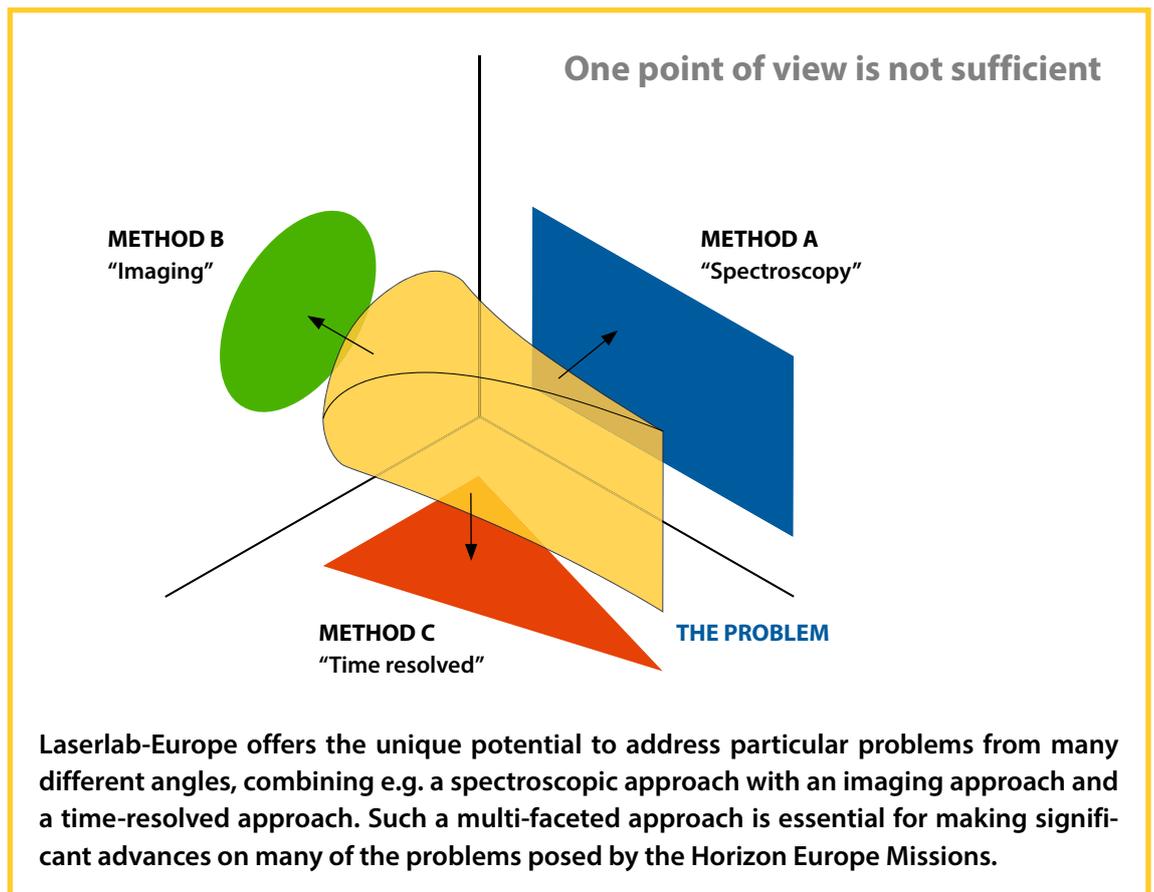
*Thematic areas of transnational access projects*

# Laserlab-Europe addressing the Grand Societal Challenges

The Horizon Europe work programme challenges the scientific community to provide innovative solutions across a wide range of fields. The Natural Sciences, Informatics and Engineering are all faced with the necessity for breakthroughs in their fundamental concepts, while providing viable solutions enabling rapid translation of scientific discoveries to industrial and societal applications.

## Laserlab-Europe and the five Horizon Europe Missions

The European Union has, within Horizon Europe, incorporated five research and innovation Missions to increase the effectiveness of its research funding by pursuing clearly defined targets, addressing: climate change, the fight against cancer, living in green and smart cities, the protection of water resources, and sustainability of soil health and food resources. These Missions require advanced investigative methods and innovative multi-modal approaches. A particular strength of Laserlab-Europe is that it employs a wide variety of investigative methods, thus providing powerful multi-modal analytical capabilities which are available for users from both academia and industry. The figure below shows an example of the type of conceptual approach that is possible within Laserlab-Europe.



While Laserlab-Europe is active in, and will contribute to, the areas of all three Pillars of Horizon Europe, examples are presented below of specific expertise and/or laser-based capabilities that illustrate specifically how it can contribute to the five Missions.



## Laserlab-Europe for understanding and facing climate change and its consequences

Europe focuses on solutions and preparedness for tackling the impact of climate change to protect lives and assets. Lasers and photonics may contribute to the adjustment to new climate conditions, or even modify the effects of a changing climate to facilitate a smoother adaptation.

**Laserlab-Europe has the critical mass and expertise to be a major player in ambitious efforts to monitor and control the many side-effects of climate change.**



Laser-spectroscopic studies for fundamental understanding of catalytic reactions involved in the stratospheric ozone destruction, and of the photochemistry behind biological degradation of biomass



Laser-based sensing technology for precise monitoring of greenhouse emissions and for remedial activities



Laser-based methods for studying the effect of climate change on biodiversity by remote surveillance and monitoring in natural ecosystems



Laser-based hyperspectral imaging for monitoring earth surface composition and change, for possible applications to volcanoes, wildfires and earthquakes



Laser filamentation to investigate prospects of cloud nucleation for rain on demand



Laser-based monitoring of the consequences of climate change on cultural heritage

## Laserlab-Europe for the fight against cancer

Lasers, photonics and bio-photonics provide a unique potential for the fight against cancer, addressing all major challenges identified within the Mission for beating cancer: understanding, diagnosis, treatment and prevention. In particular, laser science contributes to the Mission's aim to improve early detection and to develop drugs and therapies, and in this way improve the quality of life of people afflicted with cancer.

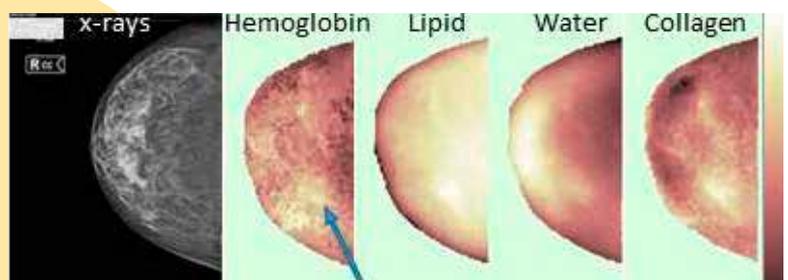
**Laserlab-Europe offers unique innovation potential in the fight against cancer through novel laser-based photonic systems and devices, revolutionising diagnostic capabilities and treatment efficacy and enabling new prevention strategies.**

-  Innovative integrated, multiparametric and multiscale analytical imaging and spectroscopic methods to elucidate the molecular and structural biology of cancer cells, and understand their interactions with a host
-  Detection of new biomarkers with prognostic and predictive value, complementary to the standard hallmarks of cancer, leading to early in-vitro and in-vivo diagnostic tools
-  A next-generation precision medicine approach, using label-free imaging and novel sensing approaches, as well as integrating multi-parametric feature extraction and predictive algorithms
-  Treatment with novel medication resulting from laser-assisted drug development, laser-driven secondary photon and particle sources, photo-activation and drug monitoring methods
-  Development of minimally invasive combinations of advanced diagnostics and therapeutic approaches, such as nanoparticle-based targeted interventions, image-guided surgery and hybrid endoscopic technologies
-  Prevention through the development of new sensing and imaging methods or devices, as well as of advanced software to provide new monitoring methodologies for health-related manifestations, and the well-being of individuals and patients



*Cancer treatment at CLL*  
© Luzitin SA

*Comparison of x-ray and optical mammograms*  
© POLIMI





## Laserlab-Europe for the green transition in smart cities

Most of the world's population lives in urban areas and this fraction is expected to reach 80% by 2050. Lasers and photonics serve as the technological backbone for unprecedented advances in the domains of energy, manufacturing, sensing, metrology, and transport. Through such developments, lasers influence the quality of life of citizens who live and/or work in cities and their surrounding metropolitan areas, hence contributing to solving global challenges.

**Laserlab-Europe offers cutting-edge laser-based diagnostics and materials-processing technologies, as well as device prototyping and know-how, that enable research and technology.**



Laser-based engineering of functional materials for energy-efficient electronic devices. Novel nanomaterials for carbon-free energy production (e.g., using photocatalytic approaches or photovoltaics), storage (by laser texturing for batteries and hydrogen), distribution, and consumption



Lasers for precision surveillance of the nearby environment, allowing laser (lidar) -based adaptive driving assistance and the emergence of fully autonomous vehicles



Laser-based methodologies and instrumentation for maintaining the green environment and monitoring the quality of life



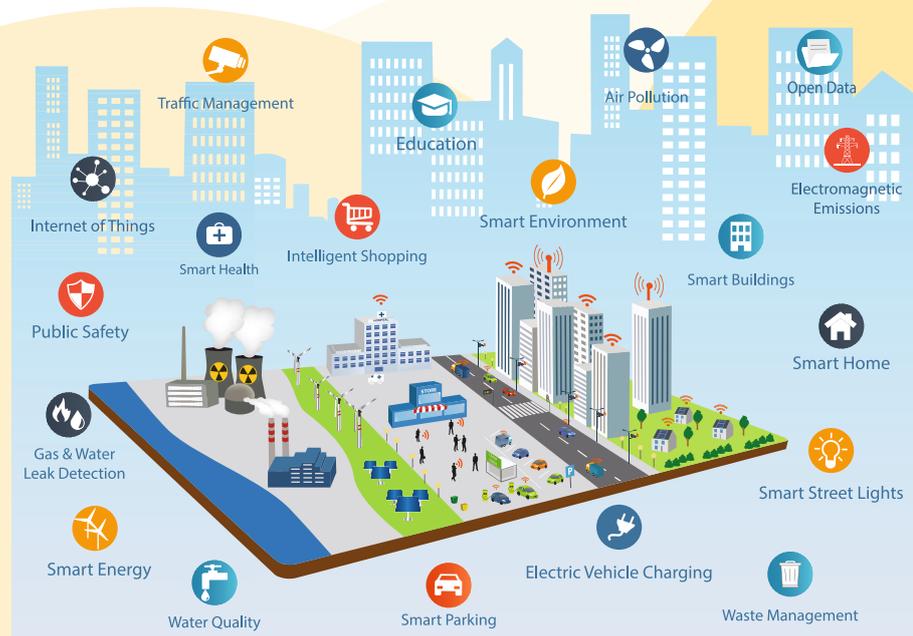
Laser ablation methods as green technologies for cleaning of building surfaces (for example graffiti removal)



Laser-based monitoring and rapid sorting of house-hold waste and building demolition material for the accurate assessment of their re-usability (critical raw materials, circular economy)



Laser-based green technologies for the fabrication of novel nanomaterials for gas sensing applications





## Laserlab-Europe for securing water quality in oceans, seas and inland

Water plays a vital role for society as the habitat of a full chain of aquatic life ultimately providing a very important human food supply. Furthermore, the oceans store green-house gases, and help to clean the planet from anthropogenic pollutants and toxic emissions. The ocean's role in providing clean energy, communication, travel, tourism and trade is paramount.

Lasers can help remove pollutants and thus replenish water's capacity to provide socio-economic benefits to our society.

**Laserlab-Europe offers extensive expertise with advanced techniques for the rapid and secure identification of pollutants and for monitoring the quality of water in oceans, lakes and ground water.**



Laser-based instrumentation for securing water safety for the population



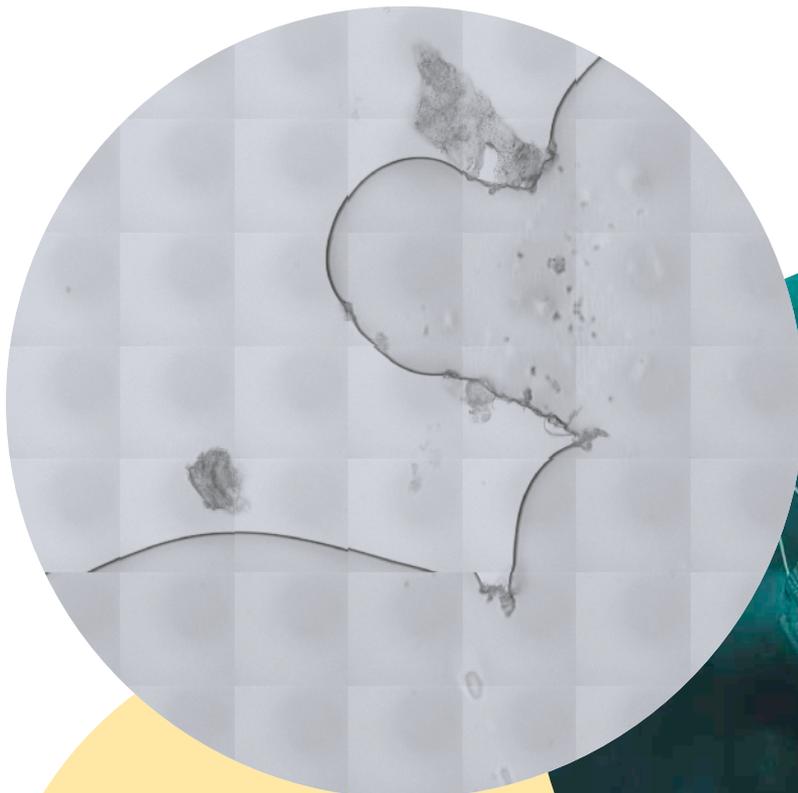
Laser-based methods for monitoring the physio-chemical environment



Laser-based detection of microplastics



Lasers to assess the degree of pathogen eutrophication in the oceans and lakes



*Identification of environmental microplastics*  
© Liron Zada





## Laserlab-Europe for healthy soil and food

There is an urgent need for effective technologies, which will support the agricultural and food-production sector by reducing the environmental footprint of agriculture, fisheries and aquaculture and promoting safe, nutritious and affordable food production for all. To achieve this, laser spectroscopic techniques provide a variety of sensitive, on line or remote probes and modalities.

**Laserlab-Europe provides efficient laser-based technologies for healthy soil and improved food production, efficiency and quality control.**



Laser spectroscopic techniques for soil quality evaluation, hyperspectral imaging for plant health assessment, and precision agriculture parameter monitoring



Laser-based evaluation of the contribution of agricultural production to climate change



Laser-based techniques for intrusive and non-intrusive monitoring of food and food packaging



Spectrochemical tools for food products assessment, addressing issues of origin, quality, contamination and adulteration



Laser-based technologies for minimizing or eliminating pesticides and plasticizers in food, certifying methods for the safety and quality of food, reducing soil over-fertilization and wasteful water supply

*Nondestructive assessment of maturity in fruit by time-resolved diffuse reflectance spectroscopy*

© POLIMI



## Laserlab-Europe beyond the Horizon Europe Missions

Laserlab-Europe's ambition is to contribute to the solutions of ever emerging Grand Societal Challenges by advancing knowledge and pushing forward the frontiers of science. With hindsight, it is evident that Laserlab-Europe's scientific output and contributions over the years have been pre-aligned with the challenges of today's Missions. Thus, the consortium is in an optimal position to strongly intensify its ongoing contributions to resolving issues and problems addressed by these Missions.

Beyond the Missions, the wider variety of important global societal challenges is addressed by Laserlab-Europe with research driven by both curiosity and demand, and by innovation and development, all of which is performed with strong links to, and involvement of academic and industrial users. This is having a transformative impact in a wide range of strategic areas of science, technology, health and life sciences, and on European economy. Laserlab-Europe promotes, for example, research in the fields of nanophotonics, quantum computing and information, thus strengthening a leading European role in the disruptive digital transformation. Furthermore, ultra-high-power high-energy laser research, within Laserlab-Europe, provides a test-bed for pushing light intensities to the extreme, opening up new and unexplored horizons in laser-matter interactions, with relevance to particle acceleration, nuclear photonics and fusion energy. Also, developments in high average power lasers will be transformative for both science and industry. Ultra-precise control over the detailed waveforms of light provides novel tools for the microscopic manipulation and control of matter for a new generation of energy-efficient devices for energy and data transmission, and for new medications.

The combined capacities of Laserlab-Europe allow investigations aimed at understanding matter and its interactions in nature over enormous ranges of distances, energies, and time scales, by combining multiple simultaneous probes and messengers within complementary methods approaches.

Collaboration with other research infrastructure communities within the European Research Area (ERA) takes the advantages of complementarity among experimental techniques one step further. In this context, Laserlab-Europe constitutes an essential building block of the recently formed super-network Analytical Research Infrastructures in Europe (ARIE), with ambitions to efficiently and jointly address important global challenges, an important segment of Pillar 1 of Horizon Europe. This position paper states in particular Laserlab-Europe's relevance for the "Missions" of Pillar 2 and its aim to significantly contribute to the innovative technology concept underlying Pillar 3.

- **Laserlab-Europe aims to ensure European leadership in photonics, which is indispensable to foster high added value breakthroughs and innovations.**
- **Laserlab-Europe is a creditable strategic partner in the development of solutions for industry and to the ever emerging and important Grand Societal Challenges.**
- **Laserlab-Europe will accomplish its role by advancing knowledge and pushing forward the frontiers of science, and thereby contribute to a better future.**

**LASERLAB-EUROPE**

CALT	Centre for Advanced Laser Techniques, Zagreb	Croatia
CELIA (CNRS)	Centre Lasers Intenses et Applications, Centre National de la Recherche Scientifique, Bordeaux	France
CESTA (CEA)	Centre d'Etudes Scientifiques et Techniques d'Aquitaine, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, Le Barp	France
CLF (STFC)	Central Laser Facility, Rutherford Appleton Laboratory, Science and Technology Facilities Council, Oxfordshire	UK
CLL	Coimbra Laser Lab, University of Coimbra	Portugal
CLPU	Centro de Laseres Pulsados, Salamanca	Spain
CLUR (UCM)	Center for Ultrafast Lasers, Universidad Complutense Madrid	Spain
CUSBO (POLIMI)	Centre for Ultrafast Science and Biomedical Optics, Politecnico di Milano, Dipartimento di Fisica, Milan	Italy
ENEA-ABC	ENEA - Centro Ricerche Frascati, ABC Facility, Frascati	Italy
FELIX	FELIX Laboratory, Radboud University Nijmegen	Netherlands
FERMI	FERMI, Elettra-Sincrotrone Trieste S.C.p.A, Trieste	Italy
GSI	Gesellschaft für Schwerionenforschung mbH, Darmstadt	Germany
HIJ	Helmholtz Institute Jena	Germany
HiLASE	HiLASE Centre, Institute of Physics, Czech Academy of Sciences, Dolní Břežany	Czech Republic
HZDR	Helmholtz-Zentrum Dresden Rossendorf	Germany
ICFO	Institut de Ciències Fotòniques, Castelldefels, Barcelona	Spain
IEP (TU Graz)	Institut of Experimental Physics, Graz University of Technology, Graz	Austria
ILC	International Laser Centre, Bratislava	Slovakia
INFLPR/CETAL	National Institute for Laser, Plasma and Radiation Physics, Center for Advanced Laser Technologies, Magurele, Bucharest	Romania
IPHT	Leibniz Institute of Photonic Technology, Jena	Germany
IPPLM	Institute of Plasma Physics and Laser Microfusion, Warsaw	Poland
ISMO (CNRS)	Institut des Sciences Moléculaires d'Orsay, Centre National de la Recherche Scientifique, Orsay	France
IST	Instituto Superior Técnico, Lisbon	Portugal
LACUS	Lausanne Centre for Ultrafast Science, Lausanne	Switzerland
LaserLaB Amsterdam	Institute for Lasers, Life and Biophotonics Amsterdam (LaserLaB), Vrije Universiteit Amsterdam	Netherlands
Laserlab DK	Laserlab DK	Denmark
LENS	Laboratorio Europeo di Spettroscopia Non Lineari, Florence	Italy
LIDYL (CEA)	Laboratoire Interactions, Dynamiques et Lasers, Commissariat à l'Énergie Atomique et aux Énergies Alternatives, Saclay	France
LL-NSC	Laserlab-NSC, Nanoscience Center, University of Jyväskylä	Finland
LLC	Lund Laser Centre, Lunds Universitet	Sweden
LOA (CNRS)	Laboratoire d'Optique Appliquée, Centre National de la Recherche Scientifique, Palaiseau	France
LP3 (CNRS)	Laboratoire Lasers, Plasmas et Procédés Photoniques, Centre National de la Recherche Scientifique, Marseille	France
LULI (CNRS)	Laboratoire pour l'Utilisation des Lasers Intenses, Centre National de la Recherche Scientifique, Palaiseau	France
MBI	Max Born Institute for Nonlinear Optics and Short-Pulse Spectroscopy, Berlin	Germany
MPQ	Max-Planck-Institut für Quantenoptik, Garching	Germany
MUT-IOE	Military University of Technology, Institute of Optoelectronics, IOE, Warsaw	Poland
Orion	Orion, Aldermaston, Reading	UK
PALS (IPP)	Prague Asterix Laser System, Institute of Plasma Physics, Czech Academy of Sciences, Prague	Czech Republic
Sofia Univ.	Sofia University, Laboratory of Femtosecond Photonics, Faculty of Physics, Sofia	Bulgaria
STRATH	University of Strathclyde, Glasgow	UK
ULF-FORTH	Ultraviolet Laser Facility, Institute of Electronic Structure and Laser, Foundation for Research and Technology Hellas, Heraklion	Greece
UL-LC	University of Latvia, Laser Centre, Riga	Latvia
USZ/Inst. of Physics	University of Szeged, Institute of Physics, Szeged	Hungary
VULRC	Vilnius University, Laser Research Center, Vilnius	Lithuania
Wigner RCP	Wigner Research Centre for Physics, Budapest	Hungary



